Set Lighting Technician's Handbook

Film Lighting Equipment, Practice, and Electrical Distribution

Fifth Edition

Harry C. Box

A Focal Press Book

COMPANION @ WEBSITE

ROUTLEDGE

Set Lighting Technician's Handbook

A friendly, hands-on training manual and reference for lighting technicians in motion picture and television production, this handbook is the most comprehensive guide to set lighting available. It provides a unique combination of practical detail with a big-picture understanding of lighting, technology, safety, and professionalism, essential to anyone doing motion picture lighting.

The fifth edition delves into every aspect of lighting and features vastly expanded sections on controlling LED lights, color science, lighting control systems, wireless systems, Ethernet-based control systems, battery power, and modern set protocol for productions small and large. With a generous number of original images, the book illustrates the use of soft light, the effect of lighting angles, and how the gaffer and DP build an effective lighting plan around the blocking of the actors. This encyclopedic volume of technical knowhow is tempered with years of practical experience and a much-needed sense of humor.

This is the ideal text for professional lighting technicians across film and television including lighting directors, gaffers, DOPs, and rigging crews, as well as film and television production students studying lighting, camera techniques, film production, and cinematography.

It includes a revamped companion website with supplementary resources, forms, checklists, and images.

Harry C. Box has worked in the motion picture and television industry since 1987 with significant experience as a lighting technician and gaffer and later as a camera operator. Harry also works for the industry trade association ESTA focusing on issues relevant to the motion picture/television market.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

Set Lighting Technician's Handbook

Film Lighting Equipment, Practice, and Electrical Distribution

Fifth Edition

Harry C. Box

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

Fifth edition published 2020
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

and by Routledge
52 Vanderbilt Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

© 2020 Harry Box

The right of Harry Box to be identified as author of this work has been asserted by him in accordance with sections 77 and 78 of the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this book may be reprinted or reproduced or utilised in any form or by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publishers.

Trademark notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

First edition published by Elsevier 1993
Fourth edition published by Focal Press 2013

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Names: Box, Harry C., author.
Title: Set lighting technician's handbook : film lighting equipment,
practice, and electrical distribution / Harry C. Box.
Description: Fifth edition. | London ; New York : Routledge, 2020. |
Includes index.
Identifiers: LCCN 2019046122 (print) | LCCN 2019046123 (ebook) |
ISBN 9781138391697 (hardback) | ISBN 9781138391727 (paperback) |
ISBN 9780429422560 (ebook)
Subjects: LCSH: Cinematography—Lighting—Handbooks, manuals, etc.
Classification: LCC TR891 .B68 2020 (print) | LCC TR891 (ebook) |
DDC 777/.52—dc23
LC record available at https://lccn.loc.gov/2019046122
LC ebook record available at https://lccn.loc.gov/2019046123

ISBN: 978-1-138-39169-7 (hbk)
ISBN: 978-1-138-39172-7 (pbk)
ISBN: 978-0-429-42256-0 (ebk)

Typeset in Times New Roman
by Apex CoVantage, LLC

Visit the companion website: www.routledge.com/cw/box

For my mother and father

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

Contents

Preface

Lighting practices for film and television production have undergone many transformations since the summer of 1991, when I first began making notes for what eventually became the first edition of this book. At that time, the conversion from vintage DC distribution equipment to AC was still taking place. Lots of different distribution systems had popped up; there was no dominant standard for connectors and junction boxes. SCR dimmers were suddenly becoming a big part of motion picture lighting for the first time, bringing with them the attendant issues of harmonic currents. Electronic HMI ballasts were new to our industry and were pretty shaky at first. It took a few years of burning out different parts of the ballast before manufacturers arrived at the bullet proof reliability we have come to expect today.

At that time there was little or no formal training for lighting technicians. Electricians learned from each other on the job. For many old-school electricians, three-phase AC systems, power factor, current harmonics, and even grounding, were new concepts. At that same time, a much larger percentage of production in Los Angeles was non-union. Necessity being the mother of invention, these thriftier productions spawned many innovative lighting techniques that have since become common practices, but they also often resorted to methods that were actually potentially hazardous. One way and another there was a great deal of confusion and misinformation being circulated. It was in this context that I first undertook writing a book for lighting technicians in the film and television industry, with the goal of thoroughly researching the many issues I was aware of, in order to offer lighting technicians an authoritative source of information and guidance.

This book has existed in a time frame spanning a massive shift toward greater awareness and education for lighting technicians. To some extent, it has been a part of that shift. The fourth edition of the book reflected the formalization of training and rethinking of safety that occurred since the early 90s. Risks that were once casually accepted were now addressed with better technology and work practices. Things like using flammable materials or non-UL-listed parts, use of electricity around water, proper grounding, these are just a few of the areas where safety was improved in our daily work.

Revising a book is a great way to take stock of the impacts of technological change. The industry has just completed two enormous leaps forward—first the painful transition from film to digital capture in the early 2000s, and second, the LED revolution in the 2010s. What topic in this book has *not* been touched by this technology? It has given us a nimbler way to color light, which forced more sophisticated control technology. It has spawned new data/power management solutions. It has vastly increased our use of small power, like batteries, small generators, and house power. It has made rigging smaller and lighter and the production footprint not quite as deep. LED technology has changed the crew roles. Juicers now need to be IT technicians and RF engineers. It brought us systems techs, fixtures techs, and elevated the lowly dimmer board operator to full wizard status as lighting console programmer.

It has changed the way lighting technicians and gaffers work on set. It has taken light that was once static and breathed life into it, enabling it to move, morph, sputter, and travel. Built-in lighting effects, creative use of pixel mapping, the ability to fade between colors and to change the look, time of day, and atmosphere within the duration of a shot, DPs are finding exciting ways to harness the technology as tools for visual storytelling. Never before has so much been so relatively easy to do. While in some ways the changes have made things easier and increased the efficiency of production, they have also raised the expectations placed on DPs and on their lighting crews. The changes have added substantially to the knowledge base that lighting technicians need to master. So, with all that going on, we are clearly due for a new edition.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

Acknowledgments

While writing the fifth edition, I was very fortunate to have the support of many top professionals in production as well as experts in the manufacturing sector. Their generosity, insights, and perspective make this book possible.

I gratefully acknowledge the many manufacturers who provided technical information, photographs, and illustrations. The manufacturers are listed in Appendix F.

I am very grateful to Mike Bauman for his generous input and terrific photographs. The man is an amazing wealth of creative talent and knowhow. Thanks to my friend and colleague Mark Doering-Powell for his ongoing advice and terrific artwork and photographs that appear in the book. I truly appreciate the continual feedback of Ted Hayash, Mark Weingartner, and Mike Ambrose, who also contributed photos. Thanks to programmer Scott Barnes for his thoughtful input, as well as the hospitality of Jared Wellman, Jason Young, Mark Hartman, and Jay Yowler who had me over for a set visit and shared their experiences.

Max DeMayo took the photo for the cover of this book. Thanks also to Al DeMayo, John Clisham, Paul Royalty, and Sean Goossen at LiteGear for supporting the project. Thanks to John Cini and the good folks at High Output, Boston for their generous hospitality. The fifth edition benefited greatly from those who read and commented on certain sections of the manuscript: Craig Brink and Adam Knapp at RatPac, Mark Wofford and Gary Murck at PC&E, Atlanta, Zack Shannon at CORE SWX, and Brian Doran and Jane Rein at ARRI. Guy Holt contributed his photos and perspective from his ongoing research into power quality issues. Frieder Hochheim and his team at Kino Flo shared research on LED color science.

For their contributions to the fourth edition, I owe a debt of thanks to Richard Cadena, Josh Thatcher, Jeff Levi, and John Amorelli for their input on the subject of lighting control technology and moving lights. Thanks to Mike Wood (Mike Wood Consulting), Rob Gerlach (Selador/ETC), Ryan Fletcher (ARRI), David Amphlett (Gekko), Jim Sanfilippo (NILA), Richard Lund (Philips), and Lee Ford Parker (JiffyFX.com) for their valuable contributions to the chapter on LEDs. Thanks to the terrific team at ARRI Lighting, John Gresch, Mike Jones, Aeron Weller, and An Tran for their continuing support, and contributions especially in regard to HMI troubleshooting. Other experts in the field helped shape this new edition: Steve Terry (ETC), Michael Lay (Strand) lent their expertise on dimming; Bob Cookson (Illumination Dynamics), Russle Saunders (Saunders Generators), and Ron Dahlquist (Dadco) on transformers and generators; John Parkinson (Power To Light), Paul Tipple and Phil Ellems (Power Gems) on HMI electronic ballasts; Stewart Lennox (battery packs); Michael Skinner on entertainment industry applications of the National Electrical Code; Andy C. Huber on underwater lighting; and my old friend and colleague Brian O'Kelley lent an AD's perspective to the opening chapter. Other lighting professionals who contributed include Erik Messerschmitt, Dave Devlin, Dwight Campbell, Martin Weeks, and many others. My thanks to the Local 728 Safety Training Program and Contract Services, especially Allan Rowe, whose comprehensive work developing Skills Training courses for Local 728 plays no small part in helping the membership remain the best trained, most experienced lighting technicians in the world. My sincere thanks to the many individuals who gave me feedback and suggestions for the fourth edition: Daniel Aleksic, David E. Elkins, John Gates, Michael Hofstein, Seth Jason, and Stephen Lighthill.

This book was first published in 1993. I am deeply indebted to many individuals for their generous contributions to this book over the years: Darryl Murchison, whose discussions during the early stages of writing the first edition helped set the book on course; Doug Pentek, Earl Gilbert, Larry Parker, Cyrus Yavneh, Russ Brandt, Dean Bray, Herb Breitling, Michael Kaiping, Scott Toland, and Jon Bart, all of whom read and improved sections of the book in its first and second editions; Richard Mula and Pete Romano, who shed much light on the subject of underwater lighting; Frank "the Dinosaur" Valdez and Gary Scalzo, who lent their expertise to the section on rigging; and Vance Trussell, whose suggestions and ongoing interest and encouragement were invaluable to me. My thanks to Eric King, who shared his expertise on HMIs and electronic ballasts. My thanks to Bernie Kret at Strand, who helped upgrade the section on electronic dimmers for the second edition. I owe a debt of gratitude to Chris Barratt, without whose generosity and vast experience I could not have created the section on generator troubleshooting, and whose legacy lives on.

A special note of thanks to the illustrators, Shawn Murphy and Lisa Cyr, who created the hand-drawn illustrations for the first edition and who may well have been inking drawings on their wedding night to make the publication deadline. Thanks also to John Huey, who created additional artwork for the second edition. For new illustrations in the third edition, I thank Dan Haberkorn. Thanks to Laura Mancini and Keith Morgan.

I am grateful to the publishing team at Taylor and Francis for their patience with me, and their care and professionalism in preparing this book.

I am thankful, once again, to Joan Box, my faithful and talented (unofficial) copyeditor who has taken an interest in my writing since I was first able to form letters. It is a true testament to a mother's love that she endures all this techno mumbo-jumbo, but it is always a joy to work together on it.

Finally, my love, thanks, and appreciation go to my loving wife, Stacey, and to my family, who are officially completely sick of this book at this point, and with good reason. Thank you for your patience and support.

CHAPTER 1

Set basics: Your first barbecue

All the technical aspects of filmmaking—cameras, lighting, sound, visual effects—involve a myriad of small details that, taken as a whole, seem impossibly complex. As with any craft, to become a master requires years of experience and exposure to many different situations. It has been my experience, however, that no single piece of equipment, procedure, or technique is really complicated; there is no one thing that cannot be explained and understood in less than 10 minutes. Making movies is the artful application of millions of relatively simple details. This book helps with some of those details, describing procedures that save time and promote safety, clarifying aspects of the craft that are confusing and often misunderstood, and supplying a wealth of information about the hundreds of gadgets of which lighting technicians are so fond.

Starting with the basics, we begin with a summary of the role of the lighting crew on a film set.

JOB DESCRIPTIONS OF THE LIGHTING CREW

The electric, grip, and camera departments fall under the supervision of the *director of photography* (DP). The *gaffer* and *key grip* are the DP's lieutenants. The gaffer is the head of the electric department, in charge of the lighting crew. The gaffer's crew consists of a *best boy electric*, *lighting technicians*, and often a *lighting control programmer* or *dimmer board operator* and a rigging crew.

Director of photography

> ***Q:*** How many directors does it take to screw in a lightbulb?
> ***A:*** One; no, two . . . no, no one.

The DP is the director's right hand. It is the DP's responsibility to create in images what the director has envisioned for each scene; to evoke the proper time, place, and atmosphere by means of lighting; and to help choose camera angles and camera movement that will be most effective in telling the story and covering the scene. He or she designs the lighting, balancing realism against the dramatic potential of more stylized effects, as called for by the script and the director. The DP's responsibility for lighting and photographing the actors requires careful attention to how their face takes light. The DP must maintain proper screen direction (a responsibility shared with the script supervisor) and lighting continuity between setups so the film can be edited seamlessly. The DP has a say in the design and color of the sets and the wardrobe and in the selection of locations. The DP works closely with the *assistant director* (AD) to schedule scenes at the right time of day for the best light.

The DP usually shoots tests prior to the beginning of photography. He or she may experiment with lighting effects, with different color casts, levels of contrast and saturation, filters, and lenses that combine to create specific looks, which answer the special requirements of the script. The DP may also conduct his or her own research prior to production to ensure the authenticity of a period look and to inspire ideas for the cinematography.

The DP holds a position of immense responsibility, creatively and financially. The producer and director both depend on the DP to achieve photographic excellence within the constraints of the production's budget and schedule. The DP always faces conflicts in fulfilling the needs of the script, director, schedule, and budget and meeting his or her own aspirations for the photography. The lighting crew fights the DP's battles on the front lines. Their ability to light the set in a time-efficient manner directly affects the DP's ability to produce great work.

Gaffer

Q: How many gaffers does it take to screw in a lightbulb?
A: How many do we have on the truck?

The gaffer is the chief lighting technician (CLT), the head of the lighting department. He or she works directly with the DP to implement the lighting plan and help achieve the photographic look of the film. The DP, the gaffer, and the key grip attend preproduction meetings together and scout the locations where filming is to take place. They discuss the DP's approach to each scene and determine what lighting preparations and equipment are required. Gaffers are problem solvers. They often have to design a special rig, fabricate a gadget, or implement technology in some idiosyncratic way to give the DP something he or she is looking for, or to provide time efficiency during production. It falls to the gaffer and key grip to research possible solutions, source the materials, design all the specifics, and if necessary, present the plan to the DP and to the production manager for approval, and then see the plan to fruition.

On the set, the gaffer is responsible for the execution of the lighting scheme and the organization and operation of the lighting crew. The DP and the gaffer discuss the lighting. Typically, when talking about the actor's lighting, the DP may specify the placement of each fixture to accomplish a particular effect. Sometimes the DP may leave it to the gaffer to translate general ideas into specifics. The DP may express the goals in terms of the motivating sources of light for the scene, the mood, and the f-stop at which to shoot. The gaffer then instructs the crew and sees to the exact placement and focus of each light to accomplish the DP's instructions. Once the gaffer has executed the lighting, the DP may "sweeten" it to taste, with a few adjustments.

The gaffer must have a very strong eye for lighting and a solid knowledge of which lights to use to create any desired effect. As the lighting starts to come together, the gaffer functions as a second pair of eyes for the DP, always on the lookout for problems—inadequate light, overexposure, hot spots, ugly shadows, and so on. Together, the DP and gaffer look for opportunities to make the scene look more interesting. The gaffer has a critical eye for the balance of light and shade, the modeling of facial features, and the separation of foreground from middle ground and background. He or she may carry a light meter on their belt for measuring light levels. The gaffer is often next to the DP, viewing the monitors, watching for lighting issues and calling for adjustments over the walkie-talkie.

A very important part of the gaffer's job is organizing and running the lighting operations. He or she must constantly be cycling through the many tasks at hand, pushing forward the progress of each project, keeping an eye on the performance of the lighting crew, thinking ahead so that the lighting technicians will have power and lights readily at hand for subsequent shots, and forestalling delay.

The gaffer should never have to leave the immediate area in which the action is being filmed. He or she must rely on the crew to be close at hand to make lighting adjustments and fetch equipment when it is needed. Once the lighting is complete, the grips and electricians clear the set, but remain nearby, in case a tweak is called for between takes. The lighting crew is always under time pressure. A technician who stays near the action, listens, and thinks ahead can do a lot to help the gaffer and DP win their daily battle against time.

Best boy electric

The best boy electric is the assistant chief lighting technician. He or she is in charge of personnel and equipment for the electrical department—a vital role in the smooth running of the lighting crew. One of the best boy's duties is scouting locations with the gaffer, making scouting notes to help the gaffer compile the list of equipment needed. The best boy supervises the equipment inventory from the load-in at the beginning of the show, through each day of the shoot, and through the wrap and return. The best boy orders expendable supplies. He or she coordinates equipment orders, returns, subrentals, and special orders with the production department and transportation departments as necessary. The best boy supervises the loading of the truck at the rental house before the first day of production, organizes the equipment and supplies in the truck for easy access, makes sure that no equipment gets lost at each location, and keeps track of damage. The best boy supervises maintenance and repairs when possible. The best boy is in charge of hiring and laying off additional lighting technicians when needed. The best boy supervises the electrical crew's startup paperwork and time cards. When there is no rigging gaffer hired, the best boy may also plan the routing of the feeder cable and supervise the distribution of electrical power to the lights.

Most important, the best boy is the emissary of the electrical department, communicating and coordinating with other departments, with the fire marshal, and with rental houses, and other equipment suppliers. A best boy who maintains good relations with each department can get cooperation when it is needed. For example, when the best boy needs to put a light on the roof of a building, the locations team must make the necessary contacts to secure that spot. When the best boy needs some extra equipment delivered quickly, his or her relationships with the transportation department and the contact at the rental house come into play. The best boy's diplomacy is key.

Lighting technicians

Q: How many electricians does it take to screw in a lightbulb?
A: It's not a bulb, it's a globe.

Affectionately known as *juicers* or *sparks*, electricians are officially titled *set lighting technicians* or *lamp operators*. The electrician's primary responsibility is placing and focusing lights according to the wishes of the gaffer. At each location, the electricians unload and reload the lighting equipment from the trucks, run cabling, and run the distribution of electrical power for the lights. On the set, electricians are responsible for placing and focusing (aiming) the lights; manipulating the intensity, direction, color, and quality of light; wiring practical lamps (such as table lamps and wall sconces), switches, and wall outlets on constructed sets; and anticipating the needs of the gaffer so that equipment is at hand when needed. Lighting technicians secure lights and stands; however, the grip department also plays a role, such as hanging pipe or truss for the lights, securing a stand with straps, or screwing it down with grip-chain.

There is a Zen to the job of the lamp operator. An experienced lamp operator handles the equipment with deft speed and economy of movement that comes with familiarity. Through the exchange of a few words or hand signals, or by clairvoyance, the electrician grasps the gaffer's intention and manipulates the lamp to create the desired effect. His or her focused concentration is on two things: the activities of the lighting crew and the behavior of the light. The lamp operator is constantly attentive to the DP and gaffer and to fellow electricians who might need a hand. Simultaneously, the electrician is aware of the light falling, blasting, leaking, and spilling onto the faces and the surfaces around the set.

The set lighting crew may be asked also to provide power for fellow crew: camera, sound, dolly, and video village. Lighting technicians typically relinquish responsibility for powering vehicles at the base camp to the transportation department. Although powering the base camp is technically within the union jurisdiction of lighting technicians, being trained to handle electrical distribution equipment, most of the time the gaffer simply does not have the personnel to spare for anything extraneous to the set. Despite the nickname, movie electricians are very rarely licensed journeymen or master electricians. They are not qualified to wire buildings or work inside electrical panels. Their job is lighting movies.

Lighting control personnel

Lighting control refers to controlling lighting remotely via a control console, dimmer board, laptop, tablet or other device. A person who operates a computerized control console is called a *lighting control programmer*. A person who operates a dimmer board is called a *dimmer board operator*, or *board op*.

The importance and sophistication of this position on the crew has evolved drastically as lighting devices have gone from having one controllable parameter, via dimming, to having many parameters of control including color temperature, hue, saturation, and special effects. On a good-sized set, it is common for the programmer to have several thousand control channels under their command. The programmer is responsible for organizing the system including supervising assignment of DMX channels to lighting devices, selecting control modes and other device settings, running data lines, setting up wireless networks, and protecting these systems from failure and interference.

The programmer is responsible for grouping and organizing the devices on the control console so that even a large number of lights can be controlled in an intuitive and functional manner. The programmer must be able to respond quickly to instructions from the gaffer or DP to set levels and colors, write lighting cues, and execute the cues during the take. The programmer typically saves important lighting setups as cues so the levels can be recalled for future setups, so the task of organizing and archiving the data is also part of the job.

On a big production, responsibilities are delegated to one or more *systems techs* (also called *DMX techs* or *control techs*). There may be any number of people organizing and addressing DMX512 devices or assisting in other aspects of setting up and maintaining communication networks and control systems. When a lot of moving lights are used, the production may also have one or more *moving light techs*.

Rigging crew

A rigging crew is an important part of almost any project, be it a feature, episodic TV series, or even a television commercial. The rigging crew works ahead of the main unit, installing cable and distribution boxes, hanging lights, and taking care of any work that will be time-consuming for the main unit to accomplish on the day of filming. The electric rigging crew works in tandem with the grip rigging crew. This may involve weeks of work to rig a major set or half a day laying in some cable on location.

A rigging crew consists of a rigging gaffer, rigging best boy, and rigging electricians. A rigging crew is invaluable to a production, especially to the DP and gaffer. The thought, planning, and careful, unrushed work, testing, and troubleshooting put in ahead of time translates into smooth sailing for the shooting crew. A properly rigged set means that the lighting will look better and the unit lighting technicians can work with greater efficiency. *Unit* lighting technicians are the *on-production* team, as opposed to the rigging crew who are *off-production*. *First unit* and *second unit* refer to separate film crews working on the same production. First unit typically works with the principal actors, while a second unit typically works on setups that would be too time consuming for the first unit, such as visual effects, miniatures, animals, establishing shots, beauty shots, but sometimes actual scenes with actors as well. The rigging crew usually also wraps out the set after the unit crew has finished with it.

The fixtures person (or department)

More and more, sets that require a futuristic or otherworldly high-tech look or a whole lot of razzle-dazzle are lit mostly by LED light engines that are built into the set. The set essentially lights itself. Often built-in lighting is selected to create a wide variety of colors and looks, so the look can change radically and be adaptive to whatever dramatic action is taking place.

On tentpole movies, the fixtures department can be bigger than the rigging crew, filling dozens of universes of DMX with lights throughout the set. The fixtures department is responsible for all the on-camera lighting. To avoid problems like flicker and color temperature issues, and because it needs to be controlled with the rest of the lighting, on-camera light sources need to be selected and supervised by a lighting technician who is a specialist in fixtures. Just like the first unit gaffer, the fixtures supervisor has to work closely with many other departments. For built-in lights they work with set design and construction. For *practical lights*, such as a sconce or table lamp, they work with the set decorator. Sometimes wardrobe has lighting in it like space helmets or underwater helmets, which involves issues of safety, practicality, and comfort for the actor. Like the gaffer, the fixtures person has to be smart, respectful, and collaborative in their conversations. Maintaining good relationships with the producer's team and other departments is essential to keeping things moving smoothly. The right personality is quite critical.

The skillset of top fixtures people has to be pretty diverse. They have to be familiar with fabrication techniques in a variety of materials—metals, fiberglass, plastics. They have to be comfortable specking-out and replacing electronics for practical lights when off-the-shelf electronics are unsuitable. They could be called upon to control any kind of light, which can include challenges like controlling the headlights of a moving vehicle, for example. They have to organize large data networks and work with a variety of control protocols including pixel mapping protocols in addition to standard Ethernet and DMX. Since the lights are to be photographed, there's also aesthetic and design decisions and careful craftsmanship involved.

Generator operator

The generator operator is in charge of the full-time operation and maintenance of the generator. A knowledgeable, experienced generator operator is an extremely valuable person to the set lighting department. Most genny operators today are teamsters. The production van driver typically operates the generators on the tractor. There is no special training, test, or apprenticeship program to be a generator operator. People who lack the proper experience are of absolutely no use to you when a generator starts to hiccup. Especially when you are on a remote location where a generator cannot be quickly replaced and you encounter issues with climate, fuel, and other conditions that affect the generators, it is especially worthwhile for the gaffer and DP to insist on using a qualified generator operator.

Grip department

Q: How many grips does it take to screw in a lightbulb?
A: Grips don't change lightbulbs. That's electric.

Nonelectrical lighting equipment is handled by our brothers and sisters in the grip department. A grip is affectionately called a *hammer*. Silks, diffusion frames, flags, reflector boards, rigging, dollies and dolly track, cranes, jib arms are all in the domain of gripology. You could say that the lighting technicians do the lighting and the grips do the shading. Each time an electrician sets up a light, a grip is right next to him or her with a *grip package*, which includes a C-stand and whatever flags, nets, or diffusion frames may be needed in front of the light. Lighting technicians graduating from the nonunion world may be used to grips taking charge of placing sandbags on the light stands, providing ladders, and leveling large stands when they are placed on uneven ground. On union jobs in Los Angeles, the electricians generally handle their own ladders, sandbags, and rigging hardware, such as pipe clamps. Grips handle gel and diffusion when used on a frame or applied to windows. An electrician applies the gel and diffusion when it goes directly on a light.

Grips are responsible for the safety of the rigging, and they are often called on to rig support for lighting equipment and backdrops. Truss, I-beam rails, chain motors, speed-rail grids, wall spreaders, and similar rigs are built by the grips. When lights are to be hung from an overhead grid or rigged to the wall of the set, the grips generally rig the support. An electrician then clamps on the light, plugs it in, and focuses it. When lights are mounted on a high platform, on top of parallels, in the basket of an aerial lift, or on an elevated platform, the grips rig and secure the light and light stand. When an interior night scene needs to be shot during daylight hours at a practical location, the grips build big black tents around the windows to create darkness outside, while providing space for lights outside the building. During production the grips are in charge of removing, and reinstalling set walls as needed during filming.

The head of the grip department is the *key grip*. The key grip supervises the grips in the same way that the gaffer supervises the lighting technicians. He or she works for the DP in tandem with the gaffer, supervising the grips in the placement of grip gear in front of each light.

The key grip's chief assistant is the *best boy grip*. The best boy grip coordinates the grip crew in the same way that the best boy electric does the electric crew.

The *dolly grip* is in charge of operating moving-camera platforms, such as dollies and cranes: laying and leveling the dolly track, moving the camera smoothly up and down and to and from exact marks with precise timing. Grips also rig support for the camera when it is placed in unusual places, such as on top of a ladder or on the hood of a car.

THE COMPANY

A film crew is composed of freelance artists, technicians, and actors who are brought together by the production company when the production is ready to be mounted. The producer and director select the department heads: the DP, production designer, sound mixer, editor, and so on. Each department head usually brings his or her own staff to the production. Usually the DP recommends a gaffer, key grip, camera operator, and camera assistants with whom he or she prefers to work. The gaffer, in turn, recommends lighting technicians he or she knows and trusts.

Each production brings new faces, new locations, and new circumstances, yet you can count on certain constants in relationships between electricians and the other departments.

Production staff

> ***Q:*** How many production managers does it take to change a lightbulb?
> ***A:*** None! If you'd just make it a day exterior we wouldn't have to keep screwing around with all these lightbulbs!

Officially, the crew is hired by the producer. Although the gaffer usually selects electricians for the crew, once an electrician is offered a job, it is the *unit production manager* (UPM) with whom he signs the crew deal memo. The UPM authorizes paychecks that are handled by the accounting department and issued through a payroll company.

The duties of the UPM include establishing and controlling the budget, making deals for locations and services, booking the crew, overseeing daily production decisions such as authorizing overtime and making schedule changes due to weather, and managing all the off-set logistics, including housing, meals, transportation, permits, security, and insurance. Because the UPM is responsible for executing the budget, he or she must approve all equipment orders and personnel requests.

Some productions have a *production supervisor* as well as (or in some cases instead of) a production manager. This distinction between production manager and production supervisor is that a UPM has served many years as an AD and has joined the Directors Guild of America (DGA), whereas a production supervisor has not. Typically, a supervisor has previously worked as a production coordinator working in the production office, not on set.

The *production coordinator* assists the production manager. His or her duties include booking the crew, booking and returning equipment, ordering expendables and supplies, monitoring petty cash, distributing production information to the various departments, and coordinating and distributing the shooting schedule and script revisions. The production manager, the production coordinator, and their staff work out of the production office, along with the accounting department.

The director's team

The "director's team" consists of the ADs, the production assistants (PAs), and the script supervisor.

Assistant director

During preproduction, the first assistant director (1st AD) prepares the script breakdown and production schedule and coordinates the actions of every department and the cast. He or she plans each day's schedule and gives final approval to each day's call sheet, which is usually prepared by a second AD. During production, the 1st AD runs the set. He or she is responsible for keeping the production moving and on schedule on an hour-to-hour basis. The 1st AD keeps everyone informed about the shots, constantly plans ahead and facilitates, coordinates, and motivates the actions of the crew in order to solve problems before they occur. The 1st AD must stay informed of any potential delays or problems. Every production company is required to have an appointed safety officer. On a studio lot, the safety officer is provided by the studio; for independent shows, the 1st AD is the default safety officer. Part of the 1st AD's job is calling and running safety meetings. An onset safety briefing, for which all the relevant crew are assembled, is given to alert the crew to the specific safety issues of the shot, the location, or the day in general.

The 1st AD is backed up by a 2nd AD, who in turn are helped by 2nd 2nd ADs and a squad of PAs. The AD staff takes care of the actors: coordinating their schedules, and ushering them through makeup, hair, and wardrobe and to and from the set. The AD staff also directs the action of background artists (extras) and supervises crowd control.

ADs and PAs can be called upon to help coordinate between departments. For example, if a lighting technician needed some furniture moved to place a light and the onset dresser was nowhere in sight, the 1st AD would have him found in short order.

Prior to the first take, the AD calls "last looks," which alerts the makeup, hair, and wardrobe onset personnel to make final touches. The 1st AD initiates each take by calling "Picture is up," a warning to everyone to finish whatever they are doing and get ready for the take. This is followed by "Roll sound." These instructions are broadcast over the walkie-talkie to all the ADs and PAs, who echo "Rolling" throughout the set, so that everyone knows to settle in for the take and be quiet. Following the take, "Cut" is broadcast by the 1st AD, and again, the AD staff echo it for the crew.

Other announcements:

"We're in" or "We're back." Announced at the start of the day and after lunch respectively to call the company to work.

"Going again." A second take will be rolling immediately.

"Hold the roll." There has been a momentary delay. This cues the sound mixer to stop recording while the problem is fixed.

"MOS." Sound will not be recorded for the shot. The term comes from the early days of sound. It is an acronym for "minus optical stripe."

"Fire in the hole!" Announced before gunfire or explosions. Be prepared for a loud noise to follow.

"Check the gate." If the project is captured on film, after each shot has been successfully completed and the director is ready to move on, the camera gate must be inspected before the next shot is announced. If there is a "hair" in the gate, the shot may have to be retaken.

"Moving on" or **"New deal."** The director is ready to move to the next setup.

"Turning around." The next setup is the reverse coverage or sees the scene from the opposite direction.

"Company move." The next setup is at a new location.

"That's lunch, one half-hour." The company is at lunch. You can head to the catering truck, or do something else, just be back in 30 minutes.

"Abby Singer is up." The Abby Singer is the second to last shot of the day. It was named for (former) AD Abby Singer, who always had "just one more shot" after the last shot of the day.

"Martini is up." The martini is the last shot of the day. (Your next shot will be out of a glass.)

"That's a wrap." The last shot of the day has been successfully completed. If filming has been completed at this location, the lighting crew begins wrapping: taking down the lights, coiling the cable, and loading the truck.

"Make it safe," "Walk away." When filming will resume in the same place, and things can pretty much stay where they are, the ADs may say "make it safe."

Script supervisor

The *script supervisor* makes careful notes on the script and keeps a running log that shows scene and take numbers, lenses used, shot scale, movement, eyeline direction, good takes, flawed takes (and the reason why they were flawed), line changes including ad libs and flubs, and so forth. These notes are used to recall matters of continuity and to note for the editor what coverage was taken and which takes the director thought were the best. In a way, the script supervisor is the onset advocate for the editor, consulting with the director on questions of screen direction and coverage. Matters of continuity are often small details that have to be carefully noted—in which hand an actor holds his beer, at what point in the scene he puts out his cigarette, whether his shirt sleeves are rolled up . . . all the things that everyone sees but no one notices. For this reason, it is vital for her (or him) to be able to see the action on every take; if you stand in her way, you risk being jabbed by her sharp little pencil. The gaffer sometimes has the best boy take detailed notes on the placement of the lights, especially if the scene may be replicated at another time. The script supervisor can provide the best boy with the applicable scene numbers for these notes. The camera assistants and sound recordist also get this information from the script supervisor.

Camera department

Q: How many camera assistants does it take to screw in a lightbulb?
A: Five. One to screw it in and four to tell you how they did it on the last show.

The camera department is made up of the DP, camera operator, first camera assistant, second camera assistant, and, when shooting in a film format, a loader. When shooting in a digital format, the camera crew may include a *digital imaging technician* (DIT) and a camera/digital utility person and digital loader.

The *camera operator* sets the shot and operates the camera. The operator is charged with the responsibility of keeping the lights, grip equipment, and microphones out of the shot. If you are setting a light close to the frame line, the camera operator can tell you where it is safe. It is a very good idea that the camera operator set the shot before the lighting crew starts lighting it, as important details, such as the exact placement of the actors, and what background will be photographed, may change during this process. Although this may cause the lighting crew to hold off on the work inside the set for a couple of minutes, ultimately it saves having to set lights twice.

The *first camera assistant* (1st AC) is responsible for the camera, including building it, configuring it (physically and in terms of electronic settings) for each shot, making lens changes and performing regular maintenance as needed. During the take, the 1st AC keeps the camera in focus and may perform any of a multitude of other tasks—zooming, making an aperture change, or ramping the shutter speed or angle. The 1st AC never leaves the camera's side.

From time to time, the 1st AC calls on the lighting crew to help get rid of lens flare—light hitting the lens that may flare on the image. Usually the grips can set a flag or hang a "teaser" to keep the light off the lens.

The 2nd AC aids the 1st AC with lens changes and magazine changes, marks the actors' positions, slates each shot, and keeps the camera reports and film inventory. Almost all camera equipment runs on batteries, but a 2nd AC needs power to run a video monitor. When a director uses a video monitor, it quickly becomes habit to supply power to the monitor as soon as the camera is placed. Similarly, a hot extension cord should be supplied for the dolly at all times.

Sound department

The *sound mixer* oversees the recording of audio. The sound mixer is the one person on the set fortunate enough to perform his or her job from a sitting position. If you want to know the sports scores, he or she almost always has the newspaper at the sound cart.

The *boom operator* is the person who actually positions the microphone within range of the actors, by holding it on a pole over their heads, wiring them with radio mics, or planting hidden microphones on the set. When a power cable must cross the microphone cable, the electrician should run it under the microphone cable so that it doesn't restrict the boom's movement.

The boom operator has to contend with shadows cast onto the actors and walls by the microphone and the boom pole. Boom operators are very good at analyzing the lighting and use great ingenuity to avoid casting shadows. The lighting crew helps the boom operator by setting toppers on lights as needed to eliminate microphone shadows. Certain lighting directions are inherently problematic for the boom operator. For example, hard front light from the direction of the camera tends to throw mic shadows onto actors, set dressings, or walls that are right in line with the actor being filmed. Raising the light higher so that the light is angled downward and then topping the light can eliminate the problem. Steep, top-down lighting is another difficult angle for the boom mic, because it tends to throw microphone shadows across the actors' clothes or table surfaces. Sometimes, the lighting is such that a boom microphone simply cannot be used, and the sound department must accommodate by using other methods such as radio mics.

The sound department has a vested interest in proper placement of the generator. Even with baffles to deaden it, engine noise can be a nuisance. Ballasts and dimmers usually hum and can become a concern for sound. Place them as far from the microphones as possible—preferably in another room or outside. Obviously, cell phones must be *off* during rehearsals and filming.

Dimming, light cues, and lighting effects create electrical "noise" in the power supply. The sound cart should be powered via separate utility power. All crew members must check with an electrician before plugging in their own electrical equipment; mistakenly plugging an expensive monitor into a dimmer channel, for example, is an experiment you don't want to be a part of.

Locations

Q: How many fire safety officers does it take to screw in a lightbulb?
A: One, but it's an 8-hour minimum.

A script might call for a city street, department store, hospital, church, factory, private residence, prison, airport terminal, office building, hotel lobby, or postapocalyptic tundra. Many settings can be more easily (and cheaply) filmed at an existing real site than recreated on the studio stage or lot. Whatever the case, the locations department finds, secures, and coordinates the film's locations.

When on location, any questions or problems pertaining to the building or grounds (such as rigging lights to the structure or access to locked rooms or circuit breaker panels) are handled by the building rep or building engineer through the *location manager* or his or her assistants. The location manager must sometimes wrangle tough situations with members of the public or employees of the location. It is best to defer any questions from these people directly to the location manager or the ADs. The location manager obtains permission to place lights in unorthodox places. Any kind of rigging that might do harm to a location or otherwise alarm the owner must be preapproved through the location manager.

Care must be taken not to damage the location. The places that are most at risk of damage are floors, walls, doorway moldings, and garden plants. When a house has hardwood floors, for example, the grips and lighting technicians can put rubber crutch tips on the legs of the stands and ask that layout board be put on the floor to protect it. Some locations impose restrictions on the use of their property. Working on a period movie, you may well find yourself shooting in a historical building with irreplaceable architectural detail. It is often the location manager's task to enforce whatever rules have been established at the location (and contractually agreed to by the producer), rules that may conflict with the needs of the lighting department. In these situations, keep in mind that it is the director's desire to film the location and it is your job to make it work. It will usually involve extra time and trouble, but it is more important to keep the location manager as an ally and to help preserve good relations with every location the company uses. In the greater scheme of things, it is better for our whole industry if the public views film production as a positive experience.

Transportation

Q: How many teamsters does it take to screw in a lightbulb?
A: Four. You got a problem with that?

The drivers are responsible for operating and maintaining all the production vehicles. In addition to the "production van" (usually a 40-foot truck that carries all the lighting equipment), transportation provides passenger vans to shuttle the cast and crew, stake beds trucks with hydraulic lift gates for delivering equipment, and any other vehicles that are needed. Stake beds are particularly useful on location when equipment needs to be shuttled to several sites in one day or must be dispersed over a large area. Drivers may also be dispatched to make runs to return or pick up equipment from suppliers. It is a good idea for the best boy to give the *transportation coordinator* as much advance warning as possible, as needs arise.

Art department

Q: How many art directors does it take to screw in a lightbulb?
A: Does it have to be a lightbulb? I've got a really nice candelabra we could use.

The construction crew builds the sets, the *set dressers* decorate the set with items not handled by an actor, and the *props department* is responsible for anything that is handled by an actor. Wall lamps, practicals, "oil" lanterns, and the like are provided and placed by the set decorators. Wiring them is taken care of by a lighting technician. During production, the *onset dresser* and his or her helpers are responsible for caring for the furniture and all elements of decoration. If a piece of furniture needs to be moved, or a picture frame removed from the wall, ask the onset dresser to do it. If you do it yourself, it will break; it's an immutable Law of Set Dressing.

Hair, makeup, wardrobe, stunts, special effects, first aid, craft service, and catering are the remaining departments on the set that electricians need to consult from time to time. They are all essential parts of the production and it pays to stay on good terms with every department.

THE GENERAL PUBLIC

One more group with whom you will come into contact, especially when working on location, is the general public. Everyone on a film crew knows how important it is to establish and maintain good relations with the public. No one knows this more than the location manager. On location, more often than not, a film crew is a guest in someone else's house. We constantly hold up traffic and ask people to be quiet during takes. By our very presence, we often put someone out. Although typically the location is being paid well for the trouble, every flower that gets trampled in the garden, every unthinking curse word uttered within earshot of sensitive ears, and every piece of equipment left in someone's way makes the public less inclined to cooperate and to let us do our work. A disgruntled neighbor may confront the first person he or she sees, sometimes quite rudely. It is the job of the locations manager and production manager to deal with complaints. As lighting technicians, our role in all this is minimal but important. Treat any comment or question from the public with politeness and professionalism. Help the locations manager stop trouble before it starts by pointing any complaints or problems his or her way. Get approval before placing a light somewhere that it is going to annoy civilians; that way, the location manager has a fighting chance at preemptive diplomacy. When locations or production make specific rules or requests with regard to working in a location, know that they are doing so because the issue is *already* sensitive. If they tell you to wrap out quietly, they are doing so because there have *already* been complaints about the noise. Many communities have ordinances that require quiet after 10:00 p.m. and no trucks and work before 7:00 a.m. In cities like Los Angeles, New York, Toronto, and Vancouver, a large segment of the population has had a bad experience with film productions, which makes it very difficult for production to work on location. There are also those who have learned that they can extort money from a desperate production manager and make noise and get in the way until they are paid. As much as possible, these are behaviors we'd like to change.

Okay, let me just finish off the list:

Q: How many stunt men does it take to screw in a lightbulb?
A: Five. One to screw it in and four to tell him how bitchin' he looked doing it.

Q: How many studio execs does it take to screw in a lightbulb?
A: No one knows. Lightbulbs last much longer than studio execs.

Q: How many actors does it take to screw in a lightbulb?
A: 100. One to screw it in and 99 to say they could have done it better.

Q: How many screenwriters does it take to change a lightbulb?
A: The lightbulb is IN and it is staying IN!

Q: How many editors does it take to change a lightbulb?
A: If we change the lightbulb, we'll have to change everything.

Q: How many grips does it take to screw in a lightbulb?
A: Two. One to hold it and the other to hammer it in.

One final note about working with the crew. This entire book is about the nuts and bolts of being a lighting technician. That's the job. But this knowledge is only maybe 10 percent of what makes you a success. The rest is your personal relationships, your ability to listen and communicate, to get the job done smoothly and reliably without ruffling other people's feathers.

BLOCK, LIGHT, REHEARSE, TWEAK, SHOOT

Progress on the set is measured in *setups*. A feature film crew may shoot two or three pages of script a day. For a television single-camera show, the average is four to eight pages per day, typically 20–30 setups per day. The AD and DP work together to determine an efficient shooting order for the needed shots. Conventionally, wider master shots are photographed first, establishing the lighting for the scene. Closer coverage, which usually requires refinements to the master setup, follows.

Although it is convenient when the shooting order is efficient for lighting, the DP and gaffer respect the fact that sometimes the AD may have other priorities. Shot order may be arranged to give precedence, for example, to a particularly difficult performance or a stunt that destroys part of the set, or to finish the work of an underage actor who can work only limited hours by law. Removing and reassembling walls of the set is often necessary to accommodate camera movement and lighting. Because this takes some time and is labor intensive, "wall order" is the kind of thing that the DP and AD want to take into account when planning the shot order.

Ideally, each new scene follows these five steps in order:

1. Block
2. Light
3. Rehearse
4. Tweak
5. Shoot

First the director, the DP, and the actors block the entire scene (i.e., plan the staging). During blocking rehearsal, the set is usually cleared so that the actors and director can work without distraction. The director and principal actors are called the *first team*. Once the scene is ready to show, the AD calls a "marking rehearsal," and all key crew pile into the set and watch. The gaffer, key grip, and camera operators learn a great deal from the marking rehearsal, and they must pay close attention, as this is typically their only chance to observe exactly how the actors intend to play the scene before they have to start lining up shots and begin lighting. The 2nd AC marks the actors' positions with tape at their feet.

Once the scene has been blocked, the actors are sent to makeup and the DP begins setting the shots and then the lighting. Often, the lighting crew has already roughed in some of the lights during a prelight. Stand-ins, who act as models for the gaffer and DP while the lights are placed, replace the actors. The *stand-ins* are known as the *second team*. The camera crew sometimes rehearses complicated camera moves using the stand-ins to save the principal actors from technical rehearsals. When there are lighting cues during the shot, and the second team rehearsal is the lighting crew's best opportunity to rehearse them and make adjustments.

Once the lighting is in place, the AD calls the first team back to the set for final rehearsal. He or she calls, "Quiet please. Rehearsal's up." The actors run through the scene with the camera and sound crew to iron out any remaining problems. The AC gets final focus marks. After one or two rehearsals, the scene is ready to shoot.

A basic piece of set etiquette that every crew member knows: stay clear of the actors' eyelines during rehearsals and takes. Be mindful of the level of concentration that acting requires, and cause as little distraction as possible.

Block, light, rehearse, tweak, shoot is a paradigm that provides all the crew members the information they need to act independently to bring all the details of the shot together smoothly. Nonetheless, there are times when some directors and ADs would clearly prefer to bypass the first four steps. The truth is lighting without blocking first always causes delays when the actors arrive and do things differently. The crew needs to actually *see* a blocking rehearsal. This gives the crew almost all the answers they need to prepare the scene. Not doing so leads to a barrage of unanswerable questions from every department. Trying to shoot without rehearsing and tweaking almost always results in delays while problems are addressed, followed by retakes. The DP needs an opportunity to tweak the lighting after the final rehearsal because inevitably the actors will sometimes need to do things differently than they rehearsed, or differently than the stand-ins did it. During the final rehearsal, the DP will often see a problem that needs to be addressed before shooting. When time seems like a luxury the director cannot afford, it is far better and faster to block quickly, light quickly, rehearse quickly, tweak quickly and shoot, than it is to shoot now and ask questions after.

CHAPTER

2 Preproduction planning: The package, expendables, personal tools

PREPRODUCTION PLANNING

During preproduction, the gaffer, rigging gaffer, and best boy meet with the DP and scout locations and sets, with the primary objective of compiling equipment lists and estimating manpower. Everything that will be needed to light the sets and locations needs to be set down on paper so that equipment vendors may prepare price quotes. The lighting order always represents a major expense to the production, so the UPM is eager to see the equipment list as early as possible in order to solidify deals with vendors and know where the budget stands.

To come up with a complete equipment list, the gaffer needs pretty clear ideas about how each scene will be lit. The gaffer reads the script carefully, making notations and raising questions for the DP. He or she discusses scenes with the DP. The input of the director, production designer, and costume designer often steer important lighting decisions. When scouting the locations and looking at the sets, the DP, gaffer, key grip, and rigging keys (rigging gaffer and rigging key grip) are confronted with the particular challenges they'll need to address: how lighting effects will be created, how lights or lighting platforms will be rigged, what control systems will be required, what colors will be used, and what special accessories are needed. These determinations translate into the specific lights and equipment needed, how much power, how much cable, and so on.

Each step of the way, the gaffer and rigging gaffer must consider three things: equipment, personnel, and time.

Equipment: What basic equipment will the lighting department carry for the duration of the show (the *truck package*)? Which scenes require additional equipment (e.g., a set with a big backing or green screen) or special equipment (aerial lifts, wet locations protection, specialty lighting equipment, and so on)? Will the transportation department need to furnish extra vehicles on particular days to move equipment from place to place?

Personnel: How many additional lighting technicians are needed to operate this special equipment (Condor, follow spot) or to prerig or wrap out cabling and equipment? Are certain days on the schedule particularly difficult, or will large locations require extra hands?

Time: What prerigging is required to achieve efficiency during shooting? How much time does it take to get into and wrap out of each set? What might cause lighting delays? What workable solutions can the gaffer suggest?

Additionally, the gaffer and DP, in collaboration with the production designer, determine what special considerations should be given to the lighting in designing the sets. Designers are generally very conscious of lighting and design the sets with windows in places that will make for good lighting;

however, looking over the designer's plans allows the DP, gaffer, and key grip to consider practical matters such as access to the set, placement of wild walls (walls that can be removed), and removable ceiling pieces. Thinking about these things beforehand saves time during shooting.

The gaffer and DP discuss how they will approach the material: the mood and style of the film, the color palette, the working light levels, and the kind of shots. If a Steadicam shot will reveal every corner of a room, that will require all lights be hung above or outside the set, for example.

Scouting locations

The director, assistant director, and department heads scout each location in a group; the director and first AD present an overview of how the scenes are played out. The DP and gaffer formulate a rough idea of how they will light each space. If the lighting is complex, notes from the scout will be drawn up as light plots. Notes are invaluable during future discussions. The gaffer, best boy, and rigging gaffer consider the special rigging required, special equipment required, location of the staging area, and placement of the production van. During the scout, they gather the information they will need to adapt the space for lighting. For the rigging gaffer, the scout is their brief opportunity to determine most of the parameters of the job. They need to map out routes of access to each set for cabling and figure out where the generator can be placed to be as close to the set as possible without causing sound problems. They must learn from the DP, AD, and director how the feeder cables can be run to the set without entering into the shots. He needs to note other equipment such as aerial lifts or parallels that may be employed outside the windows to support large lights. The rigging grip will note required grip support like wall spreaders, trusses and windows, which may need to be gelled or blacked out.

If house circuits may be used, the best boy locates and examines the breaker box to determine its capacity and the layout of circuits. He locates the light switches for sconces and house lights. He works with the location manager and the contact at the location to gain access to locked rooms or arrange for lights to be placed on a neighboring property. He must find the service entrance through which to bring in carts and equipment without encountering stairs. He must locate the elevators. If large numbers of fluorescent lights are needed, he must get a count of the number of tubes to be ordered. In short, he must fully think through the lighting needs at each location. The rigging gaffer has a lot to do on the scout and is always the last person back on the bus.

An iPad and some good software can be invaluable for noting and processing the requirements of each location. Apps like *TechScout Touch* are designed to streamline the process of compiling the equipment order and communicating it with the gaffer, DP, and production office. Once the locations have been scouted, the rigging gaffer or best boy looks over the production schedule; evaluates personnel, equipment, and time requirements; and writes up an equipment list, an expendable supply list, and a calendar showing when special equipment and additional labor will be needed. A form like the one shown in Table 2.1 is extremely helpful for remembering and determining the needs of each location.

Production meetings

At least one major production meeting is held before production begins. This is scheduled after all the tech scouts have been completed and is attended by all the department heads. The meeting is led by the first assistant director. Typically, the AD goes through the script scene by scene and describes all the major elements. Questions and concerns from any department are raised and discussed. Issues that involve a great deal of interdepartmental cooperation are the most important to flush out in detail.

Weekly Schedule of Personnel and Equipment								
Personnel Schedule		**Week of Production**						
	Totals (days)	*Day, Date*	*Day, Date*	*Day, Date*	*Day, Date*	*Day, Date*	*Day, Date*	*Day, Date*
1st Unit Location:								
1st Unit Move to:								
Programmer								
Extra lamp operators								
Rig gaffer								
Rig location 1:								
Rig location 2:								
Strike location 1:								
Strike location 2:								
Fixtures person								
Total riggers								

Equipment and Coordination Schedule	**Week of Production**						
	Day, Date	*Day, Date*	*Day, Date*	*Day, Date*	*Day, Date*	*Day, Date*	*Day, Date*
TRANSPORTATION							
Crew cab/stake bed							
Trailer							
Scissor lift							
Condor							
Tow Plant							
Notes							
LOCATIONS							
(Notes, e.g., kill streetlights)							
SPECIAL EQUIPMENT							
(e.g., balloon lights, Bee-Bee lights, equip-ment drop load, details, equipment pick up, etc.)							
NOTES							
(e.g., rig lifts, change out fluorescents, load-in 1st unit, etc.)							

Decisions involving only two parties can be identified and deferred to separate meetings. The gaffer and key grip are required to attend, listen, and contribute when it is helpful. This is usually a long and painful meeting, but it is often the only opportunity for everyone to learn about the plans and needs of other departments that might affect them.

Wireless spectrum management meeting

As discussed in Chapter 12, the wireless spectrum is a crowded space. If lighting is to be controlled wirelessly at any point during production, it is essential to establish interdepartmental cooperation and manage the use of the spectrum. This starts by holding a dedicated preproduction meeting that includes camera, sound, lighting and anyone else depending on wireless equipment.

It may be helpful to perform a site survey/spectrum analysis of the locations prior to the meeting to see what interference/traffic exists already; however, the radio environment is never static and a sample at one time might not be representative of the environment at all times. It is desirable, especially on studio lots with multiple concurrent and changing productions, that a person from the facility with knowledge about adjacent and potentially new incoming productions is present.

The meeting should be structured to accomplish the following:

- Submit each department's equipment specs, spectrum needs, and capabilities. It is each department's responsibility to obtain as much information as possible, ideally from the manufacturer (see sidebar).
- Determine what measures will be taken to ensure mission-critical channels are not stepped on, such as the following:
  - assignment of distinct channels so they do not overlap (for example, on the 2.4 GHz spectrum, channels 1, 3, and 11 do not overlap),
  - verification that video transmitters are 5 GHz and not 2.4 GHz (new equipment from Teradek, Paralinx, ARRI W, and Amimon use 5 GHz band),
  - use of frequency blocking (a setting on the transmitter that blocks it from certain channels),
  - use of reduced power level settings,
  - selection of antenna type and location, and
  - use of wired connections where needed.

RADIO EQUIPMENT SPECIFICATIONS RELEVANT TO SPECTRUM MANAGEMENT

- Brand, manufacturer, product ID
- Firmware version
- Equipment category (e.g., lighting control DMX/RDM transmitter)
- Operating frequency (e.g., 2402–2480 MHz)
- RF technology (e.g., narrow band, adaptive frequency hopping spread spectrum)
- Modulation
- Directionality
- Channel width and spacing
- User frequency management capability (e.g., multiple 20 MHz wide channel blocking)
- On-air duty cycle
- FCC maximum peak output power
- User output power management capability (selectable power levels in dB and mW)
- Antenna (gain and directionality)
- EIRP (Effective Isotropic Radiated Power) (dB)

THE LOAD-IN

The load-in is the first day of work for the lighting technicians on a feature film. The best boy supervises the checkout and load-in, making sure the lighting order is correctly filled and all the equipment is in full working order. The checkout must be extremely thorough. Even at the best rental houses and studio lamp docks, you cannot assume that all the equipment is in perfect working order or leave the counting to someone else. At the completion of filming, any broken or missing items are charged to the production as "lost and damaged." There are a lot of ways to foul up the paperwork: orders are often changed at the last minute, and special equipment may come from more than one rental house. Almost always, a few items require maintenance or are miscounted by the rental house, so count and check the equipment carefully.

Prepping lights and stands

Each light should be inspected for physical damage and tested by turning the light on and testing each of its functions at checkout. Once you establish a routine for checking lights, it takes very little time to check all the items on the checklist.

For lights like LEDs, that will be controlled from the console, the programmer determines which one of the light's DMX profiles will be assigned and then creates a patch sheet for all the lights that are on the console. The patch tells you the fixture number, universe number, and DMX start address for each light (see Chapter 12 for full explanation). During the prep each light should be labeled with this information, with the fixture number in large, bold, clear numbers. The label might look something like this:

S60 2			
Mode	**Fixture**	Uni	DMX
P25	**1202**	1	174

LUSTR 2			
Mode	**Fixture**	Uni	DMX
HSIC+7	**1092**	1	120

Start by performing a factory reset to dump anything that is in memory and set the light back to all its default settings. Check and update the firmware as needed. Set DMX start address and DMX mode/profile. If there are other custom settings like Hold Last Look or Low End Mode, use a checklist to be sure all the settings are made correctly on each light. See Chapter 7 for an example of a SkyPanel Setup checklist. If the light is RDM compatible settings can be made very easily using DMXcat® or directly from the console (see Chapter 12).

For tungsten and HMI lights and stands see Checklists 2.1 through 2.3. Take your time; you do not want to discover problems on the set when production is in full swing.

There are times when prep time is insufficient, but the goal is to check the gear as thoroughly as time allows. If the production is traveling to location where it will be hard to replace an item, it becomes even more important to ensure everything is working 100 percent. Lack of prep is a form of risk-taking. Risks need to be brought to the attention of the UPM. If management understands the risk, they may be able to line up a plan B, even if they decide against granting more prep time. The best boy

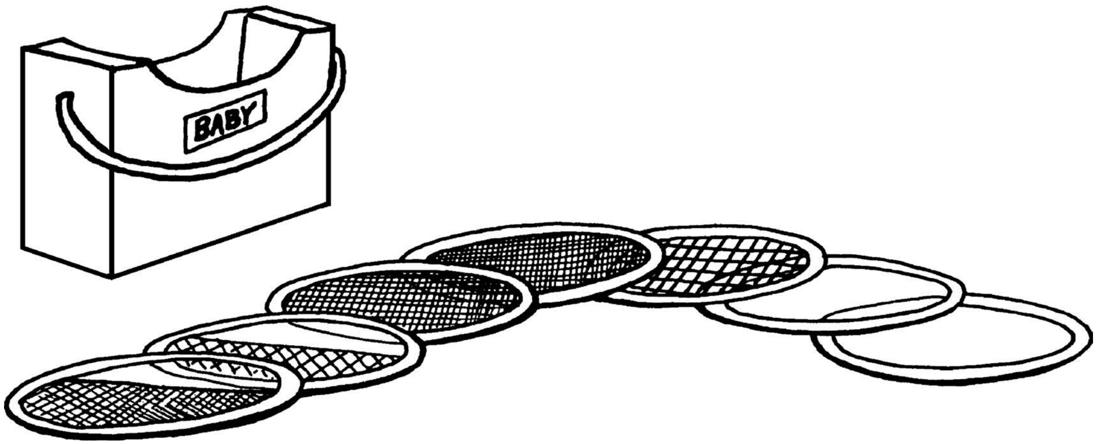


FIGURE 2.1

Complete scrim set with box. The Hollywood set includes (from left to right) a half double, half single, two doubles, a single, and a set of gel frames.

or gaffer needs to have a conversation with the production team. Generally, any situation you can't fix yourself, that creates risk that could affect schedule, cause damage, or present a safety hazard must be escalated to the producer's team.

CHECKLIST 2.1: FRESNEL AND OPEN-FACE TUNGSTEN

- ☐ Check that each light is complete. Each must have a full set of scrims, a scrim box or bag, and barn doors. Count the scrims. A complete five-piece set includes two doubles, one single, one half double, one half single, and one set of gel frames (Figure 2.1).
- ☐ Check the fit of barn doors. Check for floppy doors. For fresnels, most gaffers prefer four-leaf rather than two-leaf doors. Doors should be fitted with safety chain.
- ☐ With the power disconnected, open the fixture and check the condition of the reflector. Especially with hot-burning lights such as baby-babies or baby-juniors, the reflector can become warped and discolored by prolonged use tilted steeply downward. The reflector must be properly aligned, unbent, clean, and in good condition.
- ☐ Inspect the bulb for blisters and bulges, evidence that the bulb has been mishandled, and burnout is imminent.
- ☐ Check whether the lens is clean and free of cracks. A little dust buildup on the lens cuts the light output in half.
- ☐ Check whether the tilt lock (T-handle) threads properly. The threads sometimes get stripped.
- ☐ Check whether the tilt lock knuckle holds the light firmly. The cork disks at the swivel point wear out and occasionally need to be replaced.
- ☐ Check plugs for signs of overheating—discoloration, deformation.
- ☐ Plug in each fixture and turn it on to check the bulb and the switch. Wiggle the cord at the switch and lamp housing to ferret out any intermittent discontinuity (problem with power cord or lamp base contacts).
- ☐ Make sure that you have any needed connector adapters.
- ☐ Check the flood spot mechanism for smooth, full travel. Observe the beam as it changes. An uneven or odd-shaped beam is evidence of an improperly aligned bulb or a bent or damaged reflector.

CHECKLIST 2.2: ADDITIONAL STEPS FOR HMI CHECKOUT

- ☐ Inspect all the same items as for a tungsten light, especially inspecting the bulb for blisters and bulges and checking that the lens is clean and uncracked.
- ☐ Each unit should be complete with scrim set, barn doors, lens set (for PARs), two-head feeder cables, ballast, and power feeder cable.
- ☐ Hook up and turn on each light, using both head feeders. Inspect the head cables for bent pins or misthreaded connectors, cuts in insulation, and a loose strain relief collar at connector.
- ☐ Allow several minutes to reach full output. Using a spectrometer to measure the color temperature and green/magenta shift of each unit. Mark these measurements on a piece of white camera tape and tape it to the bail of the light. Also include the date and the unit number.
- ☐ Number each head, and globe box, so that the same head and globe are always used together. Or name them, Curly, Larry, and Moe, for example.
- ☐ Watch for unstable arcs. You can use a welder's glass to observe the bulb through the lens.
- ☐ You may also want to test the restrike capability of the light by turning it off and attempting a restrike after 15 seconds. If the light will not restrike, try again once every 60 seconds to see how long you have to wait. Note: repeated unsuccessful ignition attempts discolor the inside of the bulb; don't overdo it.

CHECKLIST 2.3: STANDS CHECKOUT

- ☐ Raise each stand to full extension. Check for binding and corrosion. Test the lock of each T-handle.
- ☐ Inspect for bent or broken braces and loose or missing brace bolts.
- ☐ Crank stands and motorized stands should be tested by raising and lowering the stand with a sandbag on the top. The weight is necessary to prevent the stand's inner mechanism from binding when lowered.
- ☐ Pneumatic tires should be fully inflated and roll smoothly.
- ☐ Check that the wheel swivel locks, brace hinges, and collars operate properly.

The production van

When shooting on location, the lighting crew works out of its truck. Depending on the size of the production, the vehicle may be anything from a cube van, to a 10-ton truck, or a fully customized, 40-foot, 18-wheel production van. A fully equipped production van like the one shown in Figure 2.2 is complete with dual generators mounted on the tractor. The truck has a large hydraulic lift gate on the back, one or more side doors with stairs, interior lighting, and a well-organized design. It may have some shelving for equipment and brackets on the doors to hold stands. The most efficient arrangement is to have all the most frequently used lights stored on shelved carts. For example, a big LED cart, small LED cart, tube and ribbon cart (see photos in Chapter 7), a tungsten cart, HMI cart, expendables cart, and so on (Figures 2.3–2.5). The lighting inventory can simply be rolled off the truck and straight to the staging area. Marking exactly what and how many of each item goes on the cart ensures you have everything at the end of the day. During transport, carts are strapped to the walls of the truck. Smaller 5- and 10-ton trucks have jockey boxes underneath both sides of the truck that carry cable and sandbags. Tractor-trailers have doors along the length of the belly that can hold a substantial quantity of cable and distribution equipment. Cable dollies (Figure 2.3) are used for moving cable and distribution equipment.

FIGURE 2.2

A 40-foot production van with two tractor-mounted generators.

(*Courtesy Mike Ambrose*)

FIGURE 2.3

The production van houses all the equipment for transport. Note that the head carts are loaded and strapped to the walls. Two cable carts are pictured at left. Further to the front of the truck shelving holds other lights, and supplies.

(*Courtesy Mike Ambrose*)

FIGURE 2.4

The expendables cart carries milk crates which typically store practical lamps, spare lamps, hand dimmers, tape, sash, Velcro, hardware, and so on.

(*Courtesy Mike Ambrose*)

FIGURE 2.5

Gel rolls are stored on the back side of the expendables cart. Rolls of diffusion, ND, plus and minus green, CTO, CTB, and CTS gels are typically carried.

(*Courtesy Mike Ambrose*)

EXPENDABLE SUPPLIES

Expendables are supplies that are purchased and used up in the course of production. The best boy and lighting technicians use prep days for organizing and prepping expendables, cutting gels for the lights, and completing any similar tasks to get everything ready for the first day of shooting.

Gels and diffusion

Normally, the crew will prepare precut color correction and diffusion gels to fit whatever lights may need them. Cuts of gel are kept in a crate, sectioned according to size and color (Figure 2.6). A 6-in. square fits inside the barn doors of units 1k or smaller. An 8-in. square fits studio babies and baby juniors. The 10- and 12-in. sizes fit inside the doors of regular juniors and outside the doors of lamps 650 W and smaller. The larger cuts of gel fit on the outside of the doors of 2ks, 1200 HMIs, and PAR lights. Anything larger than 24 in. can be gelled using a frame supplied by the grips.

The best way to cut gel from the roll is to use a template. Cut a 24-in. × 48-in. piece of ½-in. plywood and mark out a grid pattern in the sizes you need. Use a circular saw to score along the marks, making grooves ⅛-in. deep. Roll the gel or diffusion out on the template, aligning it to the edges and then use a matte knife to slice down the grooves. Mark the corner of each gel cut with the color, ½ CTO, or ¼ CTB, or 216 diffusion.

Electrical expendables

A production may or may not require all of the items described here. During prep, these items are organized in the drawers of a work box, crates on the milk crate cart, and boxes on the shelves of the truck. Label each drawer, crate, and box with its contents to make items easy to find. A large-capacity toolbox with drawers makes an excellent storage place for all the small expendable items (Figure 2.4).

FIGURE 2.6

Cut gel and diffusion are marked with permanent marker and stored according to size and type. Here, short sections of PVC pipe create a convenient gel organizer.

(*Courtesy Mike Ambrose*)

Common expendables

Tape rolls: Put together a selection of tape rolls on a loop of sash cord: one roll each of 2-in. gaffer's tape, 2-in. black paper tape, and 1-in. white cloth tape. The electrical tape rolls (all colors) go together on a separate rope.

Practical bulbs: Mark and organize practical bulbs so their wattages and types are easily readable. Label the boxes. Insert foamcore dividers in a couple of milk crates. Stock compartments with various types and wattages to keep near the set. PH-bulbs (211, 212, and 213) do not have their rating printed on the top of the bulb. It is helpful to mark the top of these bulbs with a permanent marker: one dot for 211, two dots for 212, and three dots for 213.

Black wrap: Black wrap is a durable black foil used on hot lights to control spill and shape the beam. It is available in rolls of 12 in. (50 ft.), 24 in., and 36 in. (25 ft.). White wrap is also available.

Clothespins: Nicknamed C-47s or bullets, these are used to attach gels and diffusion to the lights.

Binder clips: (the metal spring-loaded oversized paperclips) are also handy for attaching gels and fabricated snoots.

Rubber matting: Matting is used to cover power cables where they cross doorways and other traffic areas. It comes in rolls 24 in. wide, up to 100 ft. long.

Sash cord: Sash cord is made of white cotton rope. It is used for tying cable to pipe, among other things. Commonly used weights are #6, #8, and #10.

Trick line and mason line: These are #4-weight nonstretch rope. Trick line is black. Mason line is white. Used for tie strings for smaller cords and data cables.

Bungee cords and S-hooks: Black rubber bungee cords come in various sizes and should be ordered to fit the shelves of the truck and carts.

Cube taps: Cube taps are used for plugging several low-amperage lights into one outlet (15 A max). See Figure 2.7.

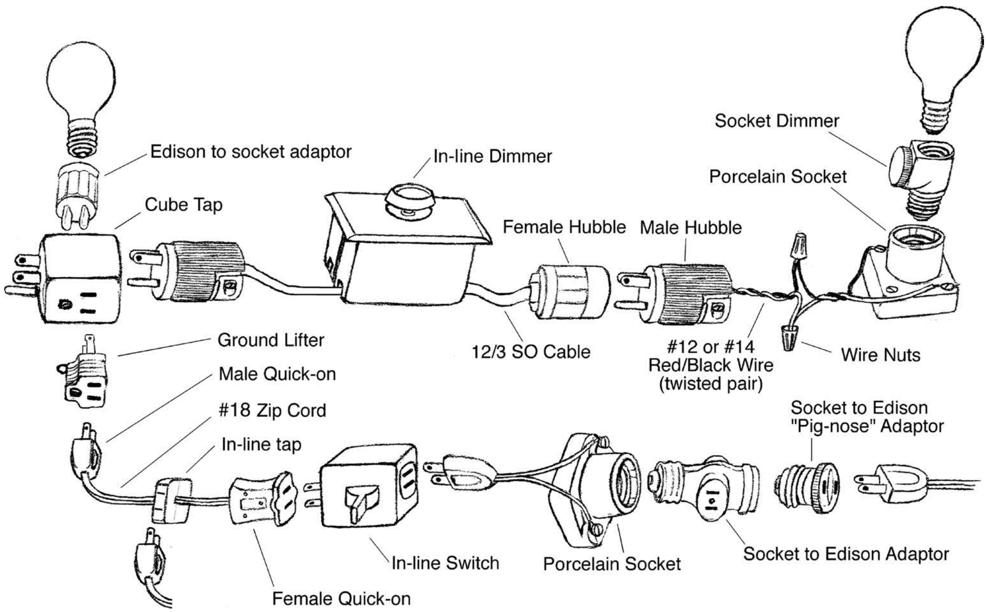


FIGURE 2.7

Electrical supplies.

Ground plug adapter: A ground plug adapter is used to adapt grounded plugs to the ungrounded outlets found in older buildings. It is also called a *cheater*, *ground lifter*, or *two-to-three adapter*. See Figure 2.7.
Quick-on plugs: These are small, low-amperage Edison sockets and plugs that can be connected to #18 zip cord quickly with no tools. Quick-on plugs can be used on small practical lamps. See Figure 2.7.
Zip cord: Light 18-gauge household lamp cord used for wiring small practical lights. See Figure 2.7. Part 530 of the National Electrical Code (NEC) requires that all cords and cables used for set lighting be hard usage or extra hard usage cables. Zip cord does not meet this requirement, so therefore quick-on plugs, add-a-taps, in-line taps, and zip cord are not approved for lighting devices except where the cord is part of an approved assembly like the cord of a table lamp.
Wire nuts: A wire nut is an insulated cap used to splice two bare wires together. See Figure 2.7.
Dimmers: Household dimmers of 600 and 1000 W are commonly used to dim small lights and practicals. See Figure 2.7.
Porcelain sockets: Lamp sockets (medium screw base, E26) are used to mount lightbulbs in set pieces and soft boxes. Use porcelain sockets, because photo bulbs will melt plastic sockets. See Figure 2.7.
Socket dimmers: A socket dimmer (150 W max) screws in between the lamp socket and the lightbulb, allowing the bulb to be dimmed. See Figure 2.7.
In-line switches: When rigging practical lights in sets, it is sometimes handy to have a plug-in 15-A switch on the line. See Figure 2.7.
Hubble Edison: Stock male and female Hubble Edison plugs to replace the plugs on stingers and power cords when they burn out. See Figure 2.7.
#12 copper wire: Black, white, and green #12 wire for wiring special lights and devices. See Figure 2.7.
Spare fuses: Consider having replacement fuses for any equipment that uses a fuse. Gang boxes use 20-A BAF bus fuses. Sometimes 100-A to two 60-A Bates splitters use 60-A inline fuses. Variacs, ballasts, and other power supplies may also have a fuse.
Electrical tape: Electrical tape is used for color coding cables (red, white, blue, black, and green). It's also handy for insulating wire splices.
Gaffer's tape: Gaffer's tape is a heavy 2-in. fabric tape that rips cleanly in the direction of the weave. It is stronger, more durable, and more adhesive than paper tape.
Paper tape: Black 2-in. paper tape is handy for masking light. It has less of a tendency to pull the paint off walls than gaffer's tape.
White and colored cloth tape: This 1-in. and 2-in. cloth tape is used for labeling and color coding equipment.
Sharpie markers: For labeling.
Ball point pens: For paperwork and labeling.
Snot tape: (3M transfer tape) This is a sticky film that is handy for mounting gels in gel frames.
Zip ties: For bundling cords or securing items to one another.
Velcro and Velcro adhesive tape: For tying cords and cables and securing items to one another.
Dulling spray: This is a spray applied to shiny surfaces to tone down reflective glints.
Streaks and tips: Colored hair spray is used to tone down or black out surfaces that are too bright. It is water-soluble, washes off easily after filming, and comes in shades of auburn, beige, black, blond, brown, gray, pink, silver, white, and others.
Practical bulbs: These are bulbs used in practical lamps, usually household (medium screw base) bulbs. Various types are used, among them photoflood bulbs, household bulbs, floodlights, spotlights, and small fluorescents. See Appendix B.
Fluorescent bulbs: High color rendering index (CRI) tubes replace fluorescent tubes in offices and commercial buildings where the existing fluorescents are not correct for photography. In large quantities these may also be rented.
Flashlight bulbs: Replacement bulbs for lighting technicians' flashlights.

Batteries: Use AA for flashlights; AAA for light meters; disk batteries for voltage/continuity meters; and 9 V for amp probe and light meters.
Cotter pins: Cotter pins are used when hanging lights to prevent the receptacle from slipping off the pin.
Visqueen heavy plastic sheet: A Visqueen heavy plastic sheet is used to protect equipment and electrical connections from rain, precipitation, dew, dust, and sand. It comes in 100-ft. rolls, 20 ft. wide (folded to 5 ft.).
Crutch tips: Crutch tips are put on the legs of stands to protect floors, in sizes of ¾ in. for small stands and 1 in. for large stands.
Refracil: Refracil is a heat-resistant cloth that will not burn when a hot light is placed on it. It protects ceiling and wall surfaces from heat damage.

TOOLS AND PERSONAL GEAR

Tool belt

When working on set, a lamp operator carries the needed tools and supplies on a tool belt (Figure 2.8) in a compartmentalized pouch. A flap folds over the tools to prevent them from falling out. Sharp tools (such as a knife) and delicate instruments (such as a voltmeter) are best stowed out of harm's way in their own protective leather pouches. Spread the weight around the belt to avoid putting stress on your back. Some lighting technicians try to carry everything but the kitchen sink on their belts. They have tools hanging, clanking, and jangling from every part of their outfits. What you choose to carry varies depending on the circumstances. Keep in mind that all the gear you buy for work is tax-deductible. Save your receipts! Some of the following are illustrated in Figure 2.9.

FIGURE 2.8

Tool belt.

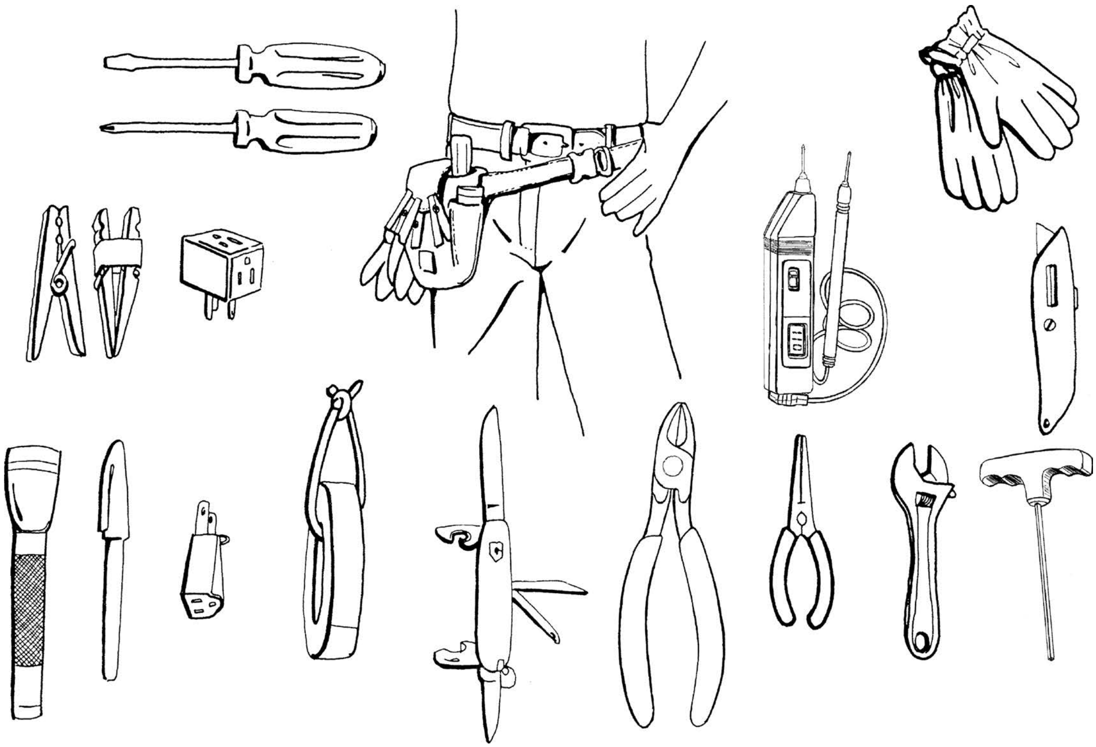


FIGURE 2.9

Tools and supplies.

Leather work gloves (or equivalent): Made of cowhide or some equivalent, these are used for handling hot lights or dirty cable and hardware. Clip them onto your belt when you are not wearing them. Leather gloves protect your hands from heat, abrasion, and grime. They cannot necessarily be counted on to protect you from electrical shock. Although they may provide electrical insulation when clean and dry, typically they are wet with sweat, making them a conductor.

Glove clip: A glove clip loops over a belt and provides a small spring clamp to hold gloves.

Screwdriver: Carry a screwdriver with a reversible tip—flathead on one side, Phillips on the other.

Utility knife with retractable blade: Knives are used for cutting gels, foamcore, rope, and so on.

Scissors: Small, sharp scissors are often handy for making more careful cuts of gels and the like.

Wire snips: These are used primarily for cutting wire for practical lamps and making wire splices but have other important uses (discussed later in this book).

Crescent wrench: An adjustable wrench is used to tighten a pipe clamp, adjust the friction of a bail, and perform countless other jobs. The standard 6-in. crescent wrench has a ½-in. maximum jaw opening that is too small to fit the ⅝-in. bolt used on many pipe hangers. You can find 6-in. crescent wrenches with an extra wide jaw, which are ideal, or carry an 8-in. wrench, which is bulkier.

Needle-nose pliers: Needle-nose pliers are used for pulling hot scrims out of a light and for wiring.
Bates cable tool: This tool performs three functions necessary for maintaining Bates connectors. It has a pin-cleaner, pin-straightener, and pin-splitter. It comes in its own pouch.
Voltmeter/continuity tester: A voltmeter/continuity tester is used to check line voltage (120, 208, or 240 V), check for voltage drop, and locate broken connections in power cords. A continuity tester tests for burnt-out bulbs and fuses and continuity in wires. Some models have a pushbutton on/off switch, which helps prevent inadvertently running down the batteries.
Circuit tester: Plugs into an Edison outlet and tells you whether the line is hot. Also indicates whether the polarity and grounding are correct.
Line sensor (voltage tick): A *non-contact voltage sensor* indicates whether a wire has current flowing through it by sensing the magnetic field.
Flashlight: Lighting technicians frequently find themselves working in the dark. When dealing with electricity, you always need to see what you are doing. Small, rugged, focusable flashlights are easy to carry on your belt.
Clothespins: For attaching gel and diffusion to barn doors. When using gel, keep several on your belt. Figure 2.9 shows an inverted C-47 (a C-74), which is handy to pull hot scrims out of lights.
Permanent marker: This is used for labeling gels, fixtures, connectors, and cables.
Ballpoint pen: A pen is used for taking notes, filling out paperwork, and taking down phone numbers.
Cube taps: Keep a supply of two or three on you.

Meters

More sophisticated electrical measuring equipment may be useful to a best boy, generator operator, rigging gaffer, or dimmer board operator. These meters are used for troubleshooting and close monitoring of the power supply and electrical system. Electrical meters are covered in detail in Chapter 17. Useful meters include an Amp Probe, Digital Multimeter. DMX512 testers and Soco testers are covered in Chapter 12.

Other hand tools

Some supplemental tools can make life easier. These are usually part of the gaffer's kit, kept in a workbox in the truck.

Automatic wire stripper: This tool provides a fast, precise way to strip insulation off the ends of wires. It is handy when wiring a lot of fixtures.
Rope wrench: This heavy-duty snip can cut cable or rope cleanly. It saves a lot of time and aggravation when making up stingers, wiring fixtures, or rigging with rope.
Crimper: These are used for crimping connectors onto wires, useful when wiring some types of fixtures.
T-handle Allen or spider wrench: Some old facilities may still use some equipment that has copper bus bars to which feeder cable are bolted with sister-lug connectors. A T-handle Allen wrench is used to tighten and loosen sister-lugs. A spider wrench is one that fits over the outside of the sister-lug bolt. It is handy when an Allen slot gets stripped.
Lighting technician's scissors: These extra-tough scissors (they can cut through a penny) are especially useful for cutting metal gobo patterns, but also great for cutting gels, rope, and the like. (A gobo is a metal cutout used to make patterns in light).

Hand rasp (also called a rat-tail rasp): This rasp can pierce and saw through luan (the thin plywood used to make set walls). It is useful for cutting a quick rat hole in a set wall, to feed a power cord into the set.
Ratchet and socket set: Makes fast work of tightening and loosening bolts.
Allen wrench sets or hex set (English and metric): These wrenches are used for fixing stands, among other things.
Full set of screwdrivers: The set should include a large and small Phillips, a very small flat-head screwdriver, a large flathead screwdriver, and a right-angle screwdriver for lamp head repairs.
Vice grips: These include small, needle-nose grips for clamping onto small parts while making repairs and large, crescent vice grips for getting a tight grip in a jammed pin connector.
Soldering iron and materials: Mainly used for soldering LED ribbon. See Chapter 7 for more on soldering ribbon.
Cordless electric drill/screw gun: Especially useful when rigging, a screw gun is handy to affix devices to a wooden structure to keep them neat and organized.
Hammer: For hammering or pulling nails (more commonly a job for construction or grip department).
Steel tape measure: For dimensioning construction projects.
Glue: Super-glue has a multitude of uses.
Large flashlights: It is handy to have some big flashlights when shooting at night. They can be passed out to lighting technicians at the end of the night to perform a walk-around "idiot check."
Can handle: This is a handle that fits over the bull switch to provide comfort and leverage when throwing large, spring-loaded switches. If you throw a lot of switches, a handle can save you a lot of strain.

Personal gear

Lighting technicians get dirty. Jeans, a t-shirt, and work boots or sneakers are normal apparel. Weather permitting, it is advisable to be prepared to protect your legs and arms with long pants and a long sleeve shirt. Be prepared for the weather. In southern California you might need only sunscreen, a baseball hat, sunglasses, and a jacket and jeans for after sunset, but be prepared for all weather conditions. You'll want to keep the following personal gear in your duffel bag:

- A full rain suit.
- Rain boots.
- Cold-weather jacket, hat and gloves.
- A change of clothes in case you get wet, especially socks and a t-shirt.
- Consider the terrain. Hiking boots or work boots are often desirable.
- Sunscreen.
- Lip ointment.
- Mosquito repellent.
- Ear protection (disposable earplugs or head gear for when firearms are used).
- Eye protection (goggles or safety glasses). The special effects department usually supplies ear and eye protection to everyone who is needed near the action during explosions and stunts.
- Goggles and a bandana are needed when working in the desert. Blowing sand gets in your eyes, nose, and mouth and can practically blind you.

CHAPTER 3

Lighting objectives

Before we start getting into all the gear, let's take a step back for a minute and think about the objectives of lighting in a film, TV show, or commercial. For the film director and cinematographer, the lighting is part of the fabric of the story and how it is told. It contributes to the mood of each scene. The lighting locates the scene in time and space. Light is an important compositional element that leads the eye around the image, separates people from backgrounds, creates depth, and communicates ideas graphically. The first part of this chapter focuses on these story-based lighting objectives.

The cinematographer meets these story-based objectives by controlling a variety of photographic parameters: light level, exposure, contrast, depth of field, frame rate, shutter angle, and so on. In the second part of this chapter we will discuss the tools used for measuring light and evaluating the video signal.

STORYTELLING OBJECTIVES

The look of a show may be gritty and hyper-realistic, slick and clean, high-tech and stylish, or lush and glamorous. It may be naturalistic or it may be stylized or theatrical. In this section, we'll look at three important elements that contribute to the look and style of a production through lighting: mood, naturalism, and composition.

Mood

Mood is perhaps the most powerful contribution of lighting to a motion picture. Lighting is expressive. It can set a tone for a scene and even reveal hints about the characters. Light can connect a character to her surroundings, or it can isolate her. A person may be surrounded by glowing human faces or anonymous figures. Lighting can also inform character by showing how a character treats light in the story. Would she invite sunlight to pour into the room, or close it out, leaving us in a dark space, with the sunlight seeping around the edges of thick curtains?

Lighting can trace the arc of a story, so spaces change in appearance and feel from one part of the film to the next. The arc may be a long day's journey into night, or an emergence from darkness into light. Motivating light sources have different associations—a blinking sign, a crappy fluorescent, a sunset, a blue computer screen, a glaring car headlight. Separate from the environment, the way an actor is lit affects how the audience experiences the character—radiant with charisma, frazzled and imperfect, strong and determined, and so on. These details may be dictated by the script or merely suggested by the tone of the scene. The color and quality of light may influence the audience's perception of a character's inner emotional state, but it can also be ironic—a miserable lonely person faced with a beautiful sunny day. Or it can just be realistic, unmelodramatic, and neutral.

Naturalism

The quality, color, and direction of the light and the sources it implies are part of what makes a scene convincing. Often unconsciously, the lighting instantly clues the audience to the setting, the type of space, the time of day, the season, and even the weather and the atmosphere of the place. Like a good novel, these natural occurrences are cues that may also contribute to mood, but realism itself gives the images truthfulness, and makes the storytelling more compelling and believable. To create natural-looking lighting and keep things consistent, the lighting crew has to control the existing light sources and recreate realistic, natural lighting using artificial sources.

The opposite of natural lighting is lighting that *gives away* the artificial setting to the audience: when the camera records multiple shadows cast on the walls and floor by an actor, when one can trace the diverging rays of light back to a lamp outside a window, when a shot shows "direct sunlight" coming into a room from two opposite directions or at different angles at each window.

Composition

Lighting is used as a means of emphasis and delineation. It helps separate the layers of the three-dimensional world on a flat, two-dimensional screen. It can also create purely graphic effects that contribute to the composition.

The DP selectively emphasizes characters or elements, letting the lighting direct the eye within the frame. For example, imagine a wide shot looking down over the congregation in a large church. The shot immediately conveys the grandeur of the ceremony, but without further help, our eye wanders without a focus. An increased light level surrounding the figures at the front of the church draws the eye to our focal point of the scene, the couple making their vows at the altar. The light falls off on peripheral figures.

When the three-dimensional world is telescoped onto a sensor (or celluloid) and projected onto a flat screen, objects do not stand out from one another. When foreground and background share the same value, they blend together. The cinematographer can reemphasize depth in the image by accentuating the outlines of people and objects, using backlight to create an edge or rim light. Backlight has long been an accepted convention in movies and TV; however, a glamorous backlight can also appear artificial. Motivating the light with some sense of source helps make it look natural. A bright window in the background, for example, could motive a bright edge light.

Backlight is not the only way to create separation. The cinematographer might choose to separate the foreground, middle ground, and background simply by lighting them to contrasting levels of brightness. He or she can line up a highlight in the background so that the dark side of the actor's face is against a light background, like a shaft of sunlight through the atmosphere, a pool of light around a practical, or a slash of light across some wall art.

Another important compositional element is depth. A composition that includes surfaces at various distances receding into the distance increases the shot's sense of perspective and scale. If the shot includes some sense of space beyond the plane of the facing wall, outside a window or through an open doorway into other rooms, the gaffer can create planes of light and dark that recede deep into the picture. Depth offers nice opportunities for interesting lighting and composition.

A DP can break up a boring block of wall by lighting it with graphic shapes or lines. This could be done by throwing a diagonal slash across the background, a pattern of moving foliage, a window frame, a Venetian blind, or by using objects in the set dressing to create irregular shadows. Lighting a textured surface at an oblique angle emphasizes the texture of the surface. The wall of a corrugated metal building appears as a pattern of vertical lines, a brick wall becomes a pattern of regular rectangles. Breaking up the background with textured light goes a long way toward creating an exciting image from one that would otherwise be flat.

Time constraints

An additional objective that has been conveniently ignored thus far is working within the time frame permitted by the production schedule. In an ideal world, the DP could devote planning and attention to every detail, and the crew would have all the time needed to rig and tweak the lighting. In real life, however, speed often becomes the top priority, and the lighting has to be designed accordingly. Sometimes it feels like we only have enough time to eliminate the really horrible problems, and once that's done, we shoot. The lighting crew spends all its energy trying to get out of the fire and back into the frying pan. Nonetheless, even under the worst of circumstances, the DP and lighting crew aspire to arrive at an image that is more than merely acceptable, but in some way evocative, and sometimes even striking and memorable.

PHOTOGRAPHIC OBJECTIVES

A film without sound is a silent movie. A film without light is radio. Obviously, you must have light to expose the image. But more than that, much of the artistry of cinematography is in the control of exposure and contrast, selectively exposing objects and characters to appear bright, slightly shaded, darkly shaded, barely visible, or completely lost in darkness, as desired. The contrast between the dark side of a person's face and the light side, changes the mood of the image. In this section we'll explore light levels, exposure, and contrast, and the tools we use to measure these things.

Light level

A single parameter that affects all a gaffer's major decisions is the needed light level. Light intensity is measured in foot-candles (fc)[1] using an incident light meter such as the digital Spectra Professional IV (Figure 3.1). A reading expressed in foot-candles is independent of the variables that affect exposure, like ISO, shutter angle, shutter speed/frame rate, and filtration.

[1] One foot-candle is one lumen per square foot. Lumens (lm) are a measure of the total visible light emitted by a source. A foot-candle is a measure of how much of that light lands on an object some distance from that source. Lux is another unit used to measure the same thing. Unlike foot-candles, lux units are part of the international system of units of measure (SI). One lux represents one lumen per square meter. One foot-candle equals 10.764 lux.

FIGURE 3.1

Spectra Professional IV digital/analog light meter. This meter reads incident light directly in f-stops and photographic luminance in foot-candles or lux, with a range of 0.1–70,000 fc.

(*Courtesy Spectra Cine, Inc., Burbank, CA.*)

One DP I worked with many years ago shot all his films on 50 ISO film stock at an f/4 or f/5.6, indoors or out, requiring a light level of 400–600 foot-candles. To do this requires many large HMI units, heavy 4/0 cable, many large power plants, and lots of hard-working technicians.

Today, a typical ISO rating of a digital camera is 800, and there are cameras rated much higher. Shooting at 800 ISO requires just 25 foot-candles of illumination to achieve an f/4. The biggest light needed could be a 100 W LED. The choice of light level affects everything: what lights to order, the power requirements, and the time and personnel needed. The ISO affects the look of the lighting. For example, using a 200 ISO film stock for an interior scene requires a fairly drastic increase in light level, virtually replacing natural light with brighter artificial sources. The large lights must very often be hung above the set, limiting realistic lighting angles. In contrast, a camera at 800 ISO requires one-quarter of that amount of light, enabling a more subdued lighting approach. Smaller lights are easier to hide, allowing more realistic angles for the light. The cinematographer can use existing light to a greater extent.

Foot-candles

Figure 3.2 shows the foot-candle scale. Each major division indicates a doubling of the amount of light, a one-stop increase in exposure. The advantage of working in foot-candles (fc) rather than f-stops is that a gaffer knows (or very quickly learns) how many foot-candles to expect from a given light at a given distance (Table 3.1 lists some approximate data; Table A.3 is a more comprehensive list). If lighting to a given fc level, the gaffer will always call for the right light for the job. F-stops, on the other hand, do not correspond directly with light level. It is not as straightforward to know what light fixture will give a particular f-stop.

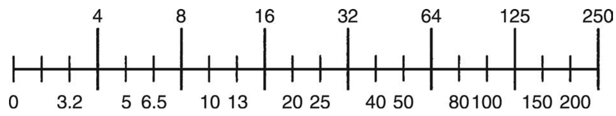


FIGURE 3.2

Foot-candle scale. Major ticks show one-stop increments. Notice, foot-candles double with an increase of one stop.

Table 3.1 Relative strengths of various sources

SOURCE	FC SPOT	FC FLOOD
Direct sunlight		6400–8000
Skylight on an overcast day		450–1800
12k HMI at 30 ft.	8250	500
9-lite PAR 64 at 30 ft.	NS lens 3600	WF lens 450
2500 HMI PAR at 30 ft.	NS lens 2880	WF lens 247
4000 HMI Fresnel at 30 ft.	2305	247
10k at 30 ft.	2465	460
5k baby senior at 30 ft.	655	110
PAR 64 at 30 ft.	VNS lens 560	MF lens 150
2k junior at 20 ft.	1000	130
SkyPanel S360-C Standard diffusion (3200) at 23 ft.		96
SkyPanel 60-C Standard diffusion (3200K) at 16.4 ft.		42
1k baby at 20 ft.	440	45
2k zip soft light at 10 ft.		100
650 pepper at 10 ft.	528	110
750 soft at 10 ft.		30
200 mini at 10 ft.	195	25
100 pepper at 10 ft.	55	23

F-stops and T-stops

The f-stop is the aperture set on the lens of the camera. The lower the f-stop, the larger the aperture, the more light passes through the lens. The f-stop increments are 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, and 22. Figure 3.3 shows the standard range of f-stops and the increments between f-stops.

A T-stop is what you call an f-stop when it is set on a zoom lens.[2] In this book, we will refer to exposure in f-stops. A light meter gives the f-stop by taking into account the film speed and exposure time. For normal filming at 24 fps and with a standard 180° shutter, the exposure time is 1/48th of a second.

[2] For a telephoto or zoom lens, the lens manufacturer inscribes the lens barrel in T-stops, which are f-numbers adjusted to account for the lower light transmission efficiency of these lenses. If you set a prime lens to f/4 and a zoom lens to T-4, the resulting exposure is the same; the lens compensates internally.

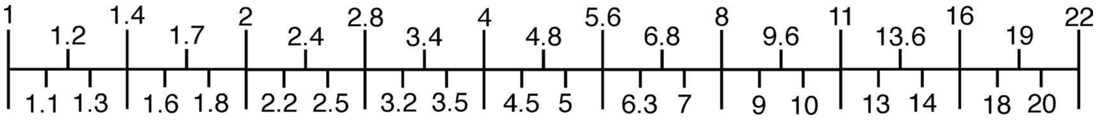


FIGURE 3.3

The f-stop scale with the actual numerical increments between f-stops.

Table 3.2 F-stops versus foot-candles for various film speeds 180 degree shutter, 24 fps

ISO	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16
25	100	200	400	800	1600	3200	6400	12500
32	80	160	320	640	1250	2500	5000	10000
40	64	125	250	500	1000	2000	4000	8000
50	50	100	200	400	800	1600	3200	6400
64	40	80	160	320	640	1250	2500	5000
80	32	64	125	250	500	1000	2000	4000
100	25	50	100	5010	400	800	1600	3200
125	20	40	80	160	320	640	1250	2500
160	16	32	64	125	0500	500	1000	2000
200	13	25	50	100	200	400	800	1600
250	10	20	40	80	160	320	640	1250
320	8.0	16	32	64	125	250	500	1000
400	6.4	13	25	50	100	200	400	800
500	5.0	10	20	40	80	160	320	640
650	4.0	8.0	16	32	64	125	250	500
800	3.0	6.4	13	25	50	100	200	400
1000	2.5	5.0	10	20	40	80	160	320
1250	2.0	4.0	8.0	16	32	64	125	250
1600	1.5	3.0	6.4	13	25	50	100	200
2000	1.2	2.5	5.0	10	20	40	80	160
2500	1.0	2.0	4.0	8.0	16	32	64	125
3200	0.75	1.5	3.0	6.4	13	25	50	100
4000	0.6	1.2	2.5	5.0	10	20	40	80
5000	0.5	1.0	2.0	4.0	8.0	16	32	64

Table 3.2 correlates f-stop to foot-candle level for a variety of ISO ratings. As you can see, foot-candles double with each f-stop. For example, at ISO 500, it takes 40 fc to get a proper exposure at f/4. If we open the aperture to f/2.8 we need only half as much light, 20 fc.

Factors affecting light levels

Lens optics and camera settings introduce several factors that may require a DP and gaffer to light to a particular light level or to a particular f-stop.

Depth of field

Depth of field is the amount of depth that appears in focus. As the aperture is opened up to lower f-stops, the depth of field decreases. Depth of field also decreases the longer the focal length of the lens and the closer the distance to the subject. Telephoto lenses have shallow depth of field; wide lenses have broader depth of field for a given distance and f-stop. On a medium focal length lens, shooting "wide open"—the aperture set to the lowest f-number on the lens—only objects that are in the plane of focus appear in focus. Whereas, if you shoot at a higher f-stop, say f/5.6 or higher, objects in front and behind of the plane of focus will be less out of focus or may even appear equally sharp.

Selective focus is an important storytelling tool. The DP who wants shallow focus with a given lens needs to use a low f-stop and, therefore, needs a relatively low light level. On exterior day scenes they'll use a neutral density (ND) lens filter to avoid having to use higher f-stops. If they want lots of depth, they'll require higher light levels. A very tight, close shot on a product label of a bottle, for example, may require a very high light level to achieve sufficient depth of field to hold the entire label in focus. Thus, the depth of field also affects the size and type of lighting fixtures used to light the scene.

Other lens characteristics, like sharpness and contrast, vary slightly at different f-stops. So, DPs often prefer to shoot all the shots for a particular sequence at more or less the same f-stop. Some lenses have the greatest clarity and definition in the middle of the f-stop scale, between f/4 and f/8, so the cinematographer may ask for sufficient foot-candles to work in the center of the scale. The f-stop will also depend on the type of lens being used. Zoom lenses do not open up as far as prime lenses. A prime lens designed for speed might open up to f/1.4, whereas a long zoom may open up to a T-3.5 or T-4. That's a big difference in light level.

Shutter speed

Slow motion photography is accomplished by capturing images at frame rates greater than the speed at which the image will be shown. For example, shooting at 48 frames per second (fps) and displaying at 24 fps produces half-speed slow motion. Increasing the shutter speed reduces the exposure time, requiring more light be provided to shoot at the same f-stop.

For example, when filming a car stunt at night with multiple cameras, the working light level must be high enough to provide a workable f-stop for the cameras that are shooting at higher speeds. If the camera running at 24 fps has a correct exposure at f/4, a camera running at 120 fps would need to open up to under an f/2, requiring very fast lenses.

Slow motion, as a narrative device, is often shot at 30–120 fps, which can be achieved by many normal production cameras. Extreme slow motion, at hundreds and even thousands of frames per second, requires high-speed cameras and will involve very high light levels. Again, commercials are probably the most common situation where things need to be shot in extreme slow motion—think fizz spraying out of a can of soda, or beer filling a glass.

Shutter angle

The selection of shutter angle is another adjustment that affects exposure time and potentially light level. The "normal" shutter angle for most digital cameras is the same as film cameras, 180°. At this shutter angle objects that move across the frame quickly will have motion blur. The cinematographer can reduce the amount of motion blur at a given frame rate by reducing the shutter angle and thereby shortening the exposure time. For example, changing the shutter angle from 180° to 45° reduces the exposure time by a factor of four. At 24 fps the exposure time is reduced from 1/48th of a second to 1/192nd of a second. To compensate and maintain the same f-stop, the light level would need to increase by 2 stops.

The formula to determine exposure time based on frame rate and shutter angle is as follows:

$$\frac{R \times 360}{A} = T$$

Where R is frame rate in frames per second, A is shutter angle in degrees, and $1/T$ is the exposure time expressed as a fraction of a second.

For example:

$$\text{24 fps, 45}^{\circ}\text{ shutter: } \frac{24 \times 360}{45} = T \quad T = 192$$

$$\textit{Exposure time} = \frac{1}{192} \textit{ of a second}$$

$$\text{24 fps, 17.28}^{\circ}\text{ shutter: } \frac{24 \times 360}{45} = T \quad T = 500$$

$$\textit{Exposure time} = \frac{1}{500} \textit{ of a second}$$

Some digital cameras are capable of shutter angles up to 360°, which increases the exposure time and extends the blur over a longer period of time and therefore distance. This produces an effect that is different from what people are accustomed to; however, it also eliminates the strobing effect that can happen when action moves across the frame at certain speeds, and it provides the cinematographer with an additional stop of exposure.

When shutter speed or shutter angle is not standard, everyone must be very clear when giving f-stops as to whether the f-stop compensation has been taken into account. When giving the f-stop, you would say it is an “f/4 on the lens,” meaning that the compensation has been taken into account. If not, you should say you are giving an uncompensated reading, which DPs sometimes call a “base” stop. This can be helpful when the cinematographer is using multiple camera crews and the cameras are using different ISO or amounts of filtration. The DP calls the base stop, and the camera assistants adjust to compensate for their particular camera setup.

Taking readings with an incident light meter

Incident light meters measure the amount of light falling on the face of the light meter. A *hemispherical light collector*, or *photosphere* (commonly known as *the ball*), collects light from the sides, top, and bottom as well as the front. The reading is taken by holding the meter up in the position of the subject. When the ball faces the camera, the meter gives an average reading of the total amount of light falling on the subject as viewed from the camera.

Alternatively, by pointing the ball at the light source, you can read the amount of light from that source. However, keep in mind that when light hits the subject from the side or back, relative to the camera, less light is reflected toward the camera than when that light hits the subject from the front. Making allowance for this, the reading of a sidelight can be accurately taken by turning the meter, splitting the angle toward the camera.

When taking a reading, use your free hand to shade unwanted light off the photosphere. If you were reading the intensity of frontal lights, you would shade off any light coming from high backlights. The facial tones are not affected by the light hitting the back of the hair and shoulders, and if you do not shade the meter from the backlights, the reading will be incorrect. Back light would be measured separately.

You can get an impression of the relative strengths of various lights—key and fill, for example—by shading the photosphere from one source, usually the key, and noting the change in the reading. You would use this technique to determine the *contrast ratio*.

When reading the output of individual lights, some cinematographers replace the hemispherical collector with a flat disk collector. The flat disk reads only light coming from the front. The disk is also used when photographing flat artwork, such as a painting or front-lit titles.

A reading halfway between two numbers is called *a split*. For example, a 2.8/4 split would be halfway between f/2.8 and f/4. Increments between stops are also commonly expressed in thirds of a stop, so you might say "one-third stop closed from a 4" to indicate that the aperture is one-third of the way toward 5.6 (it is actually f/4.5).

For even smaller increments, a DP might specify "4 and a quarter" (which means a quarter stop closed down from f/4). Going the other way, the DP would say "a quarter stop open from 4." An even smaller increment would be a "heavy 4" or a "light 4." A heavy 4 would be just over a 4, a light 4 would be just under a 4 (opened up from a 4). Establish common terminology with the people you work with and use clear language. Double check if you are not sure what someone means.

Reading the light meter is only part of determining the exposure for the scene, as we'll discuss shortly.

Contrast, latitude, and the tonal value

Contrast ratios

The *contrast ratio* is the ratio of the light on the key side, which is key plus fill, to the shadow side, which is fill alone:

key + fill: fill alone

If key plus fill reads 120 fc and fill alone reads 60 fc, the contrast ratio is 120:60, or 2:1. A 2:1 ratio has a one-stop difference. A 2:1 ratio is relatively flat, a typical ratio for ordinary television productions. It provides modeling, while remaining bright and void of noticeably strong shadows. With a two-stop difference, or 4:1 ratio, the fill side is distinctly darker and paints a more dramatic, chiaroscuro style. For most normal situations, the contrast ratio is typically kept somewhere between 2:1 and 4:1. A three-stop difference, or 9:1 ratio, puts the fill side in near darkness, just barely leaving detail in the shadow areas. A bright, sunny day typically has about a 9:1 ratio, requiring the addition of fill light to lower the contrast ratio.

Tonal values

Between pure black and pure white lies a range of *values*, shades of brightness that define the picture. The range of brightness and darkness in which a camera can capture an image is known as its *dynamic range*. Each camera sensor and film emulsion has its own dynamic range characteristics. The range in which textures are visible is called the *textural range*.

Middle gray is an important value for determining exposure. Middle gray is 18 percent reflective. An incident light meter works by defining this midpoint in the latitude. It gives an exposure reading that will make a middle-gray object appear middle gray on screen. The idea is that by defining middle gray, all the other values fall into place. However, objects that are at the outer edges of the exposure latitude begin to lose detail and texture becomes less defined until, at the extremes of the scale, only pure black and pure white are seen.

One basic goal of lighting is to illuminate the subject such that they appear correctly exposed while holding the desired amount of detail in the brightest and darkest areas of the frame. One purpose of lighting is to bring the total range of light levels within the dynamic range of the sensor or film stock.

Suppose that the exposure outside a room with windows is five stops brighter than inside the room. If the aperture is set for the interior exposure, all details in the exterior portion of the image will be completely bleached out; the edges of the windows will be "blown out." A compromise somewhere between the exterior and the interior exposures is not much better; the interior will still be very dark, and the exterior will be hot, but not blown out. The lighting must bring the outside and the inside exposures closer together.

To look natural, the exterior should be brighter than the interior, but by two or two and a half stops, not by five. To close the gap, you could reduce the exterior exposure two stops by gelling the windows with 0.6 neutral-density gel; you could light the inside, bringing it up to a level that is two stops less than the outside exposure; or you could do a little of both.

To give a contrasting example, when shooting a large night exterior, if an area is unlit and the camera has a low ISO, there is likely going to be no detail in the background. Solid blackness is usually not desirable. Cinematographers want base level of light to give some texture to the dark areas of the frame. There are various techniques for accomplishing this such as using large backlights 60–80 feet above the ground in an aerial lift, using balloon lights over the scene, or by selectively lighting objects like trees and buildings with smaller lights.

Previously, we said that as a rule, the key side of the actor's face is set *at exposure*; in other words, you would take a light reading of the key side (key plus fill) and use that to set that exposure on the lens. In reality, cinematographers place the values of the face in response to the natural sources within the scene and the dramatic feeling of the scene. In fact, a good cinematographer will tell you, as a rule, they *never* place the key side at exposure. For example, overexposing the key side by one stop while underexposing the fill side by one and a half stops gives a greater sense of light entering a space (through a window, for example). In a dark scene, the DP might underexpose the key side of the face by one stop and let the fill side fall into near darkness, three stops underexposed. If the scene is largely underexposed, it is helpful to have some source or object within the frame that is brighter and gives a reference point for the viewer's eye, such as a street light, practical light, and something else providing higher values in the background.

Spot meters

A spot meter helps the cinematographer to measure the range of tonal values in the scene as the camera will see them. A spot meter (Figure 3.4) is a reflected light meter with a very narrow field of acceptance (less than 2°). An incident meter reads the amount of light hitting the light meter; a reflected meter reads the amount of light reflected back from the subject.

FIGURE 3.4

Sekonic L-858D-U Speedmaster digital incident and spot meter. The spot meter has a 1° light receiving angle. It can read EV 1 to EV 24.4 and foot-candles from 0.01 to 180,000. Shutter angles from 1° to 358°.

(*Courtesy Sekonic*)

The reading accounts for the reflectance of the object as well as the amount of light hitting it. From behind the camera, the DP or gaffer can sight through the meter and pick out any spot in the scene to measure, taking readings of various areas of the scene, to compare the exact values of face tones, highlights, and shadows.

Many cinematographers base their f-stop on a spot reading taken off an actor's face (or his own fist held out in front of the meter to provide a flesh tone). For Caucasian skin, this reading should be about one stop above the f-stop on the lens. Of course, there is a tremendous range of tonal values in human skin which has to be taken into account.

A spot meter is also handy for measuring naturally luminescent sources, such as television screens, table lamps, illuminated signs, stained glass windows, neon lights, or the sky during sunrise and sunset. It is also handy for getting readings on objects that are inaccessible or far away.

Digital spot meters typically display readings in either f-stops or in EV units. Some meters display readings only in EV units; the corresponding f-stop is found using the conversion dial on the meter. EV units are handy, because they put reflectance value on a linear scale in one-stop increments. Each EV number represents a one-stop difference in value from the last. It eliminates the mental gymnastics involved in counting on the f-stop scale. For example, if a skin tone reads f/8, and a highlight reads f/45, how many stops brighter is the highlight? Before you start counting on your fingers, let's ask the same question in EV: The skin tone reads EV 10, the highlight EV 15; it's easy, the difference is five stops. You can even set the ASA on the spot meter so that EV 5 represents the f-stop on the lens.

Calibrated monitor

A high-quality reference monitor that has been calibrated can help the DP directly assess the lighting, and how exposure, contrast, and colors are interpreted by the camera's sensor and image processing. For it to be a valid tool; however, the monitor must be calibrated, and the viewing environment needs to be controlled. The human eye adapts so rapidly to different lighting that it can be easily thrown off by surrounding colors and light levels. So, ideally the viewing environment is controlled, such as by using a DIT tent, or at least blocking light with flags. The monitor is only as good as its resolution, contrast, and ability to produce true blacks.

Setting up the monitor with color bars

For HD monitors showing REC 709 color space, calibration is done by generating SMPTE ARIB color bars or SMPTE HD color bars from the camera and adjusting the monitor in the following order:

1. Contrast—Watch the superwhite square increase the Contrast control until it is at peak white on the monitor. You will reach a point where superwhite stops changing value. Once it is reached, back it down to the exact point where it stopped changing.
2. Brightness—The PLUGE[3] bars (the square on the lower right part of the chart that contains a series of black bars). The ARIB set represent –2%, 0%, +2%, 0% again, and +4%. Set the Brightness control so you cannot see a difference between –2% bar and 0%, but you can barely distinguish the border between 0% and +2%. +4% will stand out a little more.
3. Chroma—Watch the 100 percent color patches and increase the Chroma control to located peak chroma, which is the point at which chroma stops changing.

To ensure the monitor is producing chroma-free gray scale and accurately reproducing color, the monitor must also be calibrated by white balancing the monitor using a spectrophotometer or colorimeter, aka probe. Ideally the monitor should be calibrated by the production's post house so you know what you are seeing on set matches what the colorist sees on the monitors in the coloring bay and what you see in dailies.

Signal monitoring

For the gaffer, a light meter is still the best tool. Their primary concern is determining how much light is landing on the scene. However, there are various ways that cameras and monitoring tools can aid the cinematographer and DIT in evaluating the signal including the waveform monitor, vector scope, false color, and histogram, CIE, and other signal analysis tools.

We need to preface the discussion by noting that it is really easy to not have the scope's x/y scaled correctly or to have a vector scope mislead you into thinking the colors are fine when in fact they may be oversaturated. These tools have to be set up properly each day. In addition, there are a lot of additional variables that may contribute the overall look that the cinematographer is going after: lenses, filtration, atmosphere, and the application of LUTs on the image. Lookup tables (LUTs) overlay a different gamma and color cast, which gives the image a distinctive look, like a soft-contrast scene with airy shadow areas as opposed to a high-contrast, bleach bypass look, for example. The signal can be monitored before or after the LUT is applied, which are both valid ways of working.

---

[3] PLUGE stands for **p**icture **l**ine-**u**p **g**eneration **e**quipment. It refers to the grayscale test pattern used to adjust the black level and contrast of a picture monitor.

A waveform monitor can reveal things about the image that may not be obvious on a monitor. It traces the signal's luma (brightness) levels and can also show the individual red, green, and blue chroma levels. It displays the luma values on a vertical scale, which corresponds to the image from left to right. A waveform is a useful reference to ensure a green screen or blue screen is properly exposed (see Chapter 19) and to check if highlights are too bright or too dark.

For the purposes of this discussion, let's just focus on the HD format, which uses a percentage scale, marked in 10 percent increments. (Other formats use volts or IRE for the scale and some use the scale slightly differently.) On the scale, 0 percent represents pure black and 100 percent represents pure white. Portions of the image are *clipping* when highlights are brighter than 100 percent or shadows are darker than 0 percent. The trace on the monitor flattens out, indicating there is no detail or texture in those areas. The levels are beyond the dynamic range of the camera. With the exception of occasional, small spectral reflections up to 105 percent, the brightest part of the luma signal should generally not extend beyond 100 percent in HD. In formats like HDR other specifications apply.

As shown in Figure 3.5, RGB parade view (or YRGB) separates the luma signal (Y) and the chroma signals, red (R), green (G), and blue (B), and displays the three or four signals side by side. If a deeply saturated color shows a flattened trace around 100 percent, that color is extending outside the specified voltage range and the signal may be clipped or compressed in subsequent signal processing. A clipped signal looks bad because it contains no texture. In some cases clipping can also distort the color when it is displayed on another picture monitor, sometimes creating strange color artifacts in the highlights or shadows. Out of gamut luma (Y) can cause bleeding, bearding, buzzing or sparkling.

A signal that exceeds the upper and lower limits of the particular video format is *out of gamut*, or out of range. Broadcasters and cable networks set acceptable limits for signals. They will not accept an "illegal" signal for distribution. Additionally, RGB colors will probably need to be converted to other formats like YPbPr which is used to broadcast the signal. Colors that are in gamut in one format may not be valid when translated, transcoded, or broadcast in a different format. Gamut monitoring is therefore another important objective. Many monitors can display gamut information such as by displaying a CIE chromaticity diagram showing colors occupied by the signal and showing the bounding areas of standards like BT.709 and BT.2020 (aka Rec. 709 and Rec. 2020). In today's world content is often repurposed and may be redistributed on another platform, so color gamut is something we have to be aware of on set.

A vector scope shows color information about the signal. It is an objective tool for evaluating overall color cast, which your eyes are not. It is also helpful to show colors that are oversaturated. The vector scope is a circular display that traces the color signals something like a color wheel. Whites and grays will be traced in the center of the circle and saturated colors are distributed around the outside of the wheel. Hue is shown by the angle of the trace from the center. Reference points for standard primary and secondary colors are provided around the outside of the circle. The reference points can be used to check and align the camera by pointing the camera at a test chart under white light. The distance of the trace from the center represents the amount of saturation of the color. Traces at the very edges of the scope are deeply saturated. If colors are out of gamut, they appear as a flattened blob near the outside of the circle.

If the signal has an overall cast to it, the center whites are displaced outside the center reference mark. Whites that are not in fact white may be due to improper camera setup, camera settings that are not balanced to white, or shading by the lens or filters. If the camera is set up correctly and lens and IR

FIGURE 3.5

(A) A calibrated monitor is a valuable tool for judging exposure and contrast of the image. (B) This multi-display shows vector display (top left), signal waveform (top right), status (bottom left) and picture (bottom right).

filters are compensated for, the color cast is due to off-white lighting, or just the off-white color of the objects in the frame.

These are some of the ways signal monitoring may sometimes be helpful for lighting; however, there is a great deal more to know about digital imaging, which is outside the scope of this book. There are many excellent books, references, and online resources for further information and practical demonstrations.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

CHAPTER

Lighting strategies

4

It is helpful to think of the lighting as two related endeavors; lighting the actors with special attention to their faces, and lighting the scene, the room, or space and background. The *key light* is the strongest light on an actor's face, and placement of key lights is usually strongly influenced by the primary directions the actor faces during the scene and the inclination of their head. The DP and gaffer observe these details closely during the rehearsal and choose the lighting directions that best serve the blocking[1] and behaviors the actors will perform.

In most cases, the DP's first consideration is how to best light the faces. It sometimes happens that these key lights also light the scene, but just as often this light must be modified, cut off the walls, for example, so that the layers of the image are controlled separately. Sometimes a DP will reverse the approach by primarily lighting the space, adding to it where necessary to ensure some exposure on the actors' faces. The DP may use this approach for the wider shots and "clean up" the lighting in coverage. On many productions, the DP must remain fairly conservative about lighting actors from angles that are less flattering, but for others, realism and the emotional potential is more important.

As the DP starts to form the lighting plan for the scene, he or she is also working out the coverage with the director. Whatever lighting is established in the first shot needs to also anticipate the needs of the subsequent shots. Major lighting arrangements may influence shot order and other matters of efficiency. Also, if the DP is not thinking ahead, they can light them self into a corner.

MOTIVATING AND REACTIVE LIGHTING

Motivating light sources are sources that exist in the scene, or sources we imagine could exist out of view, that give the DP a color, quality, and direction of light they can choose to emulate. Some scenes have limited possible sources of light, which makes the choice an obvious one, like a scene around a bonfire on a beach at night. The motivating sources are either the flickering glow of a bonfire, or maybe moonlight or flashlights.

An interior scene may offer many possible motivating sources: direct sunlight through windows, the glowing soft light of sunlight bouncing off surfaces of the room, candles on a dining room table, overhead fluorescents, practical lamps, a streetlight outside, moonlight, and so on. Sources may be intermittent or transient: a flashing neon sign outside the window of an urban apartment, the flashing lights of an ambulance, the headlights of a passing car. In a darkened vehicle (car, airplane, spaceship, submarine, what have you), the DP may choose to motivate some light from the instrument panel.

[1] *Blocking* is the placement and movement of the actors in the acting space over the course of a scene.

The objective of motivating the light is to ground the scene and make it look real, but this does not mean a DP has to limit their lighting choices to sources that are motivated from some real source. The DP chooses and uses motivating sources that fulfill the DP's visual objectives for the scene.

Reactive lighting is lighting that happens in response to actions in the scene. For example, imagine a darkened interior day scene. The character is strongly edge-lit from windows, but his face is largely in silhouette until he lifts a clipboard; the sheet of paper catches the backlight and it creates a glow on his face. A common example of reactive lighting is light in a moving vehicle. Whether real or created as a lighting effect, the light on the actors continually changes as streetlights, vehicles, and store fronts pass by the windows. Reactive lighting is especially important for visual effects and process work. The lighting can help unite the foreground with background *plates*[2] that are added in post or displayed using a large LED video screen. There are manual techniques for creating these lighting effects (Chapter 19), but LED video screens have become the ultimate type of interactive lighting because the screen content replicates the real environment. All the reflective surfaces in the scene—liquids, glass, metal, shiny skin and hair—pick up the screen content. The content can even be synced to the plates that are added in post-production. Off-camera light sources like fire have also been reproduced this way.

There may be one large motivating source that pervades throughout the room, like daylight through large windows. On the other hand, there may be different sources to motivate light in different areas of the set. For example, as an actress moves from a window to a sofa in front of a fireplace, she walks out of the soft, blue window light and into the warm, flickering firelight. Even subtle differences in the color and quality of light sources make the lighting more convincing. Motivating the color of light sources also provides the DP a way to separate layers of foreground, middle ground, and background. This is known as *color separation*. A fluorescent light source might be slightly blue or slightly green, sunlight might be slightly amber, skylight is slightly blue, and so on.

The motivating source is not always the actual source, especially when lighting faces. The DP may establish an *idea* of light coming from a particular source and may use the general direction and color of that source to light the face, but they may use a separate light that is placed more ideally for lighting the actors' features for the given blocking and camera position.

In most cases, if the real motivating source is seen on camera—a practical lamp, for example—if the source is bright enough to illuminate the actors, the source itself will be too bright and blown-out or clip. For example, if an actor is sitting on a couch beside a table lamp, if we rely solely on the lamp to provide the exposure on the actor's face, the lamp will be overexposed. Conversely, if we dim down the lamp so the lamp-shade has good detail, it will fail to provide sufficient illumination for the actor's face. The actor's face may need to be illuminated separately by a source that mimics the soft quality of the table lamp. This also affords us the opportunity to "cheat" the key light where it will look best on the actor's face. What matters is that the quality of the light be that of a realistic and plausible lighting source. Care must be taken not to let light spill onto the lamp itself or to let the lamp cast a shadow as this would destroy the illusion of light originating from the lamp.

When no plausible sources exist to light the actors, as in a dark room at night, a little dramatic license must be taken. The idea is to create a look that is psychologically palatable to the audience, if not wholly realistic. For example, one approach to lighting a supposedly unilluminated night scene is

[2] The term *plate* refers to any live-action background photographed separately, either one that is added in post replacing a green screen, or one that is projected or displayed on set.

to create a low base level of nondirectional blue light and underexpose it. Then, selectively, add chips and slivers of light, use oblique angles of light to avoid lighting up surfaces, and use subtle backlight to define the contour of the actor where he or she disappears into dark shadow.

LIGHTING FACES

The shape of a face is revealed by the way light falls on the curves and planes of its features. Before placing a light, you want to know what you are going to get. This chapter illustrates lighting angles using 3D modeling software. Although using the software is a little like lighting dolls, if you indulge the use of digital mannequins for this chapter it will help us to explore some lighting variables accurately (if not totally authentically). Most of the images are intentionally stark with very little fill. For our purposes, this helps highlight the effect of each lighting position, but of course, you wouldn't always want to light this way. Color versions are available on this book's companion Web site, along with light plots for each setup.

Lighting directions are like family relations, they each have their own personality, and each one comes with its own set of problems. Figure 4.1 illustrates various key light positions around a human subject. The gaffer needs to anticipate the issues that come with each key light position. As a DP friend of mine likes to say, each light you add creates three new problems. The gaffer cannot neglect to consider these three issues: head turns, spill light, and shadows.

Head turns. From the perspective of how it models the face, the key light position is always relative to the direction the actor is facing. What happens when the actor turns their head in another direction?

Spill. Anytime the gaffer sets a light for an actor, he or she also wants to consider what else that light is going to hit. Provided there is some space between the subject and the background, spill on the background can usually be cleaned up with a sider. This is sometimes not so easy with more frontal keys.

Shadows. The gaffer needs to consider where the key light will throw shadows, like onto other actors or backgrounds. For example, when two actors are standing side by side, a side light can cast the shadow of one actor onto the other. In an over the shoulder shot, if the key light is lined up very close to the axis between the actors, one actor will shadow the other if they lean or step towards one another. Keys sometimes have to thread a needle between heads. The gaffer or DP can show the actors the danger zones and ask them to be aware, but in the end, the lighting must allow the actors to stay out of each other's light.

Rembrandt cheek patch lighting

The conventional, textbook key light position is 30° above and 45° to one side of the actor. This position throws the shadow of the nose across the opposite side of the face, leaving a patch of light on the cheek. This patch is known as the *Rembrandt cheek patch*, after portraits by the seventeenth-century Dutch painter.

This lighting angle puts light in both eyes and models the nose, lips, chin, and cheeks nicely (Figure 4.2). It is considered the most natural key light position. However, every actor has different facial features: one has a large nose; another has a broad face or a chin that sticks out or droops. Some people

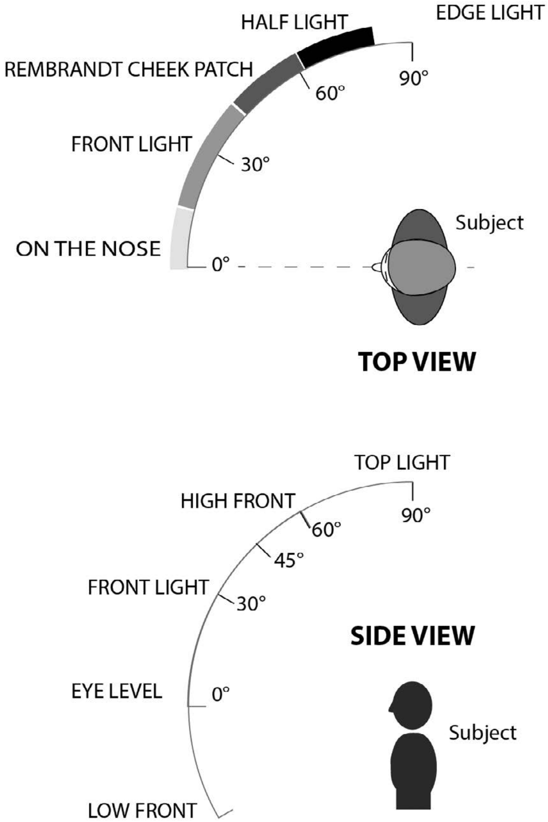


FIGURE 4.1

Top and side view of key light angles. Facial modeling depends on the angle of the light relative to the direction the person is facing.

have deeply set eyes that are difficult to get light into, or hair that interferes with the light, or wrinkles we may wish to hide. The DP responds to these differences; the 45° rule is often just a starting point.

Normally the key light is somewhere between 0° and 90° from a frontal position to the subject and between 0° and 45° above the subject's head. However, it can come from any direction that reveals at least some of the features of the face: from below, from high overhead, from the side, and even from a three-quarter back position.

Figure 4.2 shows a setup that uses two lights and two bounce cards. Key light is a softlight set 60° to the side, just above her head height. Backlight is a softlight set behind her, 30° to the right of the line of action. A 1′ × 1′ bounce creates an eye light. A 4′ × 4′ bounce on the camera right side bounces the backlight to provide a small amount of fill.

This key position models the nose, right cheek, chin, neck and clothing. It puts light into both her eyes. Her hair on the key side has good detail. The backlight on the non-key side is needed to define her hair on that side.

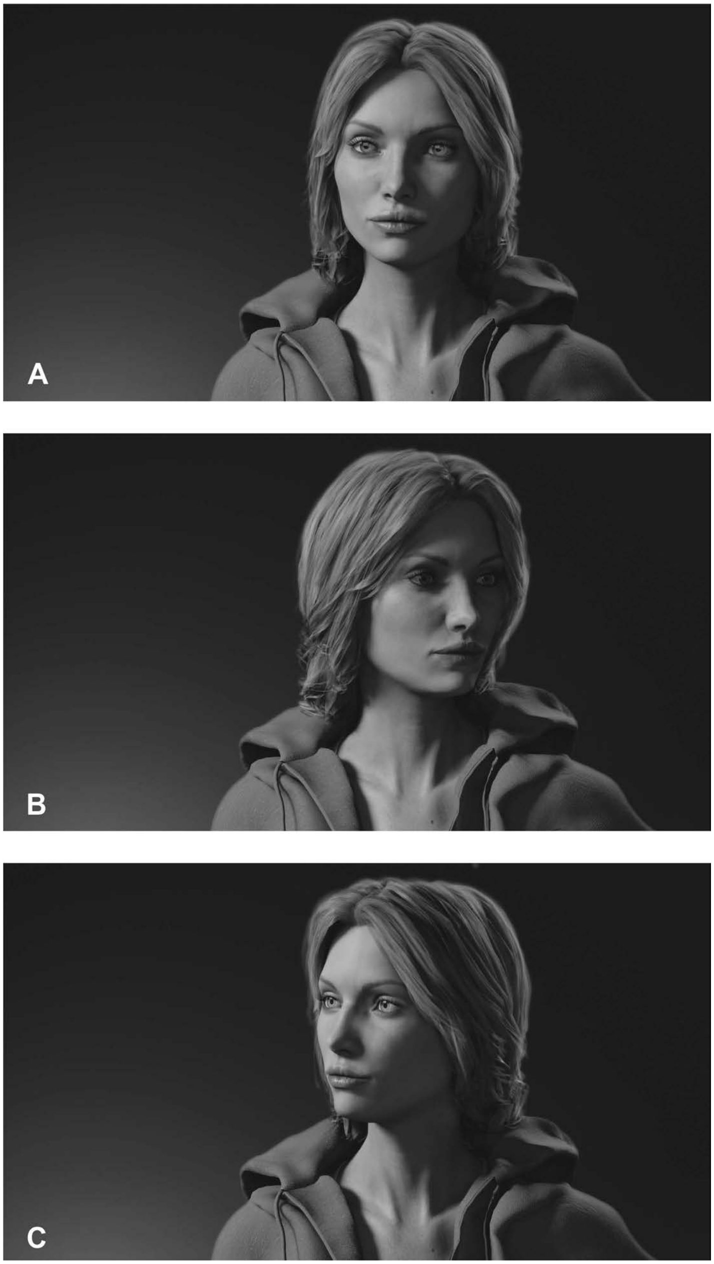


FIGURE 4.2

(A) Rembrandt cheek patch key light (this one is 60° to the side). (B and C) Head turns camera right and left.

(*Rendered in Set.a.light 3D*)

Near- and far-side keys

An important concept in selecting the key light position is *far-side key* vs. *near-side key*. When the camera faces an actor in typical coverage, the actor looks either camera left or camera right. If the actor faces to camera left, he presents more of the camera-right side of his face to camera. The left side is therefore the *far side* and the right side is the *near side*. A far-side key lights the far side of the face, allowing some shading to fall across the near side of the actor's face (Figure 4.3A). This arrangement models the facial feature by presenting more contrast toward the camera.

If we do the opposite, placing key light on the near side (camera right in this example), the image has less contrast and can appear flat (Figure 4.3B). A *near-side key*, which some people like to call the *dumb-side key* (but let's not judge) is actually quite frontal and close to camera.

Of course, there are plenty of situations where a near-side key is used. In Figure 4.4, the subject's hair creates shadows on her face when lit with a far-side key. Notice how different her face looks when lit from the near side.

FIGURE 4.3

(A) Far-side key. The key light is on the other side of the line of action (about 50° off the nose). (B) Near-side key. The key light is on the same side of the line as the camera (about 10° right of camera).

(*Rendered in Set.a.light 3D*)

No one has ever been denied a Best Cinematography Oscar because they used a near-side key; however, the preference for a far-side key is the foundation of many a lighting setup.

Side light

If we move the key light more around to the side, it no longer reaches around the face to light the far cheek (Figure 4.6A). A direct side light puts one half of the face in shadow and is sometimes called a *half-light*. As people age, their facial features grow more prominent. Side light tends to accentuate the features, which may or may not be desirable. Young children's faces tend to have less predominant features and a soft side light easily wraps around their faces.

FIGURE 4.4

(A) Far-side key; (B) near-side key.

(*Rendered in Set.a.light 3D*)

When this half-light effect is desired, the best position for the key light is not at 90° to the face but more like 75–80°. Beyond that, an unattractive shadow appears between the cheek and nose and the shadow line runs right along the ridge of the nose (Figure 4.5B). By bringing the light slightly downstage, the shadow disappears, and light wraps over the bridge of the nose a bit more. The result is a pleasing half-light effect (Figure 4.5A). It models the face nicely and gives a pronounced sense of contrast and direction.

If the actors are playing the scene largely in profile, a deep-set side light is a really great key position (Figure 4.5C). In Figure 4.6 a strong rim light emphasizes the profile. Notice how each bright profile is set against a darker area, creating a repeating pattern of light, dark, light, dark.

When keying from a side position, a head turn away from the light can be problematic. Figure 4.7A is the same lighting setup as Figure 4.5B and C, but we are in serious trouble if the actor decides to play too much of a scene away from the light like this. The addition of a back or side kicker on the non-key side can help carve out the profile of the actor to accommodate occasional turns away from the key light. Or the background area could be lit so that the actor's profile is defined in silhouette. Alternatively, you could introduce a side light key from the right (Figure 4.7C). Now you have two key lights that are lighting the actor from opposite directions. Using opposing keys—cross keys—is a workable solution for looks in multiple directions and is often used when two actors face each other in profile. However, if the look splits the keys, the result is pretty horrible (Figure 4.7D). We call this skunk lighting—a stripe down the center of the actor's face.

When two actors are side by side, side light tends to cast the shadow of one actor onto another. If raising the light does not throw the shadows down out of view, then either the light or an actor needs to move. The camera operator may be able to stagger the actor's marks to clear them of the shadows if this is not awkward for the actors. Otherwise, the light must move upstage and not be so much from the side.

Wrapping the key

A nice addition to a side light key is to use a second light to "wrap the key" around onto the far cheek with a second soft source in a three-quarters frontal position on the same side as the key. This can be done with little or no additional fill. This lightens the face without over-filling from the front and results in a very soft side light with rich contrast and a subtle gradation of tones from light to dark across the face (Figure 4.8C).

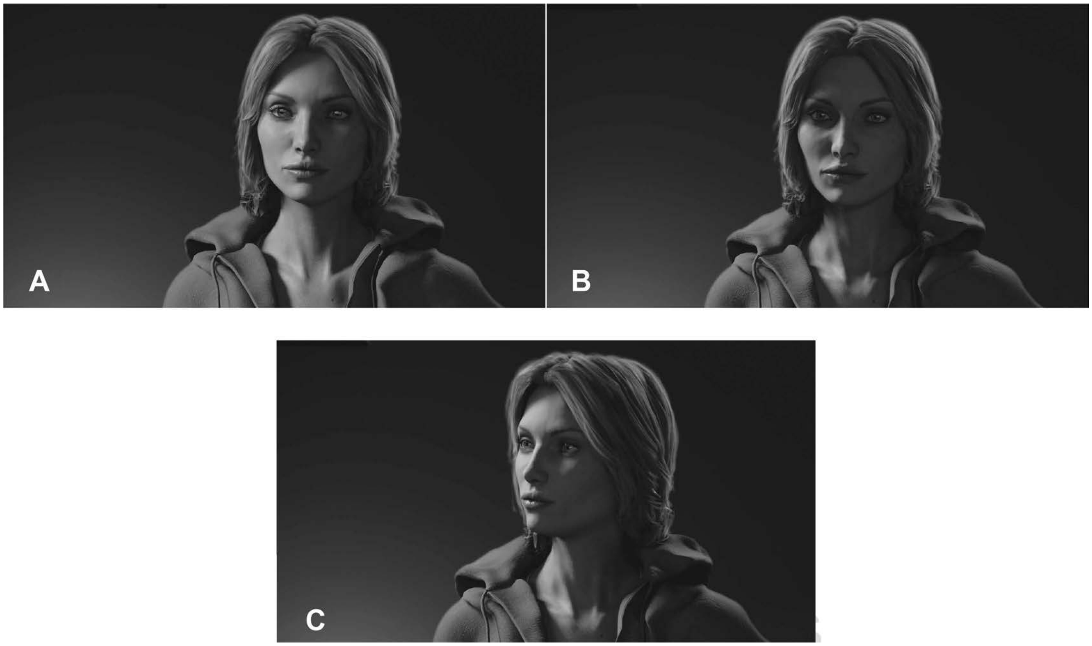


FIGURE 4.5

(A) Side light 80° off her nose. (B) Side light 90° directly to her side. (C) 90° side light with subject turned in profile.

(*Rendered in Set.a.light 3D*)

FIGURE 4.6

The dominant light here is a strong rim light set in a ¾ backlight position at head height. The side light key wraps onto the near side of the face. The side light key is set deep, slightly beyond the 90° point, and its intensity is below key to create contrast.

(*Rendered in Set.a.light 3D*)

FIGURE 4.7

In these images the key light is from the left, but the actor has turned away to the right (A) putting the actor's face in darkness. (B) Solutions include a second, low backlight to carve out the profile, or (C) adding side light on this side and/or lighter background to silhouette the actor's profile. (D) Same setup as C, but the actor has now found the worst possible direction to look, splitting the opposing keys.

(*Rendered in Set.a.light 3D*)

Front light

If we move the key light over next to the camera, in a more frontal position, the actor's nose shadow gets smaller and smaller and the whole face comes into light (Figure 4.9). The image appears bright and "flat." Front light is a convention of glamour photography. With the light directly in front of the actor (often over the camera), the nose and chin shadows are minimized to a small underline. This has the effect of emphasizing the cheek bones, de-emphasizing the nose, and filling in wrinkles or blemishes. The eyes appear very bright, and the sides of the face, the temples, and jaw fall off in brightness.

To prevent the front light from flattening out the entire scene, it is often desirable to angle the light down such that it can be cut off the background with toppers and siders (Figure 4.10) or have the light close to the actor so that the light level falls off quickly. It is also helpful to have some distance between the actor and the background; otherwise, a hard shadow becomes unavoidable.

FIGURE 4.8

(A) Key light from the side. (B) Key with wrapping fill light added from the same side as the key. (C) Backlight added to give detail to the subject's hair and shoulder and separate the subject from the dark background on the shadow side.

(*Rendered in Set.a.light 3D*)

FIGURE 4.9

On the nose key light.

(*Rendered in Set.a.light 3D*)

On the whole, front light flattens the image. When DPs want to regain some contrast, they may break up a front light by cutting it off the forehead or using a breakup pattern. For example, if the scene is established with strong sunlight coming into the room, and the camera angle is such that the sunlight is now frontal, a common technique is to make a hard cut using either a diffusion frame, or a solid flag, cutting light off the actor's face (Figure 4.11).

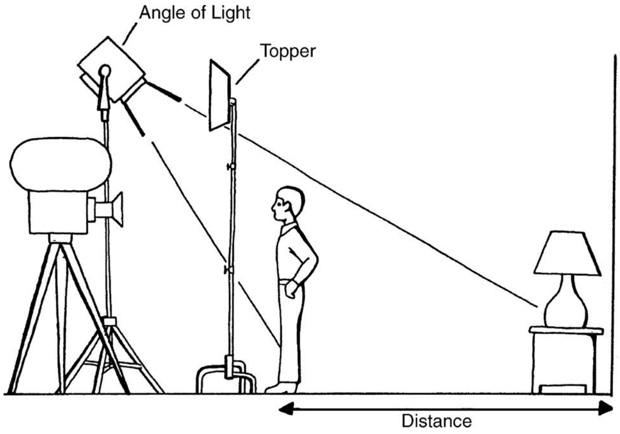


FIGURE 4.10

An on-the-nose key usually requires a topper to prevent the front light from flattening out the background. It is also helpful to have some distance between the actor and the background; otherwise, a hard shadow becomes unavoidable.

FIGURE 4.11

Frontal key light with cut.

(*Rendered in Set.a.light 3D*)

The cut might be positioned just above or below the tip of the nose, for example, leaving hot light on the mouth and chin, or positioned lower, at the sternum, cutting it off the face all together. This gives the impression of strong sunlight, while softening and reducing the light on the face. The top of the actor's face, now in shade, can then be lit from a more pleasing key position, motivated as soft reflected light from the sunlight landing on surrounding surfaces. Often, a bounce board is all that is needed to lift the face.

FIGURE 4.12

(A) Bottom light. (B) Low angle light to accommodate a downward look.

(*Rendered in Set.a.light 3D*)

Bottom light

The thought of frontal bottom light conjures up images of an eerie, unnatural visage with lighting under the eyebrows, nose, and chin casting shadows upward from the eyebrows (Figure 4.12A). However, a low light source does not necessarily have that effect. Light that is bounced up from a light-colored floor or table surface can lend the face a soft radiance (Figure 4.12B).

Naturally, a low position may be used when a light source is at ground level (a campfire, for example) or the actor is elevated. Any time you place a light in a low position, you have to be prepared to deal with, or learn to love, the shadows cast upward on the background and ceiling.

Placing soft or bounced light on the ground from the side and three-quarter back position highlights the line of the neck and jaw and the edges of arms. If the lens has a narrow angle of view (doesn't see below the waist) or the set dressing can provide hiding places for low lights, this can be a great, fast option. A small light on the floor or a bright spot of light bounced onto a white show card lying on the ground achieve similar results. A floor-bounce is an option for providing a touch of frontal fill.

High in front or high to the side

A high position can give a dramatic effect by putting the eye sockets in deep shadow and underlining the nose, lips, and chin in shadow (Figure 4.13). In *The Godfather*, Gordon Willis famously used soft, high frontal sources to give Marlon Brando a low-key, intimidating presence. In this instance hiding the actor's eyes made the character more mysterious and menacing. Top light can be effective to create a sense of faceless, anonymous figures in a room, lighting tabletops and horizontal surfaces, without illuminating faces.

The actor's shadow is thrown to the ground behind them and is seldom an issue; however, the light occupies a favorite place for the sound department to hold the boom mic. So, this lighting choice will force the boom operator to contend with the mic shadow or find another position for the mic.

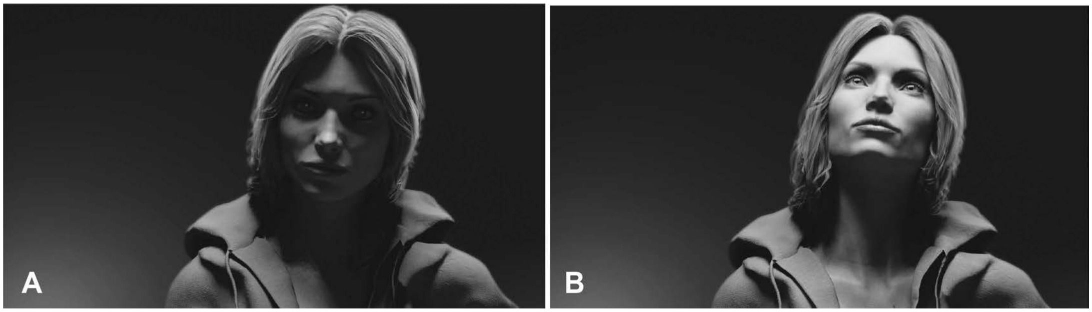


FIGURE 4.13

High front light, (A) forward look, (B) upward look.

(*Rendered in Set.a.light 3D*)

Although high front lights can have a powerful effect, for everyday scenes this is not usually the desired one. Typically, when a location or set has strong overhead light sources (from practical lights such as can lights, fluorescents, or sunlight) we try to soften or eliminate the down-light hitting the actor's face. The grips can rig a flag or diffusion frame over the actor's position, or the lighting technicians can unscrew the offending lamp or turn it off.

THE LIGHTING TRIANGLE

We have been discussing key lighting positions—the brightest light lighting the visible area of an actor's face. To this light, the cinematographer may add some amount of fill light to lighten the shadows caused by the key light, as well as backlights and edge lights to help separate the actor from his or her background and sculpt the shape of the actor's face, body, and wardrobe. As it happens, these three lighting directions—key, fill, and backlight—often form a triangle around the actors.

Fill

The object of fill light is to bring up the light level in the dark shadow areas of the face created by the key light. The amount of fill light determines the contrast ratio and has a great deal to do with the apparent lightness or darkness of the scene. If the fill light is strong, the scene tends to appear bright and flat, a look termed *high key*. Reducing the amount of fill light brings out the directionality of the key lights. A high key/fill ratio gives the sense of night or darkness, especially if the scene is lit with edge and side light. This kind of look is termed *low key*.

The light comes from a frontal position, usually from near the camera. The fill may be placed on the same side as the key to wrap the key, as shown earlier, or it may be placed over camera, under camera, or on the other side of camera from the key. The placement will affect how much the shadows are filled in. The technique of wrapping the key helps retain some truly dark shadows while the other placements will fill more of the shadow side of the face.

Most DPs fill by eye. It may be helpful to turn the fill light off and on to judge its effect. To avoid creating additional shadows a soft source is used. The type of source depends on the circumstance.

A white bounce board often works well by itself, especially if backlights provide some light for the bounce. The smaller the bounce board, the more restrained the fill level, so it is handy to have 1′ × 1′, 2′ × 2′, and 2′ × 4′ boards on hand in addition to the usual 4′ × 4′ and 4′ × 8′. Sometimes the ambient light level is sufficient to fill the shadows. When a light (or lights) are needed for fill, a large soft source is commonly used. The light may be bounced onto a large white surface like foam core, white griff, or muslin, or the light is shone through heavy diffusion.

In some environments there is so much light bouncing off the surrounding light-colored walls, floors, and ceiling surfaces that there is too much fill and it actually becomes difficult to achieve contrast. In this case, the grips can help by providing some "negative fill," 4′ × 8′ black frames (floppies) that can be placed to block the ambient light filling from one side.

Eye light

An eye light is a very specific kind of frontal fill light. It makes the eyes twinkle by creating a reflection in the eyeball, and also fills the shadows under the eyebrows. A low-wattage light fixture or white bounce card placed close to the camera creates a highlight in the eyes. The bigger the dimensions of the source, the bigger the reflected dots. Eye light does not have to be very intense, however, because the eyeball is very reflective. An eye light need not flatten out the overall image.

An *Obie light* is a light positioned directly over the camera lens, mounted to the matte box. It is convenient to use an LED so that brightness can be adjusted without affecting color temperature.

Camera-mounted lights are often helpful when tracking with actors—through caves, corridors, air ducts, tunnels, etc.—when the overall feel needs to remain dark, but a minimum amount of fill light needs to be maintained on the faces.

Backlights, kickers, and hair lights

Backlight highlights the edges of the face, hair, and shoulders of an actor. It strengthens the lines that delineate the figure from the background (Figure 4.14). Edge- and top-light positions

FIGURE 4.14

(A) No backlight. The actor's dark hair and dark suit has very little detail and will tend to blend into the dark backgrounds. (B) Two soft backlights (30° left and right of the line of action) help bring detail into the hair and define the shoulders and arms. Also, the background is lit to a contrasting tone.

can help emphasize features of the face and hair. Scenes that occur in relative darkness are often backlit to give delineation to the figures and set dressing without lighting them too much from frontal angels. Backlight is also the best angle to make rain, snow, and smoke visible to the camera.

To help accurately describe the position of backlights, we will describe them in terms of degrees off of the line of action as illustrated in Figure 4.15.

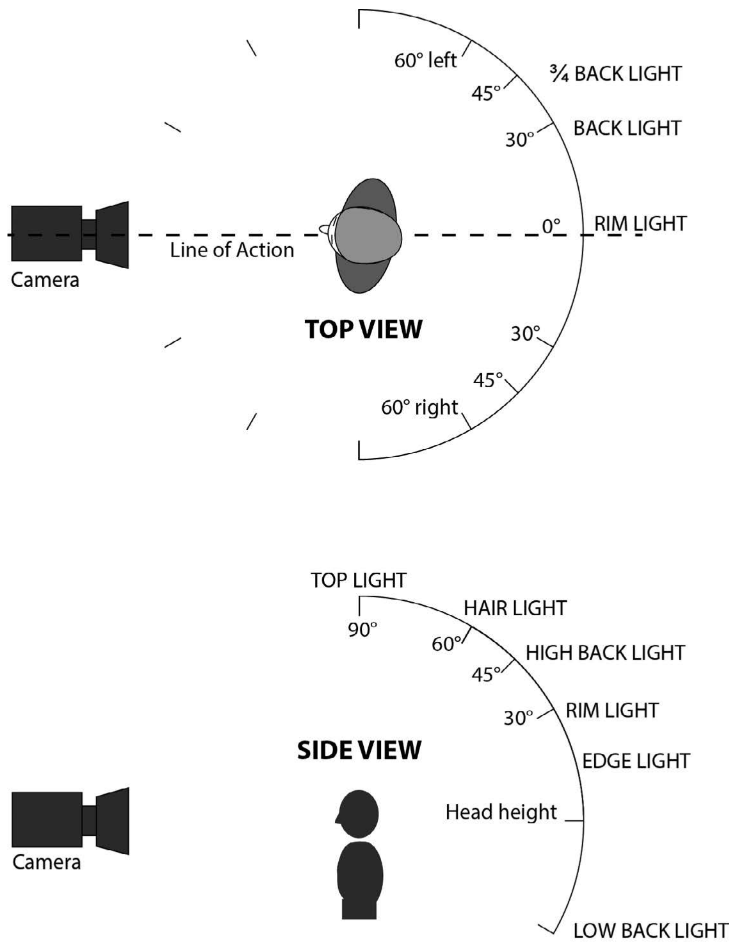


FIGURE 4.15

Top and side view of backlight angles. The effect of a backlight depends on the relationship between the camera and the subject, so it is easiest for us to refer to backlight positions relative to the *line of action*. The line of action is the line between the camera and the subject. Imagine this line extended behind the subject. The position of backlights can be described by their angle off the line of action (top view) and their angle above the subject (side view).

FIGURE 4.16

(A) Strong, low (head-height) kicker adds definition to the camera-left cheek and jaw. This is a hard light, placed as a ¾ backlight (40° off the line of action). (B) The light is now moved farther around to the back (30° off the line of action). A second low, edge light has been added on the right side.

Three-quarter backlight kicker

A kicker is normally relatively low, from a three-quarter backlight position. A light glancing off the side of the face and hair gives form to the jaw, cheek, and hair and separates that side of the figure from the background. Because these lights are low, they put very little light on the shoulders and top of the head; they mostly work on the sides of the head and body. Low backlights feel right when the motivating sources should not be overhead, e.g., car headlights, practical lamps, windows, etc.

If the actor turns profile to the camera, a three-quarter backlight highlights the profile, and can even act as a key light. Because of its low, back position, it does not cause problems by spilling onto walls and can easily be kept off the ground. As with all backlights, the problem is always keeping it out of frame and preventing flare on the lens.

In Figure 4.16A, the kicker is far enough to the side that it strikes the actor's nose. This can be distracting especially if it only strikes the tip of the nose. If the light is further to the back (Figure 4.16B) it takes a smaller bight of the actor's face and no longer reaches the nose.

High side backlight

High side backlights, one on either side of the subject, soak the performer in backlight; the effect is powerful and dramatic (Figure 4.17A). You see this technique used in rock concerts and dance performances. When blended with the frontal lights and applied with more subtlety, a pair of high side backlights rims the head and shoulders evenly and highlights the hair (Figure 4.17B). News reporters and talk show hosts seem to have a pair of backlights with them wherever they go. High backlights tend to light up the ground, tabletops, and other horizontals.

Rim

A rim light is a direct backlight that rims the head and shoulders, pulling the actor out from the background (Figure 4.18A). A rim light is a thin highlight working mostly on the hair and shoulders. From directly behind, it does very little to edge the sleeves. Low backlights are the trickiest to shade off the lens and are in danger of being in frame if the camera is not using a fairly long focal length lens.

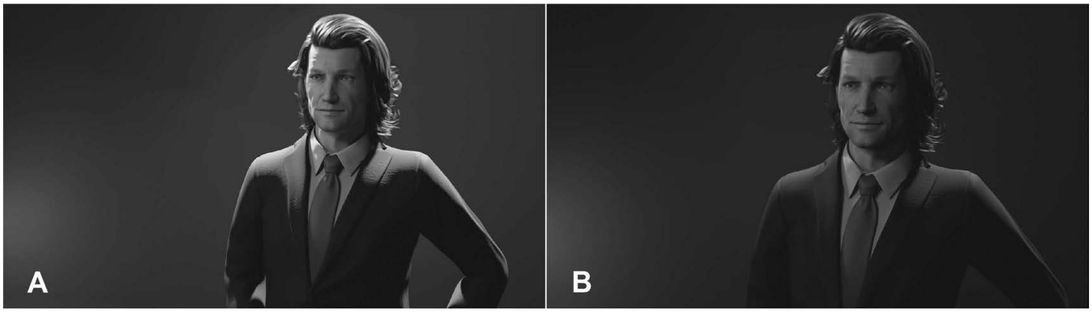


FIGURE 4.17

(A) High side backlights drenching the actor in backlight (lights are angled downward at 45° angle, about 30° each side of the line of action). (B) Same lighting setup with the backlights dimmed down for a more subtle effect.

(*Rendered in Set.a.light 3D*)

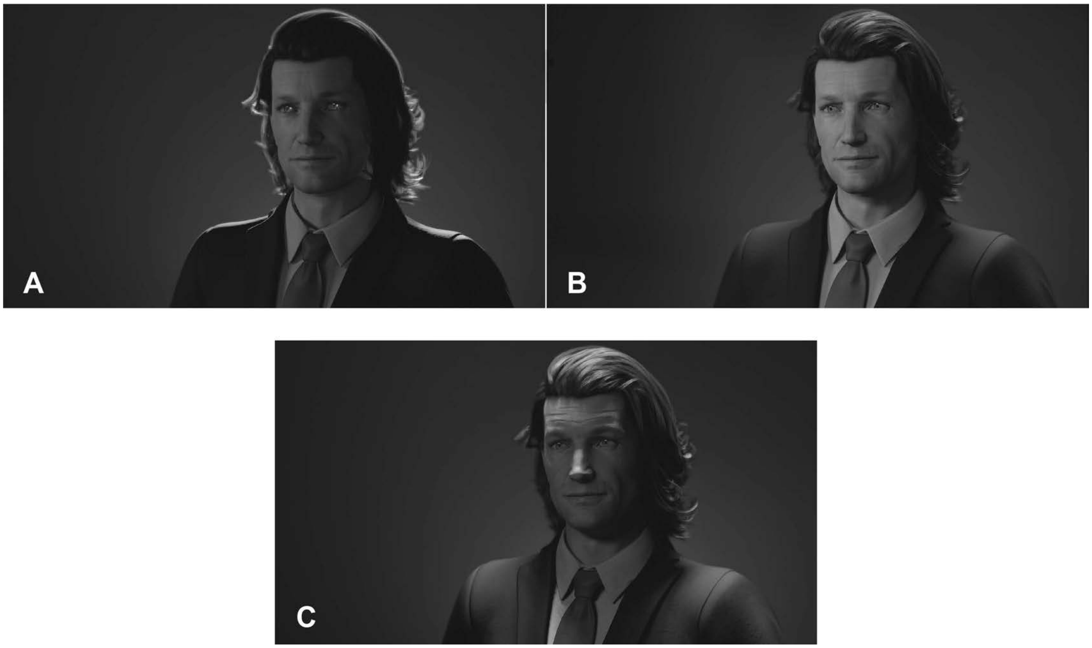


FIGURE 4.18

(A) This rim is created by a hard light placed on the line of action, about 8 ft. directly behind the actor and just high enough to be out of frame. (B) This hair light is a soft light close over the back of the actor's head, 65° down-tilt. The light is back far enough that it does not spill onto the actor's forehead. (C) Top light tends to spill onto the forehead and highlights the nose.

(*Rendered in Set.a.light 3D*)

Hair light and top light

A hair light is positioned almost over the actor, behind them, so it creates a flattering halo effect on the top of the head. Applied with subtlety, it brings out the color and texture of the hair (Figure 4.18B) (if they don't have much hair left, it brings that out too). It would likely be used with other backlights, which are not shown here.

A top light (directly overhead) lights the actor's forehead and the bridge of the nose (Figure 4.18C) in addition to their hair and shoulders. This is generally not a great position from which to light a person, unless the person is reclining.

LIGHTING THE ACTING POSITIONS

Let's look at how these lighting angles come together to light a scene with several actors interacting. The scene shown in Figure 4.19 shows Andy standing opposite Babette and Camile. Babette and Camile are lit with a strong soft key light from the left. The first shot is a master that holds all three actors in a three-shot with camera positioned as illustrated. With Babette looking left to Andy, the key

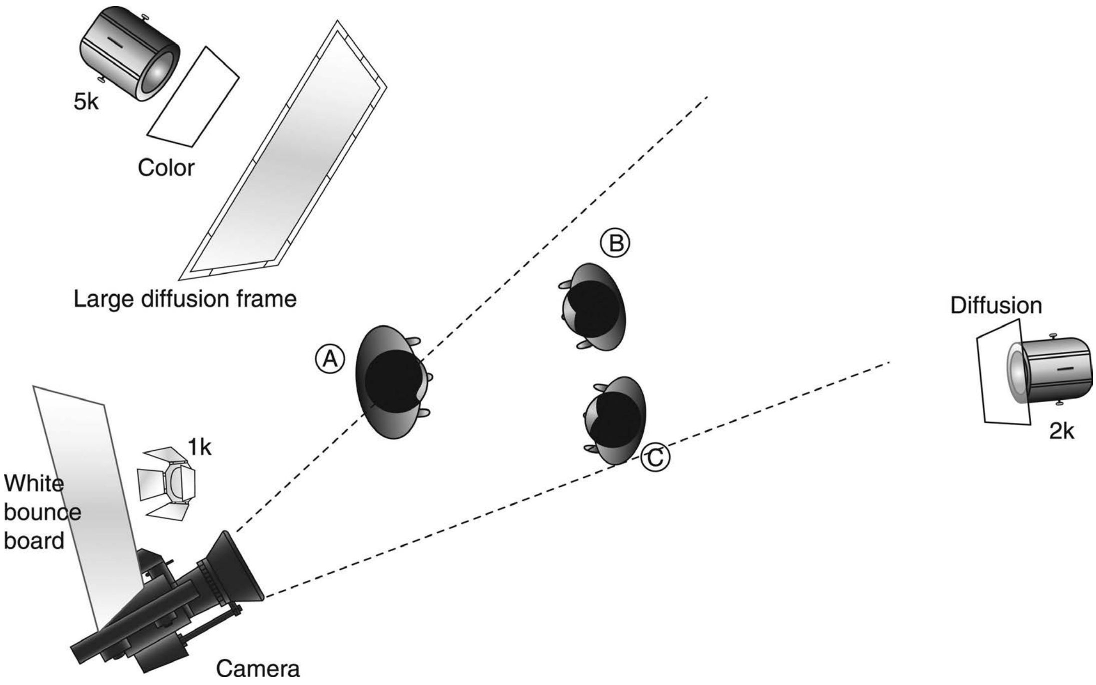


FIGURE 4.19

During rehearsal, the DP notes the direction of the actors' faces, and finds a key light angle that accommodates both actors B and C. Here the body language favors putting a large soft key from camera left. Both faces are modeled nicely from this angle.

light hits Babette's face as a nice far-side key. Camile faces more toward the key light. It illuminates most of her face. The key light does not light Andy's face at all, his back is to it, but we carve out his profile with the three-quarter backlight from the right. This backlight is also creating an edge around the camera-right side of Babette's and Camile's heads and clothing.

These three basic lighting angles can create many different looks. The relative strength of the three sources shown here, and also the color of each source, could be played in many different ways. For example, the big soft light at camera left can be played as the strongest source, warm soft window light, exposed perhaps 1 stop over the aperture setting on the camera, with a warm gel (¼ CTS is a straw-colored color correction gel that is great for this) on the light. The backlight from the right is played as a weaker bluer source, ½ stop under exposure, with a pale blue gel (½ CTB). The fill light is played 2 stops under exposure. The result will be a warm light scene with rich contrast.

On the other hand, imagine what the scene would feel like if the big soft source could be played as a weak light, exposed a stop under exposure and cool blue (¾ CTB). Imagine that the backlight from the right plays as direct sunlight through a window, neutral in color and bright (2 stops over exposure), and the fill light is neutral in color and exposed 2½ stops under exposure. The impression now is totally different. The room feels dim, and moody.

Back cross keys

When two actors are facing one another, and the camera is shooting them in profile (a 50/50 shot), a common lighting strategy is to use *back cross keys*. Actor A is keyed from the back right, actor B from the back left. From the camera's point of view, these two lights are far-side key lights for each actor. When shooting a moody, dark scene or night scenes, the key lights often move around to side and back positions. However, the back cross key strategy is used in any number of situations. Multicamera sitcoms often employ this strategy, because the proscenium-style shooting lends itself to blocking where the actors are facing one another in profile to the audience.

Figure 4.20 shows the camera position for the master shot has both actors in profile. If this were a dark night scene, the fill level would be kept very low, putting very little light on the visible side of either actor's face, giving a sense of overall darkness. Note that actor B's key light acts as a kicker, or backlight, for actor A, and actor A's key light does the same for actor B.

Once the master shot is completed, individual, over-the-shoulder (OTS) close-ups will be shot. Figure 4.21 shows the camera placements. Note that our key lights are already in good positions to light the faces. We might bring in a backlight to keep a rim on the non-key sides of the faces.

The discussion thus far has dealt with lighting a stationary group of actors with a stationary camera. Very few movies, however, are about people who never move. We apply the same basic mental process that we have been discussing to light a complex shot. When the actors move to multiple marks and the camera moves to view the scene from different angles the variables increase; however, we can usually break down the scene into a series of key positions. We can choose to light each of these key positions individually, or we can take a more general approach to the lighting, and employ larger key, fill, and backlight sources to illuminate a larger area. If a light that plays in one part of the scene is too much or too little for another part, it can be adjusted imperceptibly on a dimmer, or using a handheld net during the action.

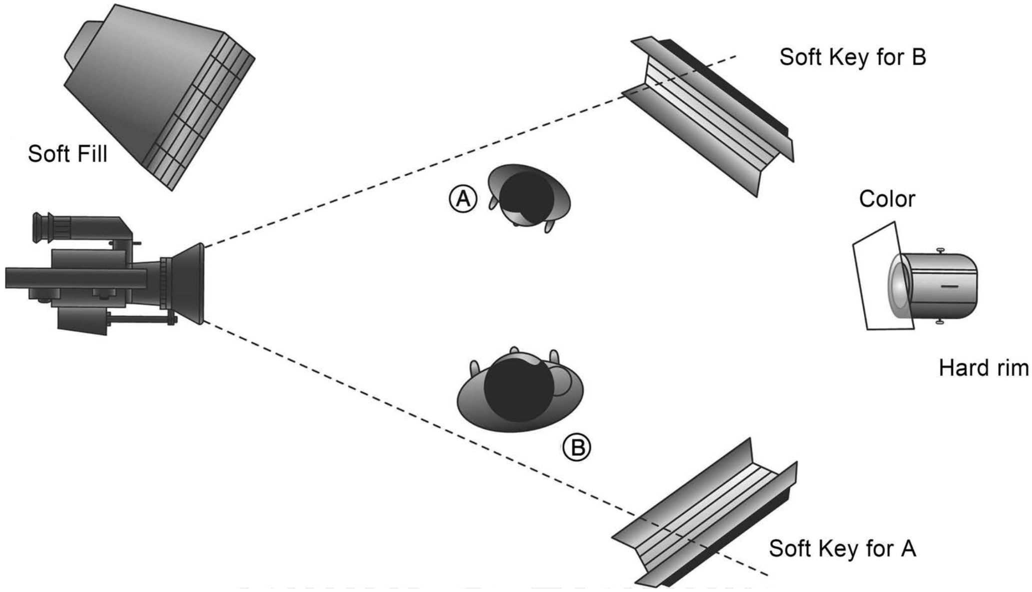


FIGURE 4.20

Here two actors are facing each other, profile to the camera, and each has a far-side key light. This lighting setup is known as "back cross keys." In this illustration, the soft wrapping light is augmented with a direct hard backlight "liner," which puts a bright highlight around the actors' profiles.

LIGHTING THE SPACE AND THE BACKGROUND

In addition to lighting the acting positions, we want to consider the lighting in the overall composition: the furniture and surfaces, the walls and architecture, the wall art and set dressing, and the exterior visible through windows—buildings, trees, or backdrops.

The gaffer looks for ways to break up the background or create variation, gradation, or specific highlights. If a scene takes place in a set with lots of windows, it is natural to scrape a slash of sunlight across the far wall, and across the furnishings. Large Fresnels or PARs are commonly placed outside windows for this purpose. Alternatively, the light from the windows might be made to emulate soft skylight, using large diffuse sources. At night, window light might be amber sodium vapor streetlight, or blue moonlight.

Another treatment of the background is to create pools of light throughout a set. The background may be lit with practicals. In a set with lots of desks or a restaurant full of tables, each table might get its own top light (from an ellipsoidal spotlight hung overhead, for example). If there is art on the walls, the gaffer might highlight each piece with a "special." If the walls are painted a dark color, the gaffer might wash light either upward from the bottom or down from above to create pools or scallops of light or use LED ribbon to create gradations of light and color by installing them in soffits or otherwise hiding them within the set.

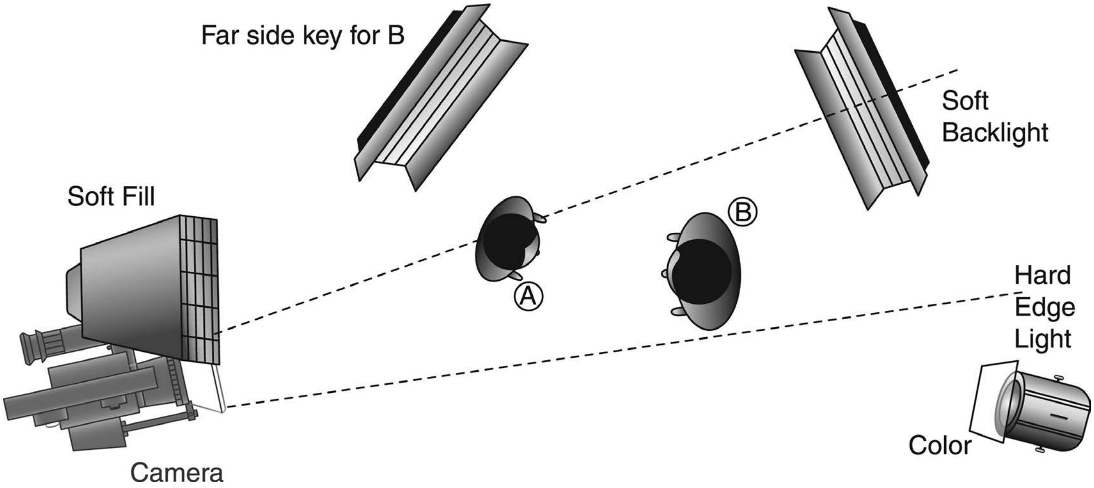


FIGURE 4.21

The setup changes very little from Figure 4.20 when the camera goes in for over-the-shoulder (OTS) coverage. Actor A's key light now serves to edge light both actors. It is easy to forget to provide an edge for the foreground actor when you are concentrating on lighting the actor facing the camera, but without it, the picture can look incomplete when reverse close-ups are edited together. Note also that in this case the liner is cheated around to the non-key side.

Ambience

Ambience is general fill throughout the set as opposed to the fill specifically for the actors' faces. Ambience for a small set can also be created from an overhead source such as a china ball or simply by bouncing light into the ceiling. Often, on small sets, no additional ambient light is needed because a base level is created by the other light bouncing around. Larger sets sometimes require a level of ambient light to raise up shadows and create an even level overall. This is commonly accomplished with overhead soft lights such as coops, space lights, or other large diffuse sources hung overhead. For a living room set, one overhead fixture is more than enough; for larger sets, it is common to hang rows of space lights. Any large set, like a courtroom, corporate office, or a classroom might need to be treated in this way.

For sets built on a sound stage, the exterior portions of the set, outside the windows, often require a significant amount of ambient light to emulate skylight. Wherever it is used, it is important to be able to adjust the brightness of the ambient light, so these lights are typically controlled remotely either on dimmers or by having separate control of the circuits for each light fixture.

Backdrops

On a sound stage, the scene outside the windows is very often a translight or scenic backing (painted backdrop). A translight is essentially a gigantic photograph. Day and night translights are commonly used depicting a backyard, the view from a high-rise office building, or what have you. The backing is usually backlit or frontlit with large relatively soft lights on about 8-ft. centers. The main objective when lighting backings is to make the light even from one side to another. Backings are often hung from track, so the backing can be moved back and forth depending on the camera angle. The lights have to be placed to light the entire length of the track.

CHAPTER

5 Manipulating light: Tools, techniques, and the behavior of light

I can't stand a naked light bulb any more than I can a rude remark or vulgar action.
—Tennessee Williams, *A Streetcar Named Desire*

Achieving an effect with lighting has as much to do with the angles, distances, and lighting materials as it does the lights themselves. This chapter covers the principles for physically manipulating the shape, intensity, and quality of light after it has left the front of the fixture. Some of this work, like setting flags, frames, and break-up patterns in front of lights, is generally the responsibility of the grip department, but understanding the principles involved is useful for everyone doing lighting.

FALLOFF: YOUR FRIEND, THE INVERSE SQUARE LAW

It is often surprising how little you need to move a light to make a big difference in the brightness. This is because the intensity of a light decreases in proportion to the square of its distance from the subject. This is known as the *law of squares* or *inverse square law*. Figure 5.1 shows that, if a fixture produces 120 fc at 10 ft., at twice the distance (20 ft.) the intensity is *one-quarter*, or 30 fc. At three times the distance (30 ft.), the intensity is *one-ninth*, or about 13 fc.

A tiny LED placed 2 ft. from an actor's face gives the same light level as a 2k at 15 ft., or a 20k at 45 ft., so which one would you use? The gaffer tries to use the inverse square law to his advantage, rather than fighting it. This can save a lot of time and grip equipment. If you use a high-wattage light and place it *far* from the action, the light level will be relatively *even* from one side of the acting space to the other. If you use a lower-wattage light source and place it *close* to the actor, the light level will fall off quickly on the objects surrounding the actor. In Figure 5.2, for the subject lit with the 20k at 45 ft., the change in brightness within 10 ft. of the subject is only about ⅔ of a stop. For the subject lit with the 200 W softlight at 2 ft., the light level 10 ft. behind the actor is more than five stops less—darkness when photographed. For the subject lit with the 2k at 15 ft., the background is a pleasing 1⅓ stops down from the subject's brightness. Note, however, that any subject that passes through the foreground position will be blown out by three stops.

All three of these scenarios offer definite advantages in the right situation. A small light source up close will put less light on the backgrounds, allowing the DP to build more mood and making practical lights and other highlights pop. A large light far away allows the actors to move through a large space without drastic changes in level or having to light many areas separately.

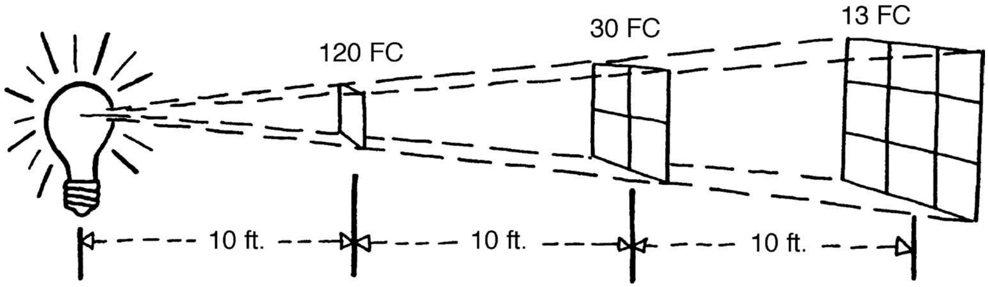


FIGURE 5.1

Inverse square law (law of squares). If a square surface of 1′ × 1′ is illuminated to 120 fc 10 ft. from the light source, at 20 ft. the same amount of light is now spread over a 4′ × 4′ area. The amount of light is therefore a quarter of what it was at 10 ft. (120/4 = 30 fc).

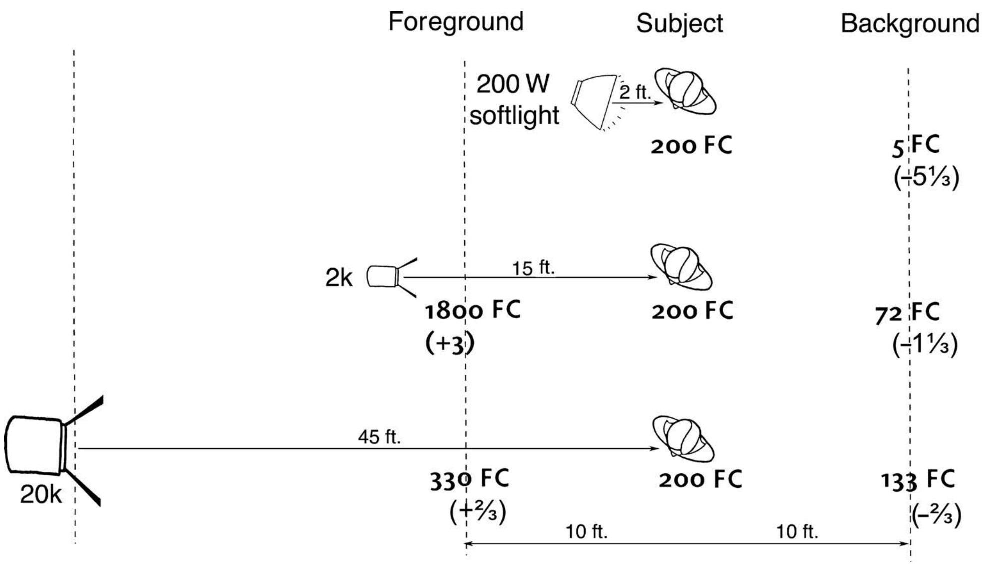


FIGURE 5.2

The inverse square law in practice. All three subjects are lit to 200 fc, but the light level in the foreground and background positions varies a great deal depending on where the light is placed. The numbers in parentheses give the difference in f-stops from the subject's position.

In the planning stages, a gaffer sometimes needs to determine what light can give the desired light level at a given distance. A *candela* (cd) is a unit of luminous intensity, or *candle power*, which is related to foot-candles and feet in accordance with the inverse square law:

$$\text{cd} = \text{foot-candles} \times (\text{distance in feet})^2$$

By measuring the intensity at a known distance, one can find a light's candle power using the above equation. You can then get an estimate of brightness in foot-candles at any distance you choose by dividing the light's candle power by that distance squared.[1]

For example, if you know that a 20k Fresnel gives 1200 fc at 20 ft. (full flood), you can calculate the candela:

$$1200\,fc \times 20^2 = 480,000\,cd$$

From this you can determine foot-candles at any distance. Say, for example, you wanted to know the intensity at 100 ft.

$$\frac{candela}{(distance)^2} = \frac{480,000\,fc}{(100\,ft.)^2} = 48\,fc$$

There are similar formulas to determine beam diameter. Photometric calculations are covered in greater detail in Appendix A.

CUTS AND PATTERNS

Light can be manipulated in various ways as it travels from the light source to the subject. We can give it shape by cutting into the beam; we can break up the beam with patterns or shade the beam with nets. Flags and nets come in various standard sizes, as shown in Figure 5.3.

A few simple but important rules apply when using any flag, net, pattern, or set piece (such as a window) in front of a light.

- To make a soft cut (fuzzy shadow line), place the flag closer to the light.
- To make a hard cut (cleanly defined shadow line), place the flag closer to the surface onto which the shadow falls.

For example, if you put a slash of light on a background wall and want the light to gradually taper off toward the top, use a soft-cut topper (the barn door of a Fresnel may work fine for this). If you want a hard, defined shadow line, on the other hand, place the flag well out in front of the light. For the sharpest definition, back the light up and place the flag as far from it as possible (without it encroaching into the shot). A larger flag will be necessary to cover the whole beam. With Fresnel lights in flood position, the beam width is roughly equal to the distance from the light. If the flag is placed 3 ft. in front of the light, a 2″ × 3″ flag is sufficient. If a harder shadow is needed, use a longer cutter (24″ × 72″) placed further from the light.

A *topper* is a flag or net used to cut the top of a light. Toppers are often used to keep light off background scenery, which also helps the boom operator avoid casting shadows on the walls. Similarly, *siders* and *bottomers* trim light from the side or bottom. A *lenser* cuts light off the camera lens to prevent flair in the filters and lens. A *courtesy flag* is set up to shade glaring light off the camera-persons,

[1] For soft sources, the inverse square law generally still applies provided that light measurements are taken at a distance that is greater than the dimension of the source. For example, if the source is a 12 × 12 ft. grid cloth, the inverse square law applies to measurements taken more than 12 ft. from the source. At closer distances, other factors affect the light intensity.

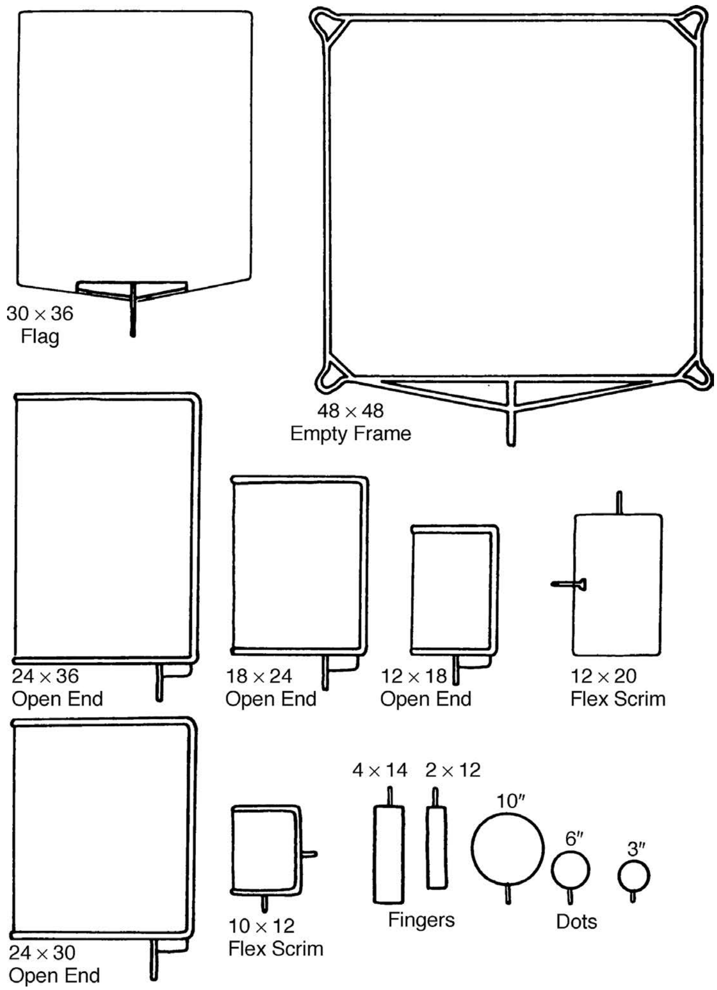


FIGURE 5.3

Common sizes of flags, nets, frames, and silks including fingers, dots, and 10″ × 12″ postage stamps.

or others. When setting a *lenser*, a hard cut is preferable. Halfway between the camera and the light is usually an effective placement when practicable. If the camera is on a long lens (a telephoto lens), the flag can be placed close to the camera. However, when a wide-angle lens is used, you will run into trouble with the flag encroaching into the shot and it must be worked closer to the light.

To avoid the encroachment problem, always place the stand on the off-camera side of the flag. First prepare the flag on the stand, then slide it in from the offstage side until the shadow covers the lens and filters. Ideally a lenser blocks light from the entire inner face of the matte box. If light hits the filters in the matte box, the image may flare.

Breakup patterns

A breakup pattern is very often used to give texture to the background of a shot. Breaking up the light with a tree branch, gobo pattern, Venetian blind, window pattern, or just random streaks of shadow gives the image greater contrast and tonal variation and helps set off the foreground subject. The gaffer may want to exploit whatever shadow-projection possibilities are offered by the set and set dressing: foliage moving in the wind, a slow-turning fan, water running down glass, lace curtains.

Again, for the pattern to be cleanly defined, the pattern maker must be as close to the surface as possible.

You get a cleaner shadow:

- from a point source than from a larger one.
- from a stronger light placed further away.
- from a Fresnel fixture than from an open-face reflector fixture.
- at full flood than when spotted in.
- from the edge of a Fresnel beam than from its center.
- by removing the lens from a Fresnel fixture altogether (though you also lose intensity and flood/spot control).
- by using a donut to remove the edges of the beam with ellipsoidal and xenon lights.
- of Venetian blinds from a Fresnel if you place a C-stand arm through the center of the beam a foot or so in front of the fixture. (No one ever believes me on this one. Just try it.)

The distance also affects the size of the projected shadows. When close to the subject and far from the light, the pattern is of only slightly larger dimensions than the pattern maker itself. When the pattern maker is very close to the light, however, the pattern is projected over a large area, extremely enlarged and distorted in shape—more expressionistic. Therefore, the size of light used, the size of the pattern maker needed to cover the beam, and the distance of the light and the pattern from the subject must all be taken into account before placing the light. In fact, these considerations may have to be taken into account when designing and placing the sets. For example, if a light is to shine through a window and needs to be placed a considerable distance from the window, ample space must be provided for lights outside the set.

Cucaloris

A *cucaloris*, also called a *cookie* or *cuke*, is a plywood flag with foliage-shaped holes cut in it. It is used to break up the light into random foliage like splotches. A *celo cuke* is made with painted wire mesh and creates a more subtle effect because the mesh reduces the light rather than blocking it completely. A cookie does not look convincing if it moves during a take. For realistic moving foliage, use a branchaloris.

Branchaloris

A *branchaloris* is nothing more than a leafy branch placed in front of a light, held on a grip stand. It breaks up the light, projects the shadows of branch and leaves onto the scene, and can be made to move naturally using an effects fan.

Tape on an empty frame

To make lines through the light (to simulate the frame of a window, for example), take an empty frame (18″ × 24″, 2′ × 3′, or 4′ × 4′, depending on the size of the source and the frame's distance from it) and run strips of black tape across it. It is easiest to build the pattern with the fixture in place and turned on, so that you can see the effect it creates.

Shading and selectively controlling brightness

The DP often needs to reduce the intensity of a selected part of the beam. The tools for doing this are typically flags, diffusion frames, and nets. A net, known as a *grip single* or *grip double*, is bobbinet fabric, framed on three sides and open on one side. The open side makes it possible to avoid creating a shadow line. If a double net makes an obvious shadow line, you can use two single nets clipped together and staggered, so the thickness builds up gradually. You can fine-tune intensity with a net by angling the net slightly. The more oblique the angle, the thicker it gets.

Fingers are used to reduce the intensity of a sliver of the beam. Dots are used to reduce the intensity of a very small circular area and can be used to even out hot spots in the center of beam field. Both come as single nets, double nets, silks, and solids.

Materials like Rosco scrim and bobbinet fabric are black woven materials, which the grip department typically keeps on hand as a quick way to dim down a too-bright neon or fluorescent practical, for example, or an out-of-focus window. It can be cut to any shape and size and draped or taped in place.

ND gel decreases the intensity a precise amount without altering color (Table 5.1). Neutral density gel is also available in combination with CTO, for gelling windows (see Chapter 11). CTO/ND acrylic sheets are sometimes used for a clean installation in larger windows.

Table 5.1 Light reduction of neutral density (ND) gels

Type	Light reduction
ND 0.3	1 stop
ND 0.6	2 stops
ND 0.9	3 stops
ND 1.2	4 stops

MOVEMENT

Movement in light is one of its most evocative characteristics: the jumping glow of a television screen; the dancing flames of a fire; the passing of car headlights at night; the movement of leaves in the wind; dance hall or concert lights; the movement of a handheld lantern or flashlight; a swinging bulb hanging from the ceiling; the projection of rain running down a windshield; the slow, smooth motion of sunlight through an airplane's windows as it banks and turns.

The more sophisticated LED panels and tubes have a library of built-in effects (covered in Chapter 7), which can be customized by adjusting speed, maximum and minimum intensity levels, and other parameters. Many LED fixtures can be operated in pixel mode, meaning the fixture is divided into multiple separately controllable sections or squares (SkyPanel 360 from ARRI, Titan tubes from Astera, and others). By fading or chasing from one pixel to another the light moves. There are also older techniques that are still useful.

Flicker effects: television screen, flame, and fire

Sit in a dark room with only the television on, but don't look at it. Watch the way the light shifts on the walls and faces in the room. You will notice that the blue television light quickly changes in intensity and color when there is a cut on screen and gradually shifts in intensity as the camera pans or as characters move around. The pace of the editing may be fast or slow, depending on the content. If you are simulating fire, you might also want to include movement, as flames move, causing shadows to shift. So, creating off-screen effects involves mimicking shifts in pace, color, movement, and intensity.

There are many different ways to do this. In order to simulate the movement of firelight side to side and up and down, at least two or three lights are needed, each with a random flicker. A good way to create movement is to put several small lights in a soft box focused in different places with slightly varying colors applied to them, as desired. Now all you need is a way to make them flicker.

Flicker generation

Gaffers have devised lots of ways to flicker lights to create television screen and flame effects. These range from really complicated gadgets such as a circular disk of mercury switches to simply waving arms in front of two short fluorescent tubes. The latter approach makes a nice effect because the light does more than just change intensity; it actually shifts slowly up and down, which reads well on film.

Whether the effect is generated by an LED using built-in effects, by the lighting control console, or with an electronic flicker box (Figure 5.4), the essential controls are the following:

FIGURE 5.4

Magic Gadgets flicker box supplies three 20 A circuits, each of which can be set to flicker up to a set peak and down to a set base level. The three circuits can be programmed to create a variety of chase effects, fire effects, and television effects. The box can also serve as three 2k dimmers.

(*Courtesy Magic Gadgets Inc., Seattle, WA*)

- The rate of flicker.
- The brightness of the light at its peak.
- The brightness at its lowest intensity.

Flicker boxes having three circuits can produce coordinated flicker effects and chase effects. Some flicker boxes also make blinking light effects and lightning flashes. Most flicker gags involve small lights, but Magic Gadgets also makes DMX controllable 2, 6, 12, and 24k dimmers and effects generators. These can also be used in conjunction with an Optical Interface. By placing an optical sensor near a light source, dimmers can be made to mimic the source. This is useful for fire and flame effects, and when actors operate practical lamps in a scene.

Another way to make a convincing fire effect is to use actual fire. If practical considerations (such as the location, the need for fire marshals, and so on) allow it, a fire bar (a propane gas-fueled pipe with holes along it) can be supplied by the effects department and used as a portable lighting source. If the intensity of the flame is insufficient, supplemental light can be imbued with the look of flame by shining a fixture through the flame of the fire bar. (Do not use a flame bar on productions that don't have appropriately trained personnel and appropriate fire extinguishers.)

Other moving light effects

Lights can be mounted to a crane or dolly or handheld by a lighting technician to make the light move. Reflecting a PAR 64 into broken mirror fragments in a shiny silver tray of water creates lively water striations. Sequences of dimmer cues can be set up to create nice shifts in angle and color. Automated lights, *movers* (Chapter 20), can create all manner of moving light effects from sweeping beam movement, to rotating gobo effects, strobe, shutter, iris, and many more. There are many exciting ways to move light.

SOFT LIGHT

When light is bounced or diffused over a relatively large white surface, the quality of the light is altered in a fundamental way. A conventional light fixture shines a beam of light from one small area—the reflector/lamp/lens—and the rays move the same general direction and diverging slightly. In contrast, a soft source is diffuse, meaning its rays of light are emitted in all directions, and the source is large, enabling light to strike the subject from a range of angles coming from different points of the source. This results in three qualities that are often very desirable:

Soft shadows. No sharply defined shadow lines are projected. The shadow lines are broad and fuzzy. Shadows appear as gradations of tone, so that the entire image is imbued with a softness that is natural and beautiful. Soft shadow lines are easier to hide in situations where multiple shadows would be distracting. Soft light is often therefore the best choice for fill light.

Soft light wraps around the features of the subject. Soft light makes an appealing key light on faces because when soft light strikes the features of the face, some light wraps into the shadows, giving them a subtle graduation of tones between light and shadow. The image can have contrast without the starkness of a hard light. Soft light tends to fill in wrinkles and blemishes in the skin. The images in Figure 5.5 are lit identically, except for the size of the key lights and their distance from the subject.

FIGURE 5.5

(A and C) Hard light key and (B and D) soft light key. The background is hard-lit separately in all the images. (*Rendered in Set.a.Light 3D*)

Bigger reflections. When lighting shiny or glossy subjects or surfaces with a glossy finish, a soft source is reflected as an amorphous highlight. Hard light, on the other hand, is reflected as a bright, glaring, hot spot.

A soft source can be used to create highlights in dark wood, bringing out dark furniture or paneling by catching a reflection of the light source. The gaffer places the light where it is seen by the camera as a reflection in the surface. Especially in cases where you don't want to throw a lot of light onto the walls, this approach yields a more natural effect.

Along the same lines, a soft source makes a nice eye light (covered in Chapter 4).

SOFTNESS OF LIGHT

Three factors influence the softness of light:

- the size of the source,
- its distance from the subject, and
- the diffuseness of the light.

The larger the source, the softer the shadows and the greater the wrapping effect, because a larger source yields more light rays at angles that encircle the features of the subject. Figure 5.6 illustrates the

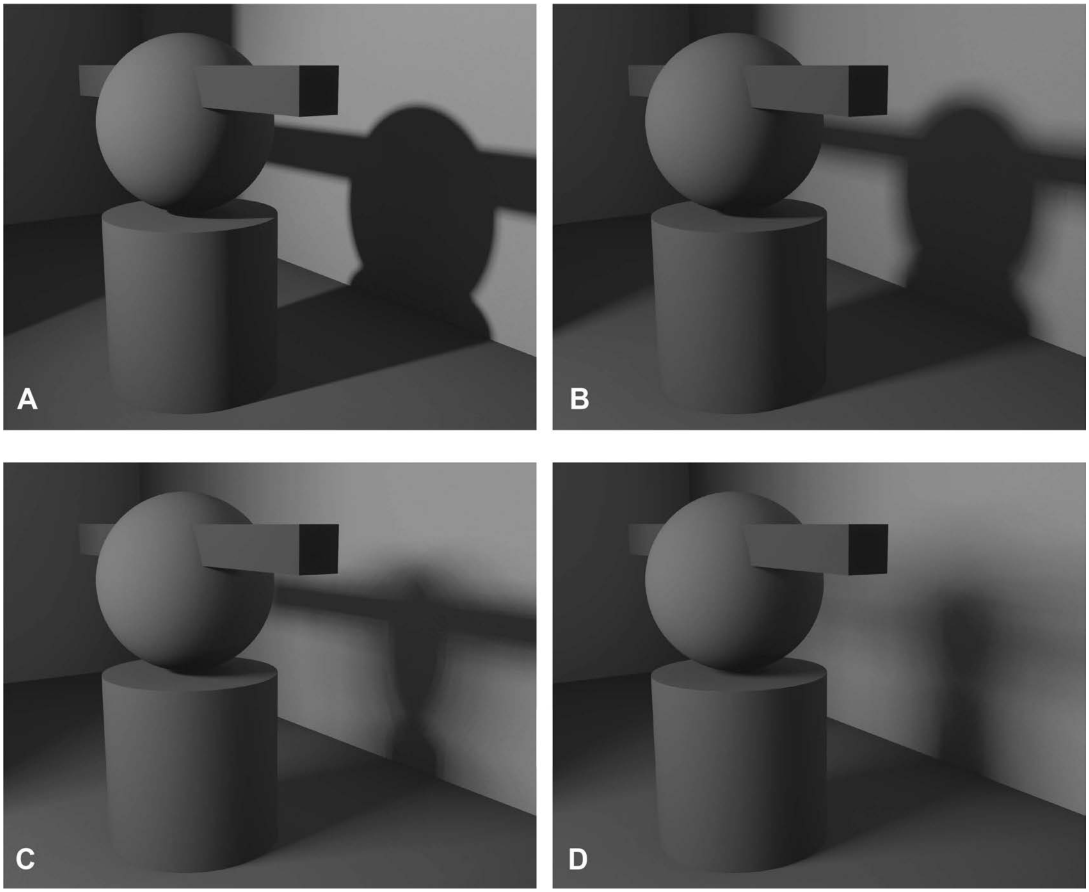


FIGURE 5.6

The effect of four different source sizes and shapes: (A) Fresnel (clean, no diffusion), (B) 1′ × 1′ source, (C) horizontal 4′ × 1′ source, (D) 4′ × 4′ source. Compare the gradation of tone in the ball and cylinder. Compare the vertical and horizontal shadow lines especially in C and D.

(*Rendered in Set.a.Light 3D*)

relationship between the size of the source, the gradation of tone on curved surfaces, and the softness of shadows. Because softness is relative to the size of the source, when focusing a light fixture onto a diffusion frame or bounce board, it is important to completely fill it with light. The surface of the diffusion frame or bounce board becomes the source of light; the larger the source, the softer the effect.

Obviously, the size of the source in relation to the subject also depends on the distance between them. The further away the source, the smaller its effective size. The sun, for example, is a very large source but, as it is 93 million miles away, its rays are completely parallel, so direct sunlight is relatively sharp. Bringing a soft light in as close to a subject as possible maximizes its softening effect. This also localizes the light, by way of the inverse square law, creating a light around the actor, which falls off very quickly.

The third factor that influences softness is diffuseness. When a diffusion material is placed in front of a hard light source, some portion of the light rays scatter in new directions. With a mild diffusion material, most of the rays continue in the original direction and some scatter. The denser the diffusion, the greater the proportion of rays that move away from the source in all directions. These are the rays that fill in the shadow lines and create the soft, gradated effect.

Diffusing light always involves some loss of brightness, so the gaffer needs to automatically compensate when selecting the light and diffusion type (covered shortly).

Linear light sources

We have been discussing how enlarging a point source into a large rectangular source creates the nice qualities of soft light, but there is another way to shape the source that also provides interesting advantages. A linear source, like a fluorescent or LED tube, is broad in one dimension, but narrow in the other. So, a horizontal tube will create soft shadows horizontally, which softens the light on faces, and harder shadows vertically (Figure 5.6C), which makes it easier to cut spill off walls. This gives DPs a balance between maintaining control but still treating faces kindly.

The idea of linear sources really came into common use because of Kino Flo's 4-ft. fluorescent fixtures, but tubular LEDs and LED ribbons have now expanded the possibilities for color control, as discussed in Chapter 7.

BOUNCE LIGHT

Simply bouncing a specular source off a white surface can create soft light. Various sized rectangles of foamcore, taped to and reinforced by a piece of bead board, are standard equipment for fill light. ULTRABOUNCE® is a matte-white waterproof fabric that makes an ideal bounce (developed by The Rag Place). White grifflon and muslin are also used as bounce fabrics. These fabrics are generally available for grip frames: 6′ × 6′, 8′ × 8′, 12′ × 12′, 20′ × 20′, and 20′ × 30′. ULTRABOUNCE® is also available as one side of a black/white 4′ × 4′ floppy.

Passive bounce light for fill. A white board can be used to bounce existing light onto the shadow areas of the face to reduce contrast. On an interior scene, often the backlights hitting the bounce board is all the illumination that is needed for fill. On an exterior scene, a bounce surface catching direct sunlight works well for fill. White fabrics on large frames are commonly used to bounce fill light into bigger spaces.

Active bounce. Bouncing a punchy light into a white surface is another way to create soft light (Figure 5.7) as a key or fill. For an interior scene you might use a 4′ × 4′ or 4′ × 8′ piece of bead board/foamcore. For a larger space, bigger grip frames are often used as active bounces. A fast and easy way to fill a room with soft, even illumination is to bounce a strong light off a white ceiling. If the ceiling is not white, you can rig fabric or foamcore to the ceiling.

When bouncing light, remember that the angle of incidence equals the angle of reflection. If you put the bounce board up high and angle it downward, you can place the lights below and in front of the board, pointing up into it as shown here.

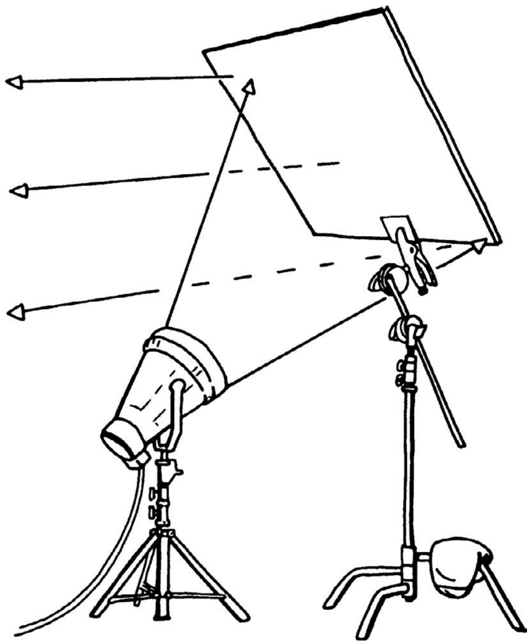


FIGURE 5.7

A strong, large, soft source produced by bouncing a 2500 W HMI PAR off a 4′ × 4′ bead board.

Book light. A book light is an active bounce that then passes through diffusion. It's called a book light because the v-shape formed by the bounce and the diffusion is like a slightly open book that is sitting on its end. For example, for a large room with windows, you could create a super-soft key light by bouncing a punchy source like an 1800 W HMI par into a 6- or 8-by ULTRABOUNCE® frame, then passing the light through another 6- or 8-by diffusion such as grid cloth. This basic setup can be scaled bigger or smaller. It is a somewhat elaborate but effective way to make a very soft source using a punchy, bright light.

Show card, cove light. In a small room where it is difficult to hide lamps, you can tape a piece of white show card into an off-screen corner (Figure 5.8). The reflected light can be better controlled if the show card is curved into a parabola. The fixture is hidden under or above, pointing at the show card, creating a soft light from that direction. You can also use a silver or gold show card.

DIFFUSION MATERIALS

There are four basic types of diffusion material, each with its own character: polyester-based frost and white diffusion, fabrics (such as silks and nylon grid cloth), spun glass diffusions, and silent diffusions. Each type is manufactured in several densities (see Appendix G).

The density of the diffusion determines the proportion of light that scatters vs. that which passes through the material unaltered. Polyester-based diffusion materials provide a wide range of calibrated density levels.

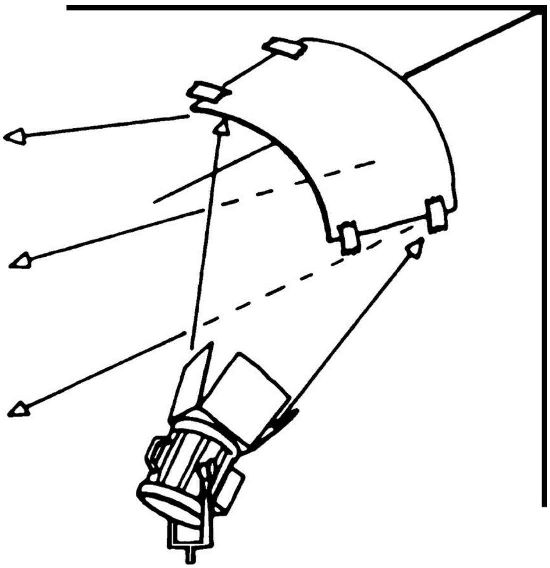


FIGURE 5.8

A show card taped into a corner creates a soft source without rigging a fixture into the corner.

For example, Table 5.2 compares four popular polyester diffusion materials. A light diffusion, like opal (Lee 410 Opal Frost), is a weak diffuser. A high proportion of the beam passes through the diffusion without being scattered; accordingly the shadow lines are only slightly softened. In comparison, when light strikes a dense diffusion, like Lee 216 White Diffusion, a higher proportion of the light is redirected in directions that can wrap around the edges of facial features and objects and cast soft, subtle shadows.

The grips mount the polyester-based diffusion material to open frames. The frames should be skinned tightly to minimize rattle. This is done by applying 3M transfer tape (called ATG tape or snot tape) to a flat frame. The tape has a backing, which you keep in place as you stick the tape to the frame. To get the diffusion straight and tight, it is best to remove the backing from only one side of the frame at first, and align and adhere the diffusion to that side before removing the backing from the remaining sides. Mark the diffusion type on the corners of the diffusion frame with a sharpie and underline it.

Some polyester-based diffusions are tough enough to be mounted fairly close to the hot lenses of a tungsten or HMI light, but there is a limit. Though rarely used, spun, or spun glass, is more durable against very hot open-face halogen fixtures.

Fabrics such as silk, muslin, and grid cloth, are available in large sizes and are often used on large grip frames (6″ × 6″, 8″ × 8″, 12″ × 12″, and 20″ × 20″). The characteristics of fabrics are listed in Table 5.3.

Silent diffusions, such as soft frost (Lee 402 and 404) and Hilite (Lee 414), are made of thicker, more durable, and rubbery vinyl material that does not rattle and crinkle as much when caught by wind or struck by rain. These materials are intended to be mounted on grip frames (rolls are available in 48″ to 96″ widths depending on the product). They are not as heat resistant as other diffusion material, and should not be used directly on a light fixture.

Table 5.2 Polyester diffusion density example

Product No.	Trade Name	Stop reduction	Transmission	Description
216	White diffusion	1½	36%	Dense diffusion. Light source is not discernible through the diffusion. The entire diffusion frame is uniformly luminescent or nearly so.
250	Half white diffusion	¾	60%	Medium density diffusion. Light source is discernible through the diffusion, but entire diffusion frame is at least somewhat luminescent.
410	Opal frost	½	71%	Light density diffusion. Light source is clearly discernible through the diffusion. Source is lightly blurred.
251	Quarter white diffusion	⅓	80%	Light density diffusion. Light source is clearly discernible through the diffusion. Source is lightly blurred.

Table 5.3 Fabric diffusion materials (grip frames and in rolls)

Material	Stop reduction	Notes
Full Grid Cloth	2.6 stops	Available in "silent" and "noisy" versions. Grid cloth is light-weight and very durable.
Half (Lite) Grid Cloth	2.0 stops	
Quarter Grid Cloth	0.7 stops	
Magic Cloth®		
Soft Frost		White vinyl, mild diffuser, holds diffusion properties when wet, seamless up to 8 ft. square.
Half Soft Frost		Like soft frost, but even more mild diffuser.
Hilite		Heavier diffusion, quiet in windy environments.
Polysilk (full silk)	1.6–2.6 stops	Heavy density with moderate diffusing effect. Light passing through silk casts a relatively hard shadow, but the silk helps to fill. Polysilk is a synthetic available in white and black.
China Silk (half silk)	1.0 stop	Medium density. Natural fabric available in either warm white or black.
Quarter Silk	0.6 stops	Very light density diffusion.
Natural (unbleached) Muslin		Muslin is a heavy weight fabric used for cycloramas and ceiling pieces, also used as a lighting tool. Very wide seamless widths (up to 39.5 ft.). Unbleached muslin has a yellow tint, which warms the light.
Bleached Muslin		Bleached muslin is less yellow than unbleached, but also retains some warming effect.
Diffusion Cloth		Very soft diffusion used on light banks and overheads.

Note: Data varies depending on the particular material used by the manufacturer.

Sources: The Rag Place, Matthews Studio Equipment.

Diffusion on the fixture

Adding diffusion to a light fixture can soften the light in two ways depending on where the diffusion is placed—it can make the source larger (by placing a large cut of diffusion on the outside of the barn doors of the fixture, for example) and it makes the rays more diffuse. To create as large a source as possible, open the barn doors wide and attach the diffusion material to the outside (as illustrated in Chapter 8). When using dense diffusion medium, the flood/spot mechanism works in reverse. To maximize the light output, flood the light to fill the diffusion with light. Maximum output is often found just shy of full flood.

There is always a trade-off between softness and control. For example, on a Fresnel light, you can retain a lot more control by placing a smaller cut of diffusion inside the barn doors. This diffuses the light somewhat and creates fewer problems with spill and reflections off the back of the diffusion; however, it does not increase the size of the source and therefore does little more than take the curse off the hard light.

Diffusion on a softlight fixture, like a fluorescent or LED, can help merge the light from the tubes or emitters into a more homogeneous light and increase its diffuseness.

Each piece of diffusion material should be labeled when it is cut from the roll. Mark the type on the corner of the piece with an indelible marker.

Fabric soft boxes

The problem with using diffusion frames is that light spills everywhere and they have to be boxed in with flags. Using a fabric soft box helps dispel the forest of C-stands because it attaches directly to the light itself and accomplishes multiple goals: it places the diffusion the correct distance from the light source, contains the back-scatter and reflects it back to the diffusion, and enables accessories, like egg crates, to control the soft light.

Almost every LED panel has a fabric soft box accessory with a fabric grid or rigid honeycomb grid and other necessary control elements. Bags are available in various shapes: square, rectangular, octagonal (a shape taken from similar parabolic umbrellas used for strobes in fashion photography), and lantern ball (Figure 5.9).

Chimera Photographic Lighting is one of the original major manufacturers of collapsible, heat-resistant, fabric soft boxes (Figure 5.10). Chimeras can be fitted to almost every kind of light fixture, LED, tungsten, HMI, Fresnels, open face, and PAR lights. A "speed ring" adapter fits in the barn-door slots of lights like Fresnels. The interior fabric is soft silver reflective material that increases light output and further diffuses the light. Accessories include 60° and 90° honeycomb grids and louvers. When a Chimera is used on a light that has a focused beam, like a Fresnel or PAR, it is helpful to use a second interior diffusion baffle to double-diffuse the light.

CONTROLLING SOFT LIGHT

Flags and teasers

By its nature soft light resists a hard cut. Making an aggressive cut too close to a large, soft source only blocks and dims the source. With larger, softer sources, flags need to be placed farther from the source. As beam size grows in geometric proportion to the distance from the source, flags, cutters, and

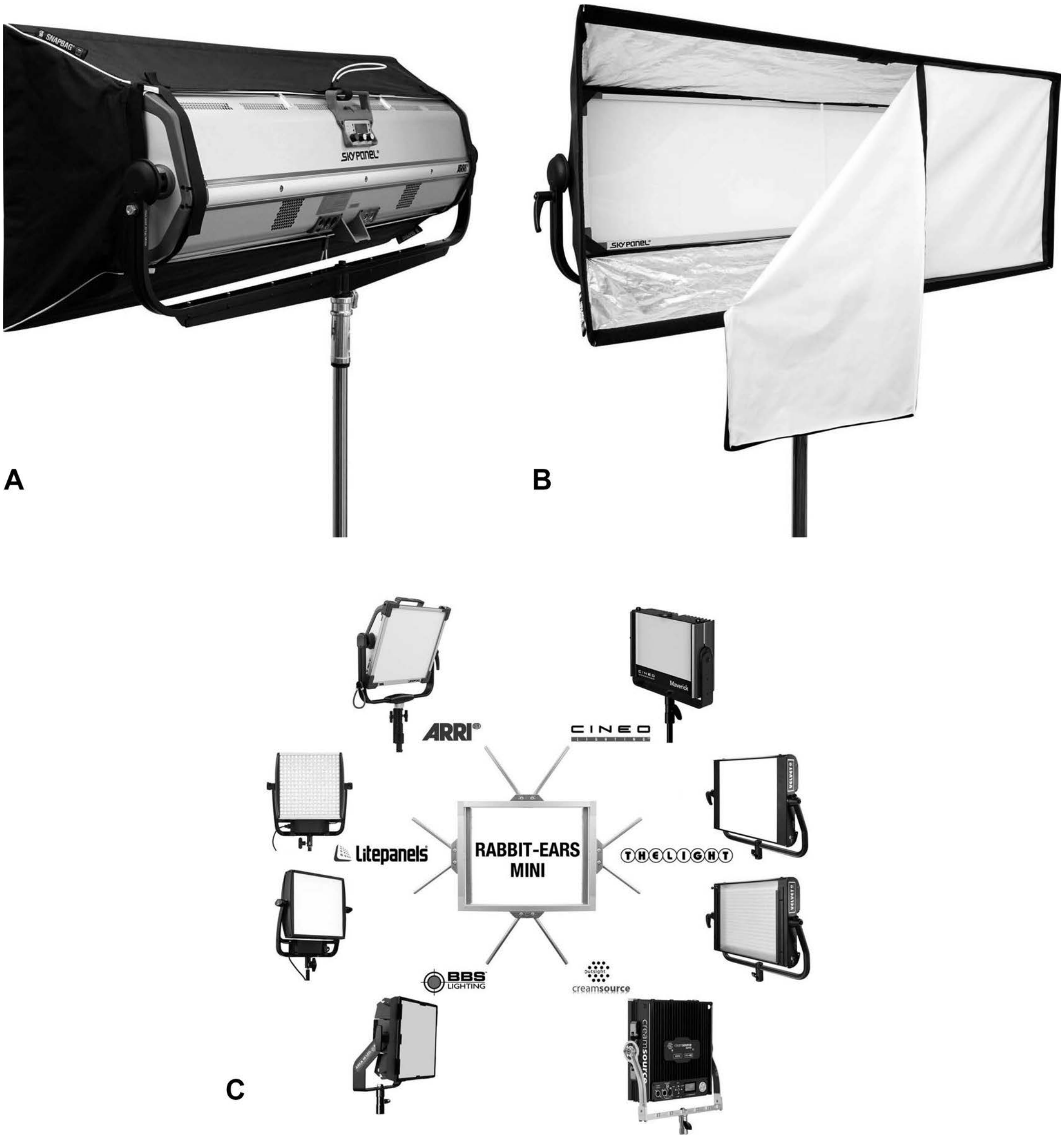


FIGURE 5.9

(A and B) DoP Choice makes the SNAPBAG®. The lining contains a flexible metal that snaps open into a rigid frame, bracing the soft box opening taut. Individually sized SNAPBAGs are available for many of the most popular LED panels. (C) DoP Choice RABBIT-EARS® adapt to any of the lights that are within a couple of common size ranges. The idea is to have one adjustable adaptor that fits any light.

(*Courtesy DoP Choice*)

FIGURE 5.10

Chimera lightbanks in use on a variety of heads (from small to large): a Video Pro bank on a 150 W Dedo fixture, a small Quartz bank on a 1k baby (fitted with a fabric louver), and large one, a 2k junior and a Daylight bank on a 2.5k HMI.

(*Courtesy of Chimera Photographic Lighting, Boulder, CO*)

teasers have to be much larger. A teaser is ideal for topping a bunch of lights all at once, or topping a very wide source. A teaser is a long strip of black duvetyn cloth stapled to 1′ × 4′ lumber or clipped to aluminum pipe.

Grids, egg crates, and louvers

Controlling large soft lights, like boxing in larger frames (8′ × 8′ or 12′ × 12′), can require a lot of grip work. The amount of grip equipment and the necessary space required can start to push lighting equipment into the shot. The better way to contain soft light is using an egg crate or louver directly in front of the diffusion surface, which controls the light by dividing the source into cells. Plastic louvers or honeycomb grids, fabric grids, or metal egg crates are a standard accessory for soft light fixtures and fabric soft boxes. Fabric grids are also available for a range of grip frame sizes. Lighttools™ and others make fabric egg crates—a collapsible fabric grid called a Soft Crate—for light banks as well as for larger diffusion frames, butterfly sets, and overhead frames from 4′ × 4′ up to 20′ × 20′ (Figure 5.11).

A fabric egg crate reduces neither the softness nor the brightness of the light source appreciably but does control how much the light spreads to the sides. This approach has the advantage of being space efficient and avoiding the time and clutter of creating a C-stand forest. Soft Crates used on large frames come in various cell sizes, referred to by their maximum beam spread: 30°, 40°, or 50°. Soft Crates for Chimera-type light banks are offered in an even wider variety of cell sizes.

Although the main purpose of an egg crate is to contain the light, on larger frames it also tends to even out the brightness of the light as you move toward the light source. As you move closer to the light source, the fabric cells occlude progressively more of the diffusion surface. The egg crate effectively reduces the exposure range in the acting space by reducing the rapid increase of brightness, what DPs like to call *sourceyness*. Close to the source, the egg crate opposes the inverse square law.

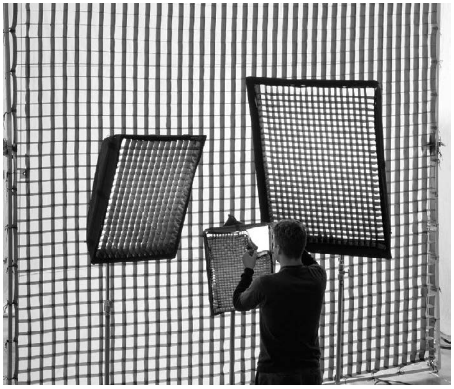


FIGURE 5.11

Lighttools Soft Crates being made ready for use on three lightbanks and a 12′ × 12′ frame.

(*Courtesy Lighttools™, Edmonton, Alberta, Canada*)

FIGURE 5.12

LED lantern light.

(Courtesy DoP Choice)

Lanterns

Gaffers have long used paper lanterns for soft localized glowing light or overhead ambient light (Figure 5.12). The popularity of lanterns inspired manufacturers to come up with sturdier and more durable lanterns for LED, tungsten, and HMI lights. Because it emanates light in 360 degrees, a lantern makes a great key light placed above/between two facing people, such as over a dining table or emanating from the center of a circle of people. Lanterns are also great as ambient fill to lift the general light level in a room. Needless to say, there are many LED embodiments of lanterns and overhead soft boxes and coffin boxes.

CHAPTER

Color

6

The lighting crew has two goals when it comes to color. The first is the technical process of matching the color temperature of the light sources to each other and to the white balance of the digital camera or chosen film stock. The second is aesthetic: introducing color into the light for effect, or to simulate real sources and create contrasts in color.

In addition to these two goals, DPs and gaffers have to be concerned about the color rendering characteristics of the lights they use. Evaluating the color makeup of solid-state light sources (HMIs, fluorescents, and LEDs) is a complex and imperfect process that is covered in Chapter 21. The responsibility for evaluating color falls more to the DP and gaffer than ever. Tools for measuring color have also been developed, which we will introduce in this chapter.

COLOR SPACE

Light is a narrow band within the electromagnetic spectrum, as shown in Figure 6.1. Wavelengths from 380 to 760 nanometers (nm) are detectable to the human eye as visible light. The color of a light source is determined by the intensity of the various wavelengths that make up the light.

The CIE 1931 chromaticity diagram[1] (Figure 6.2) represents the entire gamut of human visual perception—all the wavelengths visible to the human eye. The wavelengths are shown around the outside of the horseshoe shape. The outside edges represent the most saturated colors. Moving from the bottom-left corner clockwise, it starts with violet and deep indigo blue (380–455 nm), blue (430–455 nm), then cyan, and fades to green around the top of the diagram (520 nm). Along the right side of the triangle green fades into yellow (500–588 nm), orange (588–647 nm), and finally to red at the bottom-right corner (700 nm). Along the bottom of the diagram are the hues created by mixing red and blue light: lavender, purple, and violet. The *line of purples*, as they are called, can be made only by combining colors; they do not exist as single wavelengths. Note that any color visible to humans can be identified using the x and y coordinates on the CIE chromaticity diagram. Some LEDs use the x and y coordinates as one of the ways a color can be selected, which is useful for matching the color of the LED to any other source.

As you move into the center of the diagram, the colors become less and less saturated, and the center portion represents white light—this is the portion that we are interested in at the moment. The

[1] The International Commission on Illumination (CIE) first defined human perception of color mathematically in a 1931 study. This definition is known as the CIE 1931 XYZ color space. Although many subsequent advancements have been made, the CIE 1931 diagram still serves as a very useful model for understanding many fundamental aspects of color.

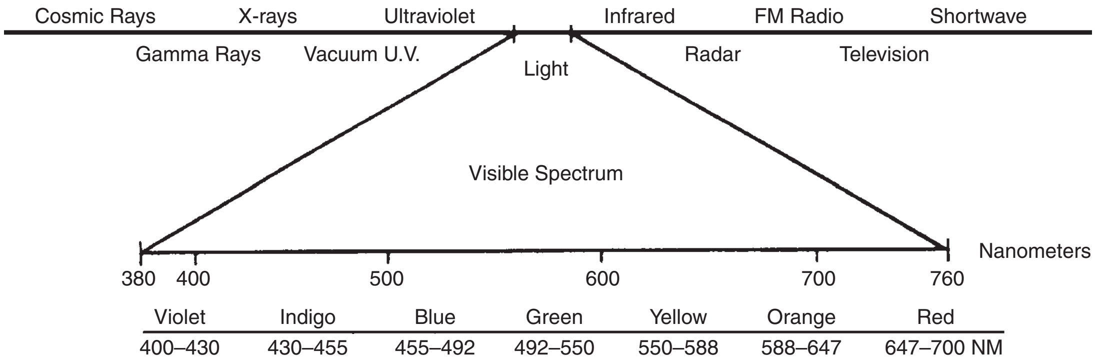


FIGURE 6.1

The color spectrum is a narrow band within the electromagnetic spectrum. Individual colors of light within the visible spectrum combine to make “white light.”

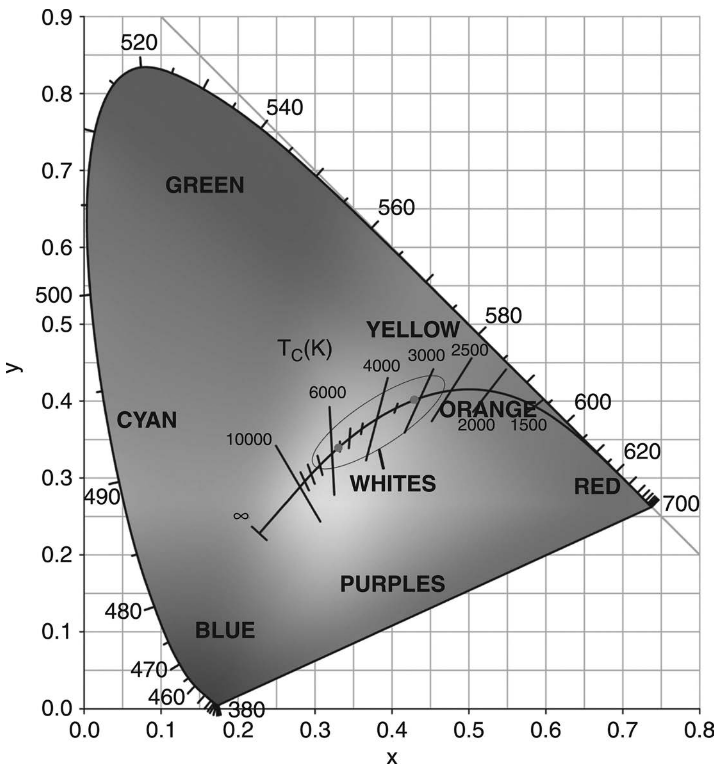


FIGURE 6.2

The CIE 1931 chromaticity diagram shows the gamut of human visual perception. The Planckian locus describes the colors of light possible from a black body radiator, such as the sun, or an incandescent lightbulb.

curved line leading from orangish white light to bluish white is called the *black body locus*, or *Planckian locus*, or sometimes called the Kelvin color temperature scale.

KELVIN COLOR TEMPERATURE SCALE

Color temperature is a scale, in degrees Kelvin, used to identify a particular color makeup of white light. There is a wide range of light that we call white light, from the glow of a household incandescent lamp (2800 K), to the diffuse light of the northern sky (6000–10,000 K). Figure 6.3 shows how the distributions of wavelengths differ for sources of different color temperatures. Daylight is much stronger in the blue end of the spectrum, and tungsten light is much stronger in the red end. The color makeup of a white light source that has a continuous spectrum, such as an incandescent light or natural daylight, falls somewhere on the black body locus.

Unlike the human eye, a video sensor or film stock does not dynamically adjust to these variations. Color rendition is always relative to the white balance of the camera or film stock. Film stocks are balanced either for 3200 K (which we call *tungsten light*) or for 5600 K (which we call *daylight*). A digital camera can be set to 3200 K, 5600 K, or to other color temperatures. Whatever the camera is set to becomes the white reference for that camera. Any light source with a higher color temperature will appear bluer to the camera, and any source with a lower color temperature will appear more orange.

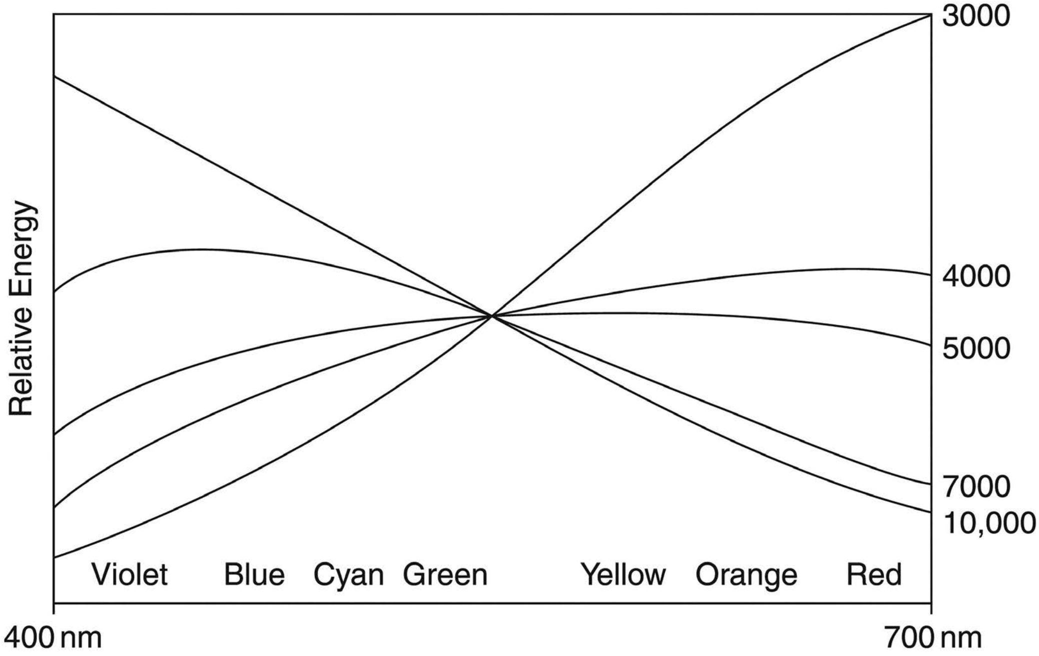


FIGURE 6.3

A spectral power distribution graph (SPD) illustrates the distribution of energy over the color spectrum. Incandescent lamps are strong in yellow-orange and red and weak in blue and violet. As color temperature increases, the curve shifts toward the blue spectral band.

You may be wondering why the Kelvin scale (a temperature scale) is used to quantify color balance. In order to have a fixed reference point, scientists decided to compare the color makeup of any source to that of a theoretical "perfect black body radiator" when it is heated. The idea is that light is emitted when a substance is heated. How much it is heated determines the color makeup of the light. When heated a little, it glows red. Heated more, it becomes orange, then yellow, and then gradually less yellow and more pale blue, and finally brilliant blue. So, the color makeup of a tungsten light is the same as that emitted by a "perfect black body radiator" heated to 3200 K.

Table 6.1 gives the color temperatures for a variety of light sources. It also lists the corresponding micro reciprocal degrees (MIRED) values. MIRED values are used to calculate color temperature shifts, as explained shortly.

Generally we'll use 3200 K color balance for scenes shot inside and 5600 K when we need to mix with natural daylight, either shooting day exterior scenes, or interior scenes where there are lots of windows. HMI lights and Xenon lights are daylight balanced sources. Fluorescent sources[2] can be either daylight or tungsten (or a few other color temperatures) depending on the tube. LEDs can be either or both, and other colors as well, depending on the colors of the emitters (see Chapter 7).

Table 6.1 Color temperature of various sources

Source	Kelvin	MIREDs
Match or candle flame	1900	526
Dawn or dusk	2000–2500	500
Household bulb	2800–2900	357–345
Tungsten halogen bulbs	3200	312
Photo flood bulbs	3400	294
1 hour after sunrise	3500	286
Late afternoon sunlight	4500	233
Blue glass photoflood bulb	4800	208
3200 K lamps with dichroic filter	4800–5000	208–200
FAY lamps	5000	200
Summer sunlight	5500–5700	182
HMI light	5600 or 6000	179 or 167
Sunlight with blue/white sky	6500	154
Summer shade	7000	141
Overcast sky	7000	141
Color television	9300	108
Skylight	10,000–20,000	100

[2] This refers to fluorescent systems like Kino Flo that are color corrected for photography. Commercial fluorescents may or may not have a complete spectrum and usually require minus green correction (see Chapter 11).

Shifting color up and down the color temperature scale

Additive color mixing is the combination of two or more colors of light to create a new color balance. This is how bi-color and full color LEDs work, for example. *Subtractive color mixing* means redistributing the spectrum by reducing the intensity of selected wavelengths in a given source, such as by applying a colored gel to the light, for example. Color Temperature Orange (CTO) or Color Temperature Blue (CTB) are gel colors formulated to shift the color of a light source along the black body locus. Whether accomplished with gel on a traditional light, or by calling up a color correction gel digitally on an LED, correction gels are in densities of full, half, quarter, and eighth correction. Full CTO, applied to a 6500 K source, such as a window, reduces the color temperature to 3200 K. Full CTO reduces a 5600 K source to roughly 3000 K. An 85 gel reduces a 5600 K source to 3200 K. Similarly, theoretically CTB applied to a tungsten-balanced source shifts the color to match the spectral distribution of daylight.

In practice, color correction gels are rarely used to make a full correction. They are used for tints, to warm up or cool down a source. Quarter CTO and quarter CTS (Color Temperature Straw) are used for simulating a warm interior source such as practical lamp, candle or oil lantern. Subtle tints can enhance the colors of the actors' faces, their clothes, and their surroundings, and can give the scene warmth. A fire light might use half, full, or even double CTO. A sunset or dawn scene might be filmed with a full CTO on the lights to simulate the golden light of the low sun.

Commonly, a quarter or half CTB is used when the DP desires a cool blue look to a particular light source. An exterior winter scene shot on a sound stage might use soft lights gelled with a half or three-quarter CTB to cool the scene. Skylight entering a window, twilight, or moonlight also call for a cooler light.

When using a daylight light source in a tungsten-balanced scene, half or quarter CTO creates a "half blue" look. However, half CTB on a tungsten light is bluer than a half CTO on an HMI light for reasons we will get to in a minute.

Using MIRED units to calculate color shifts

The Kelvin temperature that results when a CTO or CTB correction is made to a light source (with gel or electronically) depends on the color temperature of the *light source*. A one-eighth blue gel alters a tungsten source 200 K (from 3200 to 3400 K), but it alters a daylight source 600 K (from 5600 to 6200 K). Table 6.2 shows the color temperature resulting from applying common color correction gels to different light sources.

When operating a full-color LED, the operator can select a color temperature in CCT Mode, by dialing in a particular Kelvin temperature, or in Gel Mode, by selecting a tungsten of daylight source color and selecting a CTO or CTB gel. The following describes how Kelvin color temperature and gel color are actually related, both with real gel and in the firmware of full-color LEDs.

To calculate the Kelvin color temperature that results when a CTO or CTB gel is applied, the calculation has to be made using values called *MIREDs*. Gel manufacturers quantify the effect of color correction in MIRED units rather than degrees Kelvin because MIREDs provide a linear scale on which to calculate the shift of a given gel on any source, which the Kelvin scale does not.

Table 6.2 Color temperature resulting from applying common color-correction gels

Gel applied	MIREDs	Source 6500 K	Source 5600 K	Source 3200 K	Source 2900 K
⅛ CTO	≈ + 26	5550 K	4900 K	2950 K	2700 K
¼ CTO	≈ + 64	4600 K	4100 K	2650 K	2450 K
½ CTO	≈ + 109	3800 K	3450 K	2350 K	2200 K
85	≈ + 134	3475 K	3200 K	2250 K	2100 K
Full CTO	≈ + 159	3200 K	2950 K	2100 K	2000 K
Double CTO	≈ + 312	2150 K	2050 K	2100 K	2000 K
⅛ CTB	≈ – 18	7350 K	6200 K	3400 K	3050 K
¼ CTB	≈ – 35	8400 K	7000 K	3600 K	3250 K
½ CTB	≈ – 78	13,200 K	9900 K	4250 K	3750 K
Full CTB	≈ – 137	59,350 K	23,800 K	5700 K	4800 K
Double CTB	≈ – 274	-	-	26,000 K	14,100 K

Note: Results are rounded to the nearest 50°. Exact results vary depending on the brand of gel and exact color temperature of source.

The MIRED value is equal to 1 million divided by the Kelvin color temperature:

$$\frac{1\ \text{million}}{\text{K}} = \text{MIRED value}$$

The MIRED shift of a particular gel needed to get from any Kelvin temperature (K_1) to any other Kelvin temperature (K_2) is as follows:

$$\text{MIRED shift} = \frac{1\ \text{million}}{K_1} - \frac{1\ \text{million}}{K_2}$$

Note that tungsten color temperature is 312 MIREDs, and daylight is about 179 MIREDs. To correct a daylight source to tungsten, a shift of +133 MIREDs is required. To correct a tungsten source to daylight, a shift of −133 MIREDs is required.

In Appendix G, Tables G.1–G.3 tell you what gel to use to get from any color temperature to any other color temperature. Table G.4 lists the MIRED value for any Kelvin number from 2000 to 9900 K. Tables G.5–G.7 list the color shift in MIREDs of color correction gels of various manufacturers.

Correlated color temperature (CCT)

The color makeup of sources that do not have a continuous spectrum (HMIs, fluorescents, and LEDs) can also be given a Kelvin rating, termed the *correlated color temperature* (CCT). The correlated color temperature is the Kelvin rating that—to human color perception—most closely matches the color makeup of the source. You'll notice, in Figure 6.2, that above the black body locus the color of the light moves toward green, and below the locus it moves toward magenta. The hash marks that cross the black body line connect points that have the same correlated color temperature.

Green/magenta axis

As you can see, white light is controlled on two axes, blue/orange and green/magenta. By controlling the amount of green in the light, the color of a source can be moved along the hash marks and adjusted to fall on the curve of the black body locus, which cameras will see as white light. Some LEDs are capable of adjusting color on this axis by having additional colored LED emitters. With HMI and fluorescent lights it is done by adding "plus green" and "minus green" gels to shift the color.

There is an established scale for green/magenta for camera filters called the *color compensation* (CC) scale. Color meters give green/magenta correction on a CC scale. Minus green correction may be required, for example, by commercial fluorescent lights, and to a lesser degree by imperfect HMIs and LEDs. A magenta gel can be applied to a green fluorescent to neutralize the green appearance. Conversely, plus green gel might be applied to an LED that appears too magenta. Green/magenta correction gel is denoted in fractional densities of plus green and minus green—half, quarter, or eighth. The color compensation scale provides a more precise measure. LED I/O interfaces and spectrometers can often show green/magenta shift in either system. They are related as follows.

CC filter	Gel name
30 M (magenta)	Full minus green
15 M	Half minus green
7.5 M	Quarter minus green
30 G (green)	Full plus green
15 G	Half plus green
7.5 G	Quarter plus green

Table G.9 lists green/magenta correction gels and the corresponding color meter readings. Lee's Zircon correction gel comes in fine gradations:10 M, 5 M, 3 M, 2 M, and 1 M. This is helpful for correcting small inconsistencies, which are common between LED lights that do not have green/magenta color adjustment.

If light sources do not match with regard to green/magenta, it can create problems in postproduction. When the colorist attempts to reduce the green appearance caused by one light, other lights will turn pink. This is why it is so important to correct green/magenta shifts in lights.

However, the DP may intentionally create an off-color look. Plus, green gels are often used to emulate fluorescents, or just cast elements of the scene in a sickened, green pall. Some LEDs, like ARRI's SkyPanels, include industrial/urban sources in the SOURCE menu—mercury vapor, sodium vapor, or fluorescent can be dialed up as a look. The gel companies make urban looking gels like Lee 651 (high pressure sodium), 653 (low pressure sodium), and 652 (urban sodium), which are for tungsten sources and gels like 642 (half mustard yellow) for daylight sources.

MEASURING COLOR

Measuring the color of today's solid-state light sources requires a spectrometer that is designed for cinematography/photography. A high-performance color meter like the Sekonic C-800 uses a CMOS linear image sensor to precisely measure and evaluate the color makeup of a light. The meter has a bandwidth that includes all the visible wavelengths of light, from 380 nm to 780 nm.

A spectrometer is a far more sophisticated instrument than the color meters of the past, two-color Minolta II and III meters and the tristimulus Sekonic C-500, Gossen Colormaster 3F, or the Minolta CL-200. These color meters are accurate for incandescent sources; however, not for solid-state lights.

Here are some of the things that a spectrometer is useful for:

- Accurately reading the color temperature or correlated color temperature (CCT) in degrees Kelvin of natural and artificial light sources (Figure 6.4).
- Identifying the x and y coordinates of a light source color (CIE 1931) (Figure 6.4).
- Identifying the correction gel or camera filter, brand and number, to match the source to a target color temperature or to match the camera to a source (Figure 6.5).
- Reading LB/CC values between a source and target color. Light balancing (LB) readings are MIREDs between source and target color. The meter denotes MIRED shift with the symbol MK^{-1}

FIGURE 6.4

Text mode on Sekonic C-800 spectrometer. The reading shows the correlated color temperature (CCT), color compensation (CC#), foot-candles, and the x and y coordinates of the color point of the light. The light's display panel matches the meter reading pretty closely, 5625 K, 0.25 GN.

FIGURE 6.5

This color-meter mode tells you how to correct the test source to the target source. The target is set at 5600 K in this example. The CCT reading is 10,041 K, requiring a light balancing compensation (LBi) of 79 MIREDs (MK^{-1} means MIREDs). Quarter CTO is the nearest correction at about 64 MIREDs. The reading also shows a CC compensation (CCi), 6.1 M. A quarter minus green is 7.5 M. The gel brand is user selected, Lee in this case.

(and also daMK^{-1} [deca per mega Kelvin] is one tenth of a MIRED). *Color compensation* (CC) indicates green or magenta needed to correct a source to a target color.
- Measuring color rendering properties of a light source using one of several evaluation systems: CRI(re), TLCI/TLMF, TM-30–15, SSI. This gives an index value between 1 and 100, which represents an overall color rendering score. For systems that use test patch colors, the meter shows the individual index values for each test patch color used by the system (see Chapter 21).
- Displaying a spectrum graph of an illuminant and comparing spectral graphs of multiple light sources or reference sources.
- Memorizing measurements for future comparison.
- Setting preset color temperatures (2500–10,000 K). For example, setting a preset for whatever color temperature is selected for the camera. For a variety of reasons, the DP may choose to work at a particular color temperature other than the standard 3200 K or 5600 K. For example, a particular digital camera's color characteristics may be more optimal, or the particular combination of existing light sources may be easier to manage at a selected color temperature.
- Reading foot-candles (or lux) and giving exposure.

COLORED LIGHT

For a more complete palette of tints and saturated colors, full-color LED lights and theatrical gels offer a vast array of alternative possibilities. Theatrical gels come in more than 400 shades. Many of them can be replicated on a full-color LED in Gel Mode by selecting the Lee or Rosco gel number from the menu. (This is just one of the ways colors can be selected on LEDs. See Chapter 7.)

When selecting colors, the DP and gaffer need to take into account how colors will interact with the camera sensor. Often colors are not captured quite as they appear to the eye. The saturation of colored light tends to be exaggerated when photographed, and dialing down the saturation may give a better rendering on camera.

Before using colored light, consider how it will interact with the pigments of the wardrobe and set. The color of the light mixes subtractively with these colors, meaning that only the hues that are shared by the light and the object are reflected. Shining red light on the green object, almost nothing will be reflected back, and the object will appear muddy. The best way to judge exactly what a tint will do on a particular costume, paint color, or skin tone is to shoot a test. A test is also the best way to compare the effects of several possible tints side by side.

LED full-color

Full-color LEDs achieve a wide gamut of colors by mixing LED emitters that are pure colors in with white emitters. Colored emitters are usually red, green, and blue, but sometimes other colors as well such as amber, lime, and rose. If we plot the colors of the red, green, and blue emitters on a CIE chromaticity diagram, they form a triangle that defines all the colors that the light is capable of achieving. The triangle does not cover all of human visual perception, but it often covers more than the gamut of an HD camera. Colors that are outside of the gamut of the camera are represented as the same hue, but are limited in saturation to the maximum provided by the camera and display. See Chapter 21 for more about color gamut of cameras.

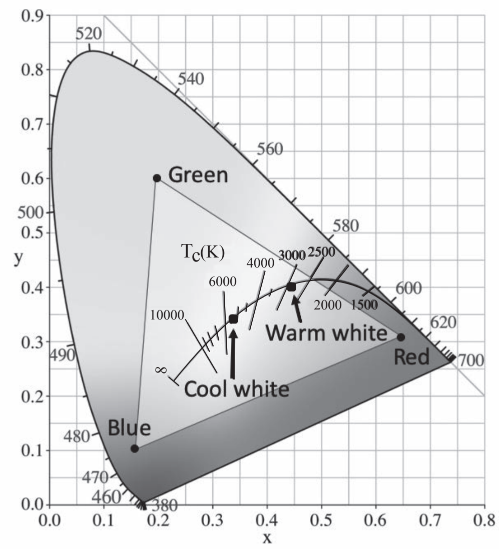


FIGURE 6.6

Red, blue, green, warm white, and cool white color points plotted on a CIE chromaticity diagram. The primary color points define the color gamut of the light fixture.

Red, green, and blue are foundational both for human vision and for photography. These are the colors that camera and display systems are built around. The photoreceptors in the eye sense the amount of each of these colors in our surroundings and the mind perceives the spectral mix as millions of colors. The same is true of cameras. They reproduce colors by sensing the amount of red, green, and blue in each pixel of the image. The appearance of a color is a combination of its hue and the saturation. A saturated color is a spike at one wavelength, whereas a less saturated version of the same hue contains a larger proportion of white light. A color becomes more pastel as it is desaturated.

Theatrical gels

Colored gel, also called *effects gels* or *party gels*, comes in 20″ × 24″ sheets or 4′ × 25′ rolls. The DP can choose from dozens of warming shades, such as gold, amber, straw, fire, salmon, pink, rose, apricot, and so on. *Cosmetic colors*, used primarily in theater productions, combine a slight diffusion with colors that are intended to enhance skin tones: cosmetic peach, burgundy, rose, rouge, and so forth. Colors such as salmon, pink, and chocolate are also used to enhance skin tones. Straw and bastard amber often simulate a low afternoon sun or a flame.

CHAPTER

7 LED lights

CAPABILITIES OF LEDS

LEDs are the most recent addition to the lighting arsenal. In the space of about 10 years, LEDs developed from a promising yet limited new light source to becoming the dominant technology taking over and completely changing many aspects of lighting. There are many factors that contribute to the spread of LED lights. Rapid year-over-year improvements to LED emitters and phosphors have increased brightness and consumer confidence in color rendering (although there can still be big differences in color rendering between lights).

Perhaps the greatest driving force behind rapid acceptance in the market was the promise of remote control of color and intensity. The light is entirely solid state, so controlling the electronics via a digital control network is straightforward. Dimming provides a wide range of intensity levels without the same color changes as tungsten lights. Adjusting color temperature, and, for full-spectrum lights, generating pastels and saturated colors can be done from the lighting console or from an app as well as from the back of the fixture. Remote control offers DPs greater ability to tweak the lighting without the penalty of the technician having to get to the light (bring in a ladder, move the furniture out of the way, etc.). Full-color LEDs provide an easy way to punch up convincing, ready-made, lighting effects. DPs and gaffers are dreaming up all kinds of ways to harness the technology to design lighting effects that propel the drama in ways that have never been done before, or execute effects that would have been very complicated to pull off in the past.

Lower power demand is another advantage. We now have LEDs as bright as a 10k that can plug into a standard household outlet. Coming at the same time as substantial increases in camera sensor sensitivity, the power demand of a small lighting package can fit easily onto a few 20 A circuits, potentially reducing the size of the needed electrical power distribution system, reducing the need for external dimmers, big cable, and the associated labor (see Chapter 18, “Power sources”). Many small and medium-sized LEDs can be battery powered. Add wireless control, and you have a light that can be flown in on a moment’s notice without any cables.

LEDs are generally lighter, slimmer, cooler, and easier to handle than tungsten and HMIs, although there currently are no LEDs that compete with the biggest and brightest tungsten and HMIs. Depending on the electronics used to drive and dim the LEDs, the lights can be designed to be flicker-free up to very high frame rates. Most LED lights developed for professional motion picture photography are flicker-free up to 1000 fps and higher or can be set to operate in a flicker-free mode. (There are exceptions to be aware of. Always check the manufacturer’s documentation.) In these key ways, LED lights have changed expectations: they have changed what DPs expect from the lighting crew, and what producers and directors expect from DPs.

To reap these benefits, however, the responsibility falls to the lighting crew to operate these lights, which can be quite complex. There is also a corresponding increase in the sophistication of the control console and the programmer who operates it. Operating and troubleshooting wired and wireless control networks is now an essential skill for every lighting technician. For the gaffer and DP, there are new challenges to ensure that colors and skin tones are rendered and recorded accurately and that light sources match each other. (See also Chapter 21, “LED color science and technology”).[1]

LEDs are now used in every category of fixture (form factor) and many new forms besides.

Panels (softlights)
Small hand lights/ENG camera-mounted
Ringlights
Flashlights
Ribbon
Narrow-beam punch lights
Cyc lights color washes
Architectural washes
Fresnels
Ellipsoidal spotlights
Dedolights
Space lights
Automated lights
Balloon lights
Underwater lights
Tubes
Pixel tubes
Pixel tape
Pixel screens

We’ll discuss specific lights and their features later in this chapter, but first let’s take a moment to go over some general characteristics of LEDs, starting with color and dimming.

COLOR OPTIONS

By itself, a light emitting diode produces one color in a narrow spectral range. There are two ways an LED can then make usable broad-spectrum, white light: by passing the light through a phosphor layer to shift and spread it out, or by combining different colored LEDs into one fixture and producing white light through additive color mixing. Most full-color lights combine both approaches.

Phosphor white, daylight, or tungsten

A phosphor-based “white” LED comprises a die (diode chip) that emits blue light (450 nm), covered by a phosphor coating. A portion of the blue light activates the phosphor layer, which spreads the spectrum from shorter wavelengths to longer ones (Figure 7.1). Depending on the chemistry of the phosphor used, the color balance of the resulting light can be correlated to “daylight” (somewhere in the range from 5200 K to 6000 K) or stretched closer to a “tungsten” color balance (3200 K).

Lights that use a single phosphor LED and have a fixed color temperature have the benefit of greater light output per watt than bi-color types since all the LEDs serve a single purpose. Brightness is often most crucial when shooting outdoors, so single-color LEDs tend to be daylight balanced. Also, lights like Nila’s Boxer and Varsa heads, which are very bright and flicker free up to very high frame

[1] We are ignoring the challenge of cost. New and advancing technology always requires significant investment by manufacturers, rental houses, and equipment owners. Production companies resist increasing their budget for what they see as the same result. The accountant is unaware of, and unable to tally, gains in production efficiency which, while incremental and largely invisible, have been very significant.

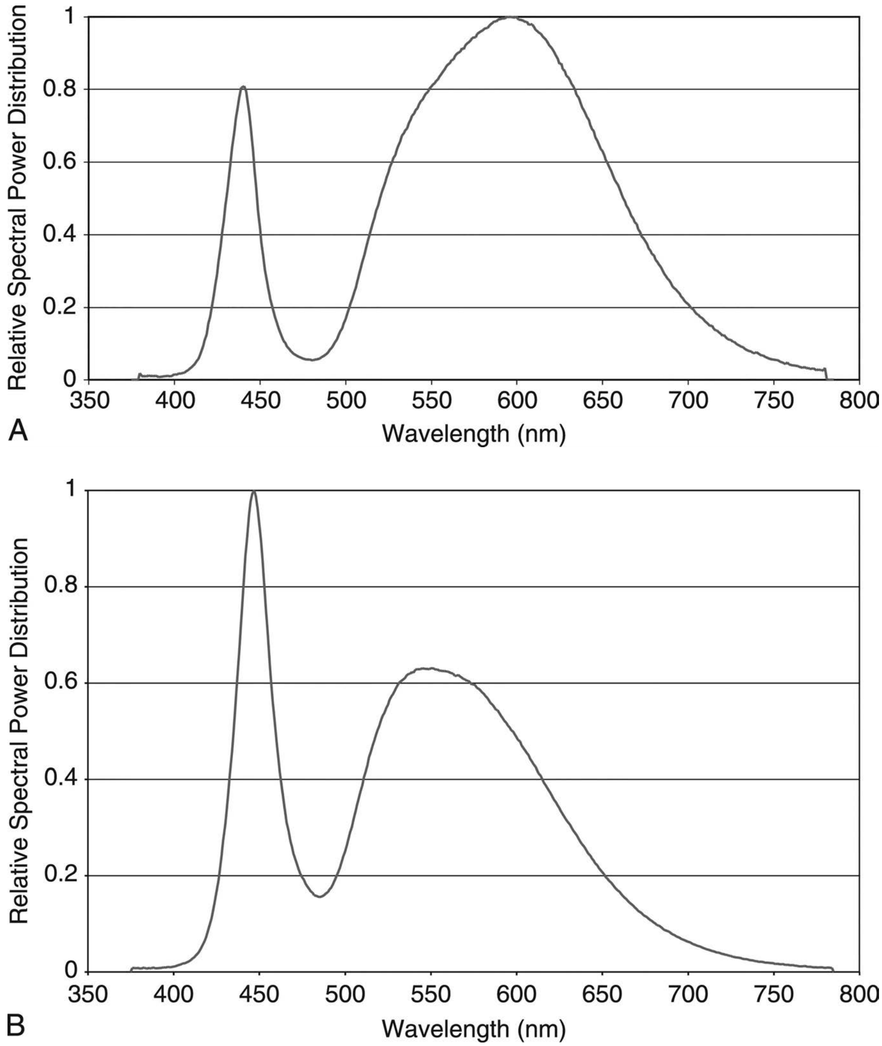


FIGURE 7.1

Spectral power distribution phosphor-based white LEDs. (A) 3200 K LED, (B) 5600 K. Notice a big spike at about 465 nm, the blue hump color, and a broader hump between 500 and 700 nm, produced by the phosphors.

rates, are ideal for extreme slow-motion photography. Nila's lights are tested to be flicker free at any frame rate at 100 percent output and up to 5000 fps when dimmed.

Many manufacturers have single-color versions and bi-color versions of their lights. The single-color version is more cost effective for applications where the light will mostly perform one function, such as in a permanent rig in a studio. Examples are given in Table H.1 in Appendix H.

FIGURE 7.2

The 200 W Nila Boxer is capable of light output comparable to an 800 W HMI. It comes with a set of spreader lenses 10°, 20°, 40°, 60°, 80°, and oval 60° × 10°.

(*Courtesy Nila*)

Remote phosphor

With a single phosphor-based light, changing its color temperature involves gelling the light. There is a more efficient way to shift a phosphor LED's color temperature. Instead of having a phosphor layer built into each LED emitter, the phosphor layer is embedded into separate, interchangeable phosphor sheets. The user selects the color temperature by installing the appropriate phosphor sheet (Figure 7.3), which slides into a slot directly in front of the emitters. This approach can yield greater light output than other white light designs, without any sacrifice in color rendering. See Table H.2 in Appendix H for examples.

Bi-color

A bi-color fixture simply crossfades between cool-balanced LEDs and warm-balanced LEDs to achieve a range of color temperatures through additive color mixing. DPs commonly want warmer or cooler (yellower or bluer) light to suggest different motivating sources and to create subtle color contrast. The lighting technician can just adjust color temperature with a knob (Figure 7.4). See Tables H.3 and H.4 in Appendix H for examples.

FIGURE 7.3

Cineo Maverick fixture is available in phosphor sheets: 2700 K, 3200 K, 4300 K, 5600 K, 6500 K, chroma blue, and green.

(*Courtesy Cineo Lighting*)

FIGURE 7.4

LitePanels's Astra. Top knob selects CCT; the other knob dials in intensity.

The reasons behind tunable-white and full-spectrum lights

At their best, phosphor-based chips can achieve good color rendering and high scores on various color rendering indexes. However, there are a number of reasons that it may be desirable for a light to have a broader range of color control possibilities.

- Any LED that relies on two white phosphor LEDs to create color temperatures between daylight and tungsten introduces a slight shift toward magenta in the middle of the range (Figure 7.5). Adding green LEDs to the mix enables the light to compensate as necessary to stay on the black body locus.
- With a single-chip or bi-color LED, the color rendering is dependent on each chip having consistently excellent color qualities. These chips are the crème de la crème of LED chips and manufacturers charge a premium for them. When light manufacturers use more affordable chips, color can vary noticeably from one light to another. If the light can be calibrated, the light manufacturer can use less exacting white chips and achieve consistency at lower cost.
- Depending on the electronics, some lights need to compensate for color shifts associated with dimming.
- White phosphor LEDs are weakest at the longest wavelengths. Adding amber and red LEDs to the mix enhances color rendering. Adding green and blue LEDs strengthens the blue-green hues, which also enhances the reds because blue-green tones are the complement of red-orange ones.

Color tuning can be implemented different ways. A *tunable white* light, like the Cineo LightBlade or any of the Mole Vari-series Fresnels and space lights, has a base of bi-color phosphor emitters and adds enough of specific colored emitters to tune the magenta/green output. Lights like the ETC Source Four Daylight HD (4000 to 6500 K) and Tungsten HD (2700 to 4500 K) focus on a particular segment of the color temperature scale and use a mix of LEDs to achieve very high color rendering and lumen output with the ability to create tints that can be tailored for a given skin tone.

Full spectrum

Full spectrum lights use a complex color system to achieve a broad gamut of colors including a wider range of CCT whites as well as pastels and saturated colors. Table 7.1 shows a few of the LED combinations that are used for color systems in lights. Tables H.5 and H.6 in Appendix H give some examples of full-spectrum lights.

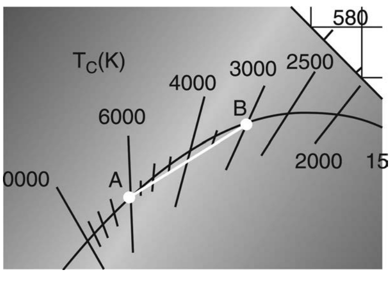


FIGURE 7.5

A bi-color LED achieves variable CCT along a straight line that connects the color points of the two emitter colors (A and B). Because the locus is not a straight line, it is not possible to track the locus using only two color illuminants.

Table 7.1 Combinations of LED emitters used for color system in lights

LED colors		Characteristics
Phosphor daylight and tungsten		Bi-color correlated color temperature (CCT). Example: Aladdin Base Lite.
R, G, B	red, green, blue	Saturated colors (does not render whites well). Theatrical applications.
R, G, B, W	red, green, blue, white	CCT, G/M tunable white, saturated colors. Example: ARRI SkyPanel, Digital Sputnik DS-1.
R, G, B, A, W	red, green, blue, amber	CCT, G/M, tunable white with extended warm white/amber range, saturated colors. Example: Creamsource Sky.
R, G, B, CW, WW	red, green, blue, cool white, warm white	Broad CCT spectrum, G/M, tunable white. Saturated colors. Example: Kino Flo FreeStyle.
R, G, LG, B, W, A	phosphor red, green, phosphor lime green, blue, white (4000 K), amber	CCT, G/M, tunable white, saturated colors. The phosphor lime green enhances blue/green and increases efficiency/output. The phosphor red produces a wider spectrum in the reds. Example: DMG Lumière Mix.
R, RR, G, LG, B, W, A	red, rose red, green, lime green, blue, white, amber	CCT, G/M, tunable white, saturated colors. Rose red and orange/red LEDs enable more refined straws and pinks and increase output. Example: ETC Series 2 Lustr.

LED COLOR CONTROL METHODS

With full-color LEDs having such a large pallet of available color options, the design of the user interface is crucial. For the lighting technician it must be easy and intuitive to operate, for the lighting console operator it must be easy to program, and for the gaffer and DP it needs to make colors easy to identify, match, and tweak as necessary. Figure 7.6 shows one example, the on-board control interface used on Kino Flo's full-color LEDs.

LEDs generally use one or more of the operation modes given in Table 7.2. On feature-rich lights, the user can create or tweak a color and then save the new color to memory, name it, and load the color presets into other lights.

Figures 7.7–7.12 provide a little more context for Table 7.2.

It is worth noting that there are significant differences in the ways that different LED manufacturers have developed their color science. Color rendering is discussed in Chapter 21. It is too complex a topic to go into here, except to note that some manufacturers have developed advanced features in their full-color lights to address some of these issues. For example, Kino Flo conducted significant research into the differences between cameras' color sensitivities that enabled them to develop lighting LUTs. On the controller, the user can select the camera profile they are using from a menu on the light's

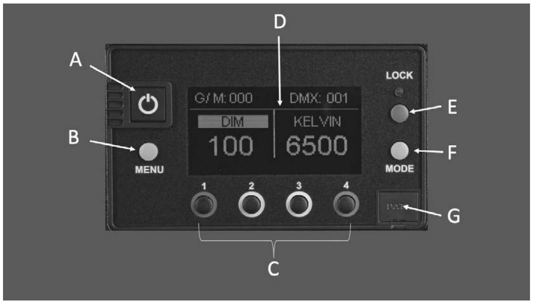


FIGURE 7.6

The manual controls and display of the Kino Flo FreeStyle LED DMX Controller. The primary control knob on the side of the controller (not shown) is used to set intensity, Kelvin color temp, and green/magenta. (A) The ON/OFF button turns the emitters on and off (the control panel is always ON). (B) Menu button accesses menu options for general settings, DMX, DMX Wireless settings, and Reset panel. (C) Preset buttons. (D) Display shows dimmer setting and the Kelvin color temperature as well as the green/magenta shift, and DMX address. (E) Lock disables the control knob and all buttons to prevent settings from being changed inadvertently. (F) Mode button selects the function of the control knob and highlights it (Dim, Kelvin, G/M or DMX address). (G) Mini USB for firmware updates, bias, and DMX address. Press the knob to toggle between course and fine adjustments.

(*Courtesy Kino Flo, Inc.*)

Table 7.2 SkyPanel modes from the fixture interface (Firmware 4.4)

Mode	Description	Application
CCT (correlated color temperature)	Two parameters: one adjusts the color temperature, from 2800 K to 6500 K for example; the other adjusts the magenta/ green shift. Figure 7.7.	Enables tweaking white to match to the sensitivity of a particular camera or to match color with sources, e.g., a green fluorescent look.
Gel colors	Input Lee or Rosco gel numbers and source color temperature. Figure 7.8.	Emulates work method for gaffers/DPs to specify familiar gel numbers.
XY color coordinates	X and Y coordinates define specific color values within the CIE XYZ color space. Figures 7.9 and 7.10.	Enables matching a color from any source by determining its x and y color coordinates using a spectrometer and setting those coordinates in the light.
HSI (hue, saturation, intensity)	Starting with the existing color, adjust the hue and add or subtract saturation with separate controls. Figure 7.11.	Find a color you like in an intuitive way. Tweak colors by eye or to camera. Reduce oversaturated colors without affecting hue or intensity.
Discrete color channels, e.g., RGBW	Controls each LED color circuit directly (red, green, blue, etc.) from 0 to 100. Figure 7.12.	This is not an intuitive way to create a color you are after, but it is a simple mode for use with a basic dimmer board and uses a minimal number of channels.
Colors based on real-world sources	Enables user to select from a list of different light sources like cool white fluorescent, overcast sky, sodium streetlight, warm antique bulb, etc. The light emulates the spectrum associated with that source.	This is a helpful short-hand for getting quickly to a particular look.

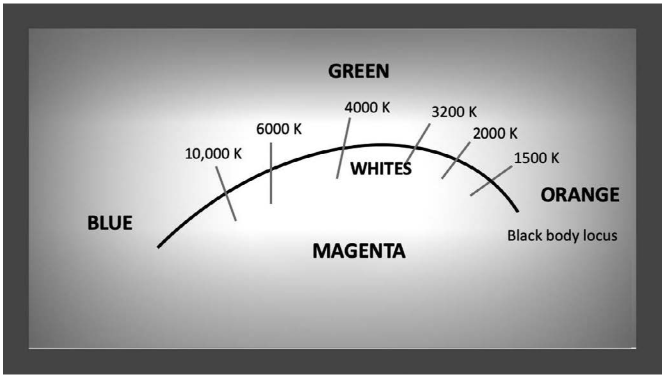


FIGURE 7.7

CCT color adjustment has two parameters: Kelvin color (blue/orange following black body locus) and green/magenta adjustment (at right angles to the black body locus).

FIGURE 7.8

The control panel of a Kino Flo ballast in Gel color mode—in this case Lee 42 Loving Amber. Take note that the Kelvin setting here is 6500 K, meaning that the light's color will be equivalent to a 6500 K light source with #42 Loving Amber gel applied to it. Frequently used colors can also be stored in the presets (labeled 1–4) for quick recall. Note that this fixture also shows the hue, 014° R, and saturation, 034 (or 34 percent) associated with 6500 K + #42 gel.

(*Courtesy Kino Flo, Inc.*)

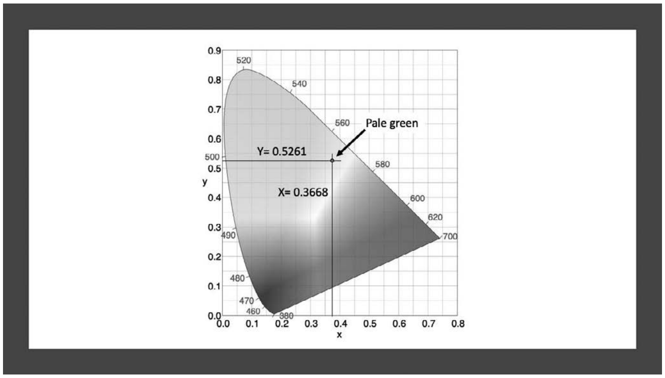


FIGURE 7.9

The x, y color coordinates refer to specific color points in the CIE 1931 chromaticity diagram. The x, y coordinate of any source can be measured using a spectrometer and matched (see Figure 7.10).

FIGURE 7.10

The x, y coordinates on control panel of an ARRI SkyPanel.

controller unit. The profile helps ensure the white point of the light output is as close a match as possible to the sensitivity of the camera. Another example, ARRI, LiteGear, and Kino Flo (and there may be others) developed ways to avoid creating out-of-gamut colors by restricting the light's color output to Rec. 709 or Rec. 2020. See Chapter 21.

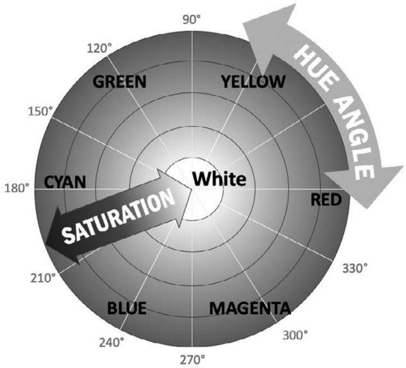


FIGURE 7.11

HSI (hue, saturation, intensity) has three parameters, hue angle (0°–360°), saturation (percentage), and intensity (percentage). HSI colors are arranged around the outside of a circle, with white light making up the center. The hue angle defines the color; saturation defines the amount of white that is mixed into the color. At low saturation the color is a tint; the higher the saturation value, the closer the light becomes to pure color. This way a specific color can be identified by hue angle and saturation.

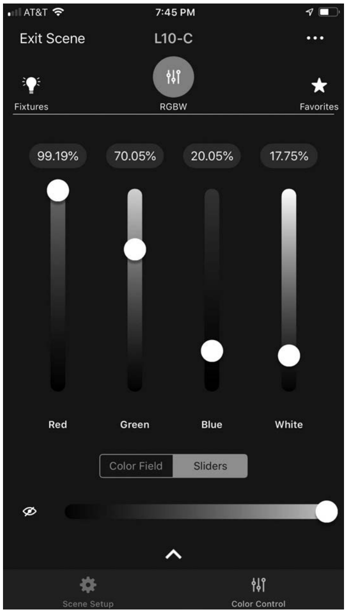


FIGURE 7.12

RGBW color mixing on the ARRI Stellar app. By varying the relative amount of red, green, and blue, various colors can be achieved. The mix shown here produces a pale gold. Raising the white channel decreases saturation. On the app, once a color is mixed, it can be dimmed using the slider at the bottom. Without this slider, maintaining the color mix while dimming is extremely difficult.

LIGHTING EFFECTS

An innate quality of LEDs is that, when an emitter is switched on and off, the response is instantaneous; there is no lag or delay as there is with a tungsten light and no ignition and warm-up as there is with an HMI. When an LED is assigned a new dimmer level, the effect can be immediate or it can have a programmed fade to simulate any real-world light source. In combination with full-color control, this is a powerful tool for creating very precise lighting effects. It can even be programmed to simulate the characteristics of a tungsten light. For example, the fade-to-warm effect was created to match the familiar and evocative feeling of a theatrical fade-out.

The more sophisticated full-color lights have a built-in menu of lighting effects (see sidebar). Manufacturers have had fun fine-tuning these built-in programs. For example, Kino Flo units not only provide a candlelight effect, but also candle in a breeze, candle in a still room. TV effects include movie, music video, and sports, which each simulate the color, pace, and changes in brightness associated with different types of programming. Not to take all the fun away from the lighting crew, the programs are all tweakable to make them faster or slower, or create bigger or smaller level changes, different colors, and so on. As an example, SkyPanel's current menu of available lighting effects are listed in the sidebar.

EXAMPLE EFFECTS MENU (SKYPANEL FIRMWARE 4.1)

- Candle
- Clouds Passing
- Club Lights
- Color Chase
- Cop Car
- Explosion
- Fire
- Fireworks
- Fluorescent Flicker
- Light Strobe
- Lightning
- Paparazzi
- Party
- Process
- Pulsing
- Television
- Welding

DIMMING LEDS

Dimming curves

Dimming response refers to how change in brightness corresponds to change of input value. A light with a *linear* dimming curve theoretically reduces intensity by half (one stop) when dimmed from 100 percent to 50 percent, and another stop when dimmed from 50 percent to 25 percent, and so on. As you can see, the relationship between stops and percentage points on the controller changes throughout the range. So, when a gaffer or DP is trying to set a certain brightness, and needs a ¼ stop more light, there's no knowing how many points that is; could be two points more or ten points more. It is largely trial and error. There are many electronic design variables that affect the dimming characteristics of LEDs. For the user, it comes down to getting familiar with the characteristics of the lights you have.

There is no fix for this, but some lights have selectable dimming profiles (Figure 7.13) that allow the user to choose to have a finer, more gradual response in a selected portion of the dimming range in exchange for a more abrupt response in other parts. If you tend to work in a certain segment of the dimming range you may want the greatest resolution in that range so you can precisely set levels. There are other reasons you might want to select a certain dimmer response. For example, the DP may want less abruptness in the end of a fadeout, or may want to match the dimmer response of LED lights with that of tungsten lights operating on SCR (silicon controlled rectifier) dimmers so that a fade-up or fade-out happens in unison. The dimmer response also affects how dynamic lighting effects appear. For example, a TV flicker effect will appear less dynamic if a flatter dimmer response has been set.

ARRI calls their dimming curves *linear*, *exponential*, *logarithmic*, and *"S" curve*. Linear is a proportional relationship between intensity and input value. Exponential (the default setting) provides higher resolution (flatter response) in the lower intensity levels. Logarithmic provides higher resolution near the top of the intensity range. "S" curve gives highest resolution at the top and the bottom of the dim range, with more abrupt change in intensity in the middle of the dim range.

There are other dimmer curve types that have their origins in conventional SCR dimmer response (see Chapter 15). For example, *square law*, which has more resolution between 55 percent and 15 percent, is meant to appear more natural to the human eye. Because our eyes dilate when light level decreases, we actually experience a flatter response to light level changes. Square law appears on camera (which does not dilate) more like how we experience a given change in light level.

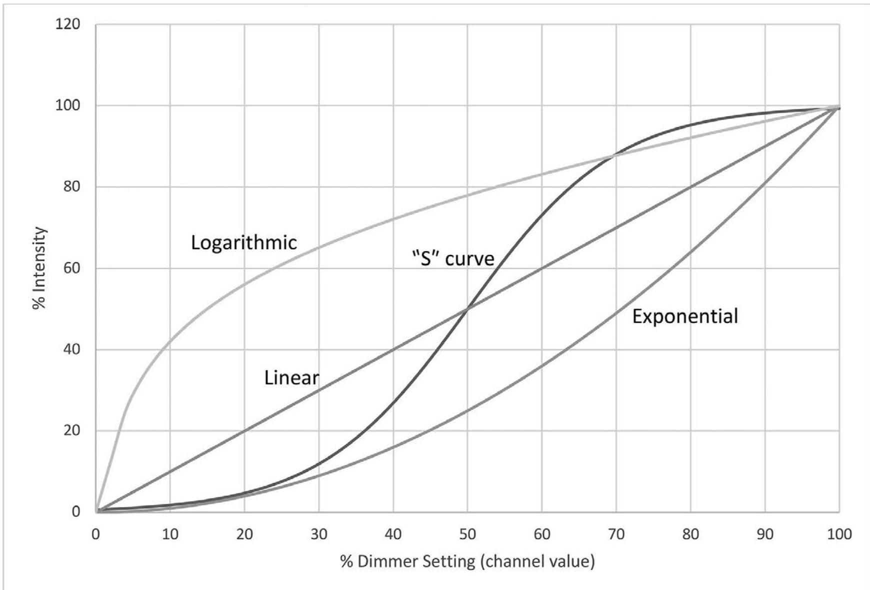


FIGURE 7.13

Dimming curves. Note: this graph is intended to illustrate the concept only. These are not the dimming curves of an actual light.

Bottom of the dimmer range

We have transitioned to a new mode of operation where the dimmer is simply dialed up or down as needed, and the consequence is often that LEDs are used at very low dimmer settings. There are notable downsides to this. Most manufacturers will tell you, below 10 percent on the dimmer, color becomes very challenging to manage. The manufacturer's advertised color rendering measurements are taken at the light's optimal performance, at 100 percent. Maintaining color quality at low dim levels is complex because dimming changes the temperature, which affects different color LEDs at different rates (among other factors).

In addition, if you are operating a light only in the bottom third of its dimmable range, you are left with one-third of the dimmer resolution. Fades cannot be as smooth and can appear quite abrupt. With some LEDs you can improve the smoothness of fades by selecting different control parameters (16-bit dimming rather than 8-bit, Low End Mode, exponential or S-curve dimming law), but it may be a better idea to set the light at a higher dimmer setting and compensate by using thicker diffusion, or cover the face of the light with ND gel or a double layer of bobbinet, for example.

Dimming out to zero is a challenge for many LED controllers. They tend to blink out once they get close to zero. This is a product of how the dimming circuitry is arranged. For more about LED dimming and possible flicker issues see Chapter 21.

THE SEVEN THINGS EVERY LIGHTING TECHNICIAN SHOULD KNOW ABOUT LEDS

With so many different types of LEDs and each one doing things somewhat differently, it is more of a challenge for lighting technicians to be intimately familiar with every light that may show up on set. It is good practice to download the operation manuals for any complex lights used on set. Place the manuals on an iPad or in a binder and make them available for any technician or day-player who comes on set.

A technician, working on a new show, should assess whether there is any technology he or she isn't familiar with. Here's some of the most important items a gaffer will expect lighting technicians to know. There are seven—like the deadly sins. Not all of the following is applicable to every light.

1. **Basic operation**. Know how to turn the light on, turn it off, dim it, and adjust color. Most controls are fairly intuitive to figure out; it just takes a little practice. The most important thing is to engage, satisfy your curiosity, read, experiment, become an expert.
2. **DMX**. Know how to set up the light for wireless and wired DMX operation. DMX control has become so commonplace, it is essential, day-one knowledge. Know how to set the DMX address. Know what control mode is being used on set and be able to set up any light in the inventory. Most DMX devices have an indicator light to show if they are receiving data. For example, the ARRI SkyPanel's DATA light will be blue to show a valid DMX signal, or another color to show Art-Net, sACN signal, or lead/follow mode. If it is red there is a signal but no communication. No light means no data signal.

3. **Reset and Setup**. When new lights are received from a supplier, it is important to *reset* the fixture to its factory default settings. This dumps any unexpected fixture settings and color presets saved by the previous user. Fixture settings may include any number of things that will change the behavior of the light. Dimmer law, for example, can drastically change the intensity associated with a given dimmer level from one light to another. To avoid unexpected behavior, reset lights when they arrive from the rental house or studio lamp doc. Then load the show's fixture settings and any desired color presets that are to be used frequently on your production.
4. **Tungsten/Daylight**. When working in gel mode, be sure the correct type of source is selected. Adding 179 Chrome Orange to a tungsten light looks quite different than adding it to a daylight source, for example.
5. **Lock (and other gotchas)**. To prevent settings from being changed unintentionally, some lights can be locked, which disables the controls. To avoid embarrassment and delay, make a note of how to get in and out of lock mode. Similarly, be sure you know how to back out of the menu.
6. **Accessories**. Be familiar with all the accessories that come with the light, how they are used, and where they are stored. Accessories include alternative power supplies or control add-ons, cables, mounting hardware, handles, battery mounts, as well as diffusers, egg crates, soft boxes, and sometimes lens sets and barn doors.
7. **Kryptonite to LEDs**. Heat, water, and rough handling can be deadly to LEDs. Excessive heat can prematurely age the emitters very quickly. Many LED fixtures provide safeguards against overtemperature situations by automatically increasing the speed of a cooling fan (if it has active cooling) or by automatically reducing power or shutting off altogether if the light approaches redline. This is the manufacturer's way of drawing your attention to the heat issue, so you can change what is making it overheat, like poor ventilation or intense direct sunlight. You need to be able to identify control panel indications and light behaviors for an overtemp condition. For example, the ARRI SkyPanel shows a flashing red or solid red status LED if the fixture is overheating. Unless the light is waterproof (IP65 or higher), it probably provides little or no protection against water. Water can destroy LED printed circuits and connections, taking the light out of service for an expensive repair. Lastly, when LED fixtures are stored, transported, and handled, you want to protect vulnerable parts. The face of a panel light, for example, contains diode chips and printed circuits; you don't want to stack lights on top of one another in such a way that anything comes into contact with those parts.

Control

In addition to manual control on the back of the fixture, there are a wide variety of remote control options, from a wired dedicated remote accessory (Figure 7.14), to IR, and Bluetooth. Short range controllers are actually super useful for controlling a light on a stand or in a rig where the light is in close proximity, but out of reach.

Of course, almost all LED lights can also be connected directly to a control network (via DMX, wireless DMX, or an Ethernet protocol) and controlled from a console or app. Control networks are

FIGURE 7.14

ARRI SkyPanel wired remote.

covered in Chapter 12. Light manufacturers have found that they can vastly simplify the operation of complex lights by creating their own app for it. Apps like ARRI's Stellar, DMG Lumière's MyMIX LED, and others are designed to be intuitive and to add additional value and features to the lights. For example, Digital Sputnik's DS Voyager Controller app enables the use of graphics in pixel mapping their Voyager tubes. This opens a world of options for creative lighting effects because the user can use their own content, graphics, and videos to generate lighting effects. (For more on pixel mapping see Chapter 12.)

SOFT LIGHT FIXTURES

An LED panel creates soft light using an array of LED emitters, equally spaced over a relatively large surface area. Panels often incorporate a diffusion layer to blend together the multiple emitters into one large, even source. Lights that have closely spaced emitters can produce blended light even without diffusion, a phenomenon called *multi-point soft light.* The light does not show multiple shadows.

There is a wide variety of available panel and tube fixtures. It may be helpful to break them down by functionality and application.

Rigging versatility with lightweight softlights

Fixtures designed to be easy to rig are lightweight and use a separate controller/power supply, so are still easy to control when rigged out of reach. Rather than using a clunky yoke, these fixtures can be supported by a center back-plate with a ball-mount. Kino Flo, who originally pioneered using ball-mounts and egg crates on their lightweight fluorescent fixtures (Figure 7.15), designed them for attachment to a C-stand grip head. Today their lights (Figure 7.16), and those of others, have interchangeable mounting parts including a goose neck for use with a regular baby stand and a handle for hand-held operation. Modular systems, like the Rosco's DMG Switch light (bi-color) and Mix (full color, Figure 7.17), is similarly adaptable to be supported a variety of ways.

LEDs like LiteGear's LiteMat products go even further to minimize weight and profile (Figure 7.18). The structure of LiteMat fixtures is corrugated polypropylene material. They feature a snap-on back-mounting plate for attachment to a C-stand, but because the fixtures are lightweight, they can also be taped, screwed, or stapled to a wall or ceiling. You can easily arm a light out on the C-stand. The LiteMat can literally be hung on an existing picture hook on a wall or suspended from a drop-ceiling or existing chandelier. In sensitive locations, like historic buildings, lights can be hung without heavy stands and grip rigging.

The LiteTile Plus 4, 8, and 10 is a versatile system that can create a powerful wall of light practically any size. The LED engines are mounted to a foldable fabric, which takes up almost no space (Figure 7.19). Finished with Velcro at the edges, LiteTiles are designed to attach, or "tile," together into any shape and size. The controller is designed with a lead/follow arrangement, so no matter how many are tiled together, they can be controlled as a single unit. LiteTiles fold flat for storage and transport.

FIGURE 7.15

Four-foot Kino Flo fixtures hung on a pipe in a practical location. Fluorescent fixtures can be fitted with tubes having a variety of color temperatures, or with party colors, blacklight, or with matte color compatible single-wavelength blue and green output.

(*Courtesy Kino Flo, Inc.*)

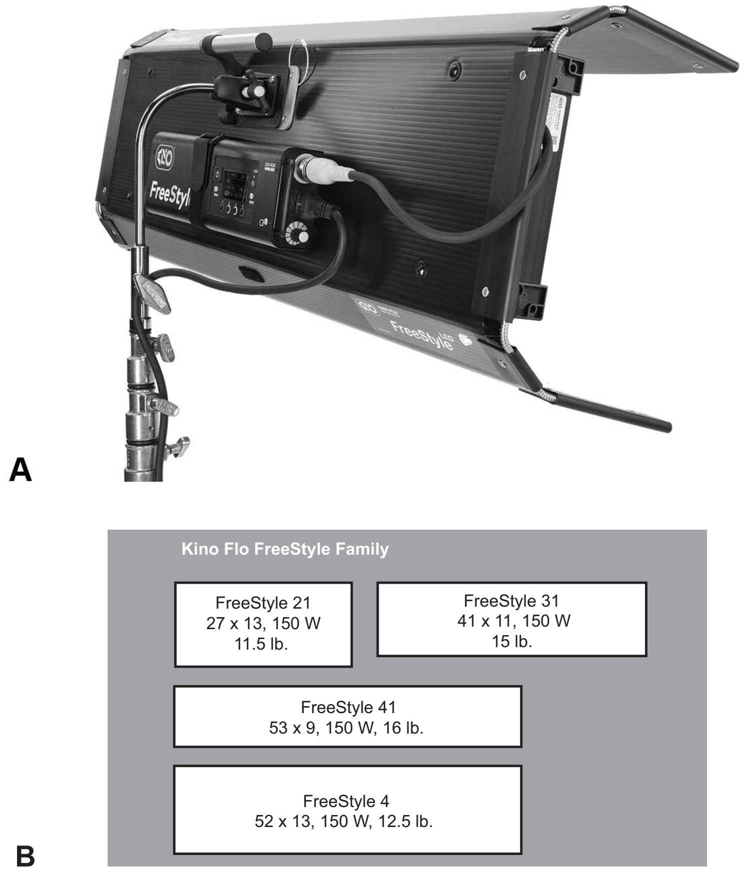


FIGURE 7.16

(A) FreeStyle 31 (backview). The FreeStyle series are full-color fixtures using Kino Flo's True Match® color management system (full color, 2500–9900 K). The LED panel has a quick release to remove it from the fixture/barn doors for versatility in rigging. The separate ballast can be mounted to the back of the fixture or hung or mounted to the stand. (B) FreeStyle family.

(*Courtesy Kino Flo, Inc.*)

Small "face" lights

When working in close, often a low wattage, 1- to 2-ft. diameter softlight is all that's needed. In this situation it is often more ideal to have a fixture that is self-contained, with an onboard power supply and manual controls, silent (passive cooling), and have very good color rendering. Many lights this size are easy to power from a battery and have a full complement of softlight accessories. Interchangeable

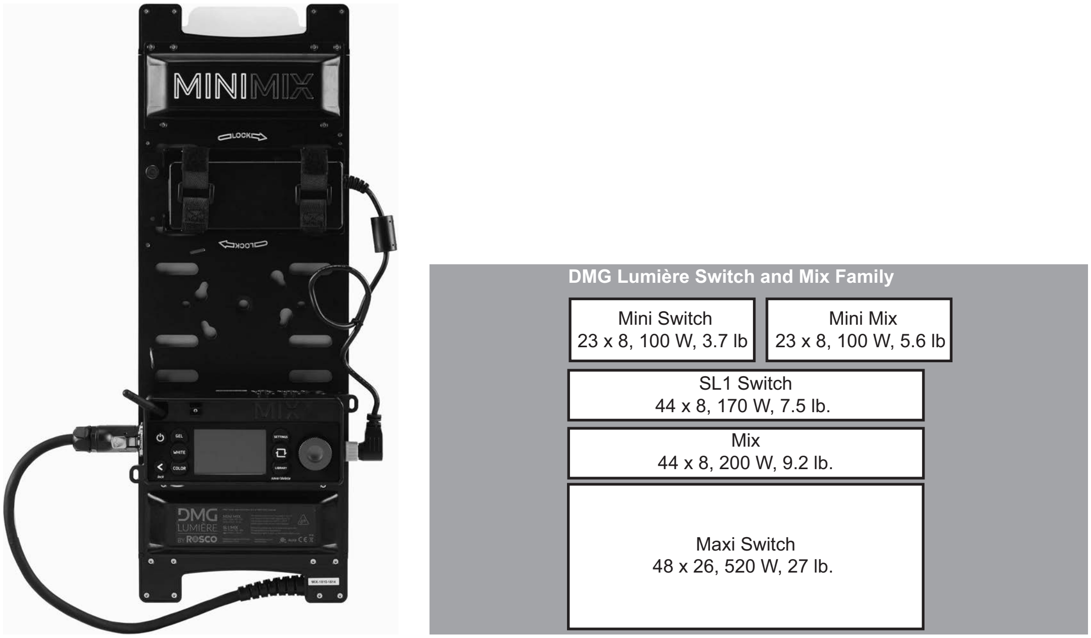


FIGURE 7.17

(A) Mix (back view) from DMG Lumière (by Rosco). (B) The Switch and Mix family are known for their color rendering, versatility and range (Switch 3000–5600 K, Mix 1700–10,000 K). The rigid aluminum housing is a mere ¾ inch deep and provides a twist/snap system for attachment of handles, mounting hardware, battery and power supply as needed for the situation. For run and gun handheld operation, the power supply and battery lock together and are worn with a shoulder strap.

(*Courtesy DMG Lumière and Rosco, Inc.*)

diffusion panels, snapgrids, Chimera bags, fabric egg crates, and barn doors are fairly standard control accessories (Figures 7.20–7.22).

Larger full-featured heads

Kino Flo Celeb family include bigger, more powerful sizes with the same full-featured, full-color control (Figure 7.23).

Metal lights that have a rigorous heat management system, like the ARRI SkyPanel, are necessarily a bit heavier and bulkier, but a large heatsink enables a whole lot more brightness, combined with color-accuracy, durability, long LED life, and long-term reliability (Figures 7.24–7.25).

Green/blue screens, backings, and translights

Lights that are capable of pure green and blue colors are ideal for saturating the matte color, whereas a tungsten or daylight source creates a certain amount of color contamination. If the screen can be lit separately from the action, lighting with saturated colors is preferable. Large, soft sources help light the

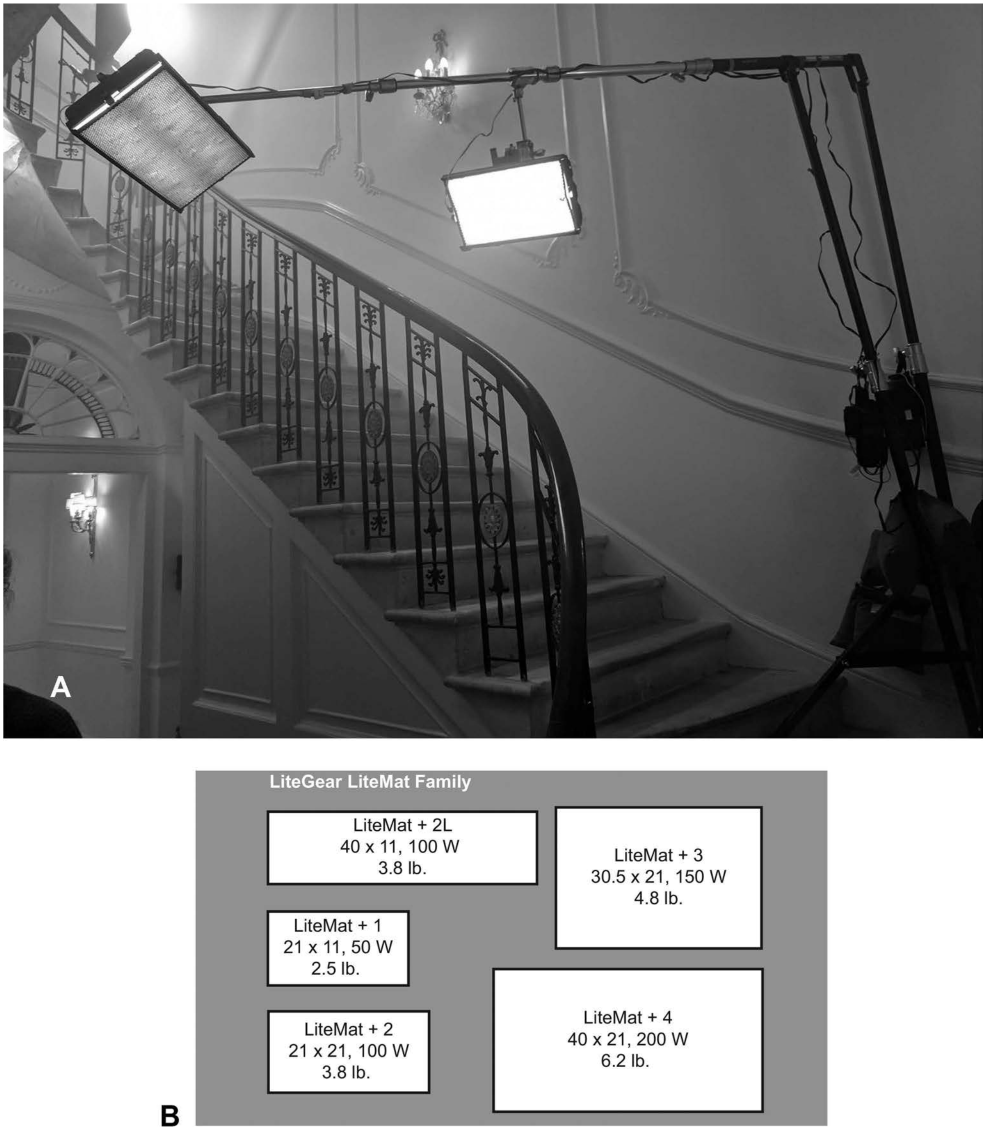


FIGURE 7.18

(A) Two lightweight LiteMat fixtures rigged on a menace arm. (B) LiteMat family are durable, 1-in. thick, color correct bi-color (2600–6200 K). Fixtures can be taped to the wall or ceiling. Features a center-mounted back plate that adapts to a number of mounting options including ball-mount ⅜-in. pin for mounting to a C-stand gobo arm or for mounting the power supply/battery to the light for hand-held use. Velcro around the perimeter of the mat enables attachment of accessories, such as PolySkirt, grid-cloth diffusers, louvers, polygrid.

(*Courtesy Mike Bauman*)

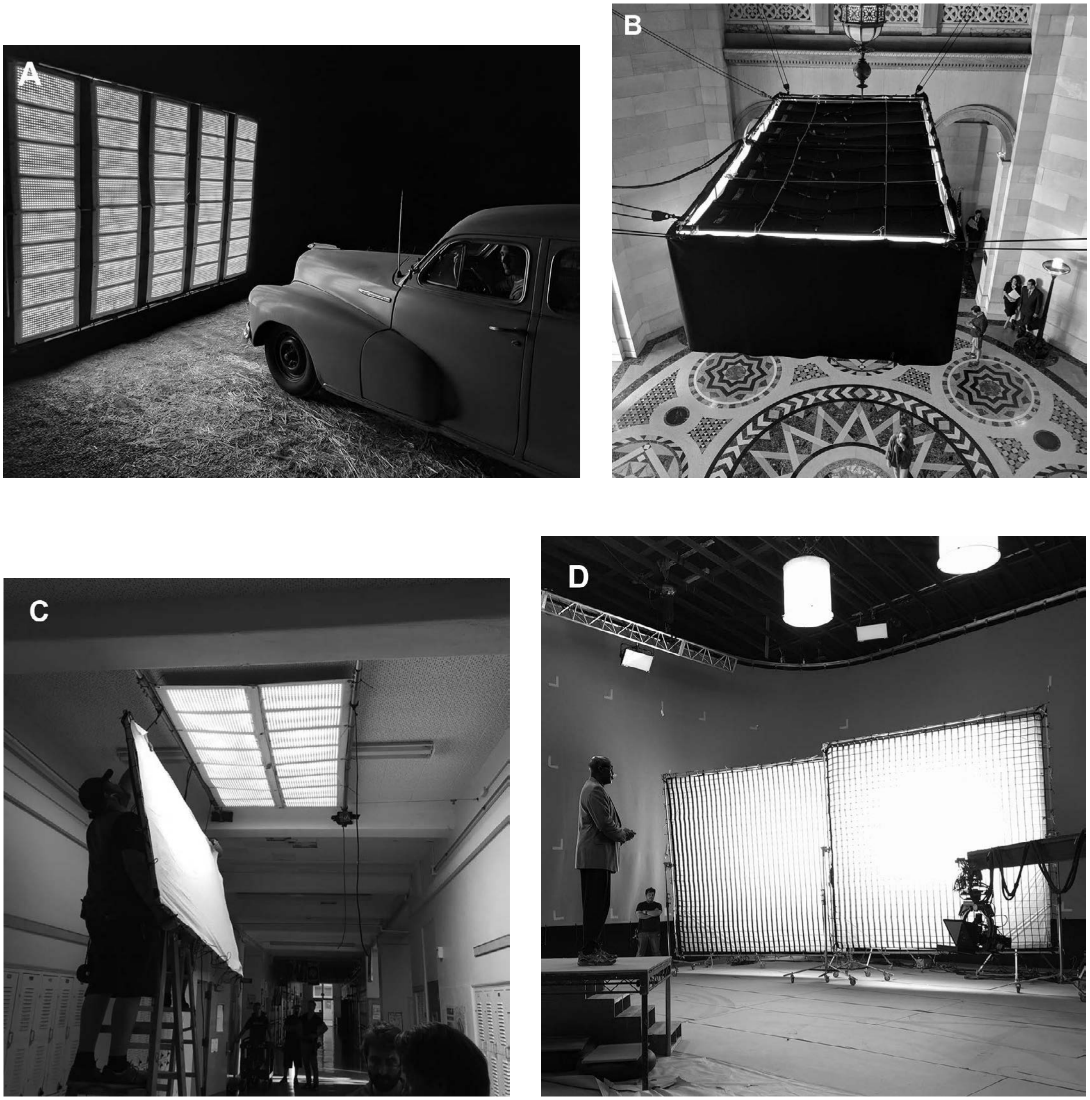


FIGURE 7.19

LiteGear's LiteTile features bi-color LED engines (2600–6000 K) in an engineered textile housing. (A) LiteTile+ Plus 8 (92 × 24, 400 W, 7.6 lb.). The spacing of the emitters in LiteGears LiteTiles is narrow enough that the light is soft without diffusion. (B) Four LiteTile+ Plus 4 (46.5 × 24, 200 W, 4.4 lb.) makes a light rig that is easy to support. (C) The virtues of thinness and light weight can be seen in how closely these LiteTiles are rigged to the ceiling. (D) LiteTile can rig into existing grip or butterfly frames. Their thinness makes them a huge space saver.

(*Courtesy Mike Bauman*)

FIGURE 7.20

A cart full of Creamsource bi-color fixtures. From top to bottom, Doppios, Minis, and Micros.

(*Courtesy Mike Ambrose*)

screen evenly and eliminate possible shadow lines. Kino Flo's fluorescent Image 80 fixtures are a popular choice, being affordable in large numbers. They can be fitted with super blue or super green tubes that provide very narrow color spike at the proper wavelength (Figure 7.26). (Matte photography is discussed in detail in Chapter 19.) ARRI SkyPanels, Kino Flo's Image L80 (Figure 7.27) are also commonly used.

A

B

FIGURE 7.21

The Diva-Lite 21 LED (back view). (B) Diva-Lite family are full color. They can be fit with Kino's classic lightweight barn doors, a center-mount, and removeable honeycomb louver. The power supply, which is back-mounted to the fixture, has wireless DMX.

(*Courtesy Kino Flo, Inc.*)

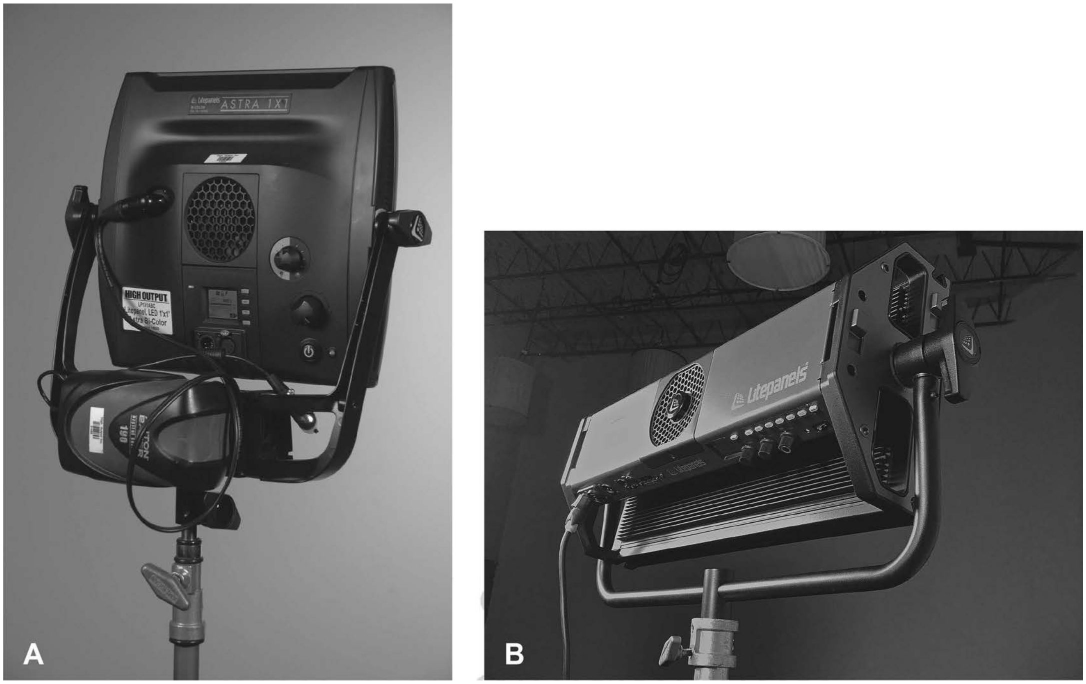


FIGURE 7.22

(A) Litepanels's 1 × 1 Astra Bi-color, (B) Litepanels's Gemini 2 × 1.

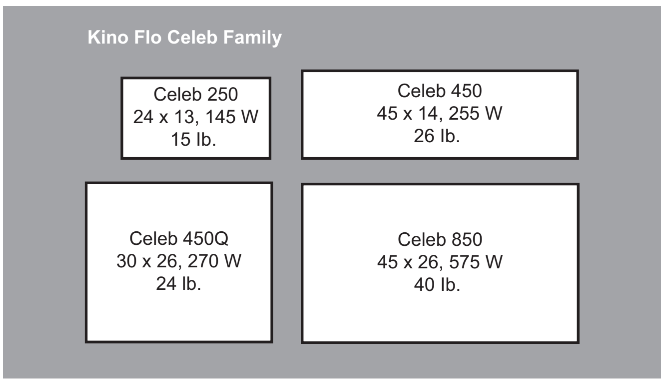


FIGURE 7.23

The Kino Flo Celeb® family.

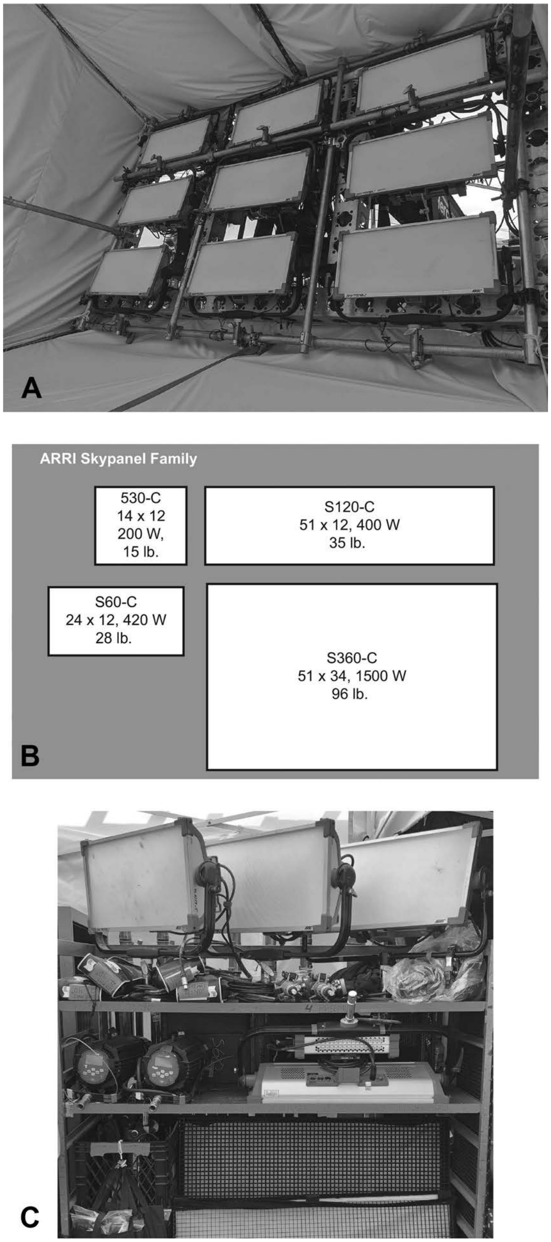


FIGURE 7.24

(A) Nine ARRI SkyPanels S120-Cs rigged in a large softbox. SkyPanels are significantly brighter (and heavier) than other lights their size. (B) SkyPanel family. (C) A whole lot of color: SkyPanel S60-Cs; Source Four Lustr, LiteGear Spectrum 4, and LiteMats of various sizes.

(*A Courtesy Mike Bauman. B and C Courtesy Mike Ambrose*)

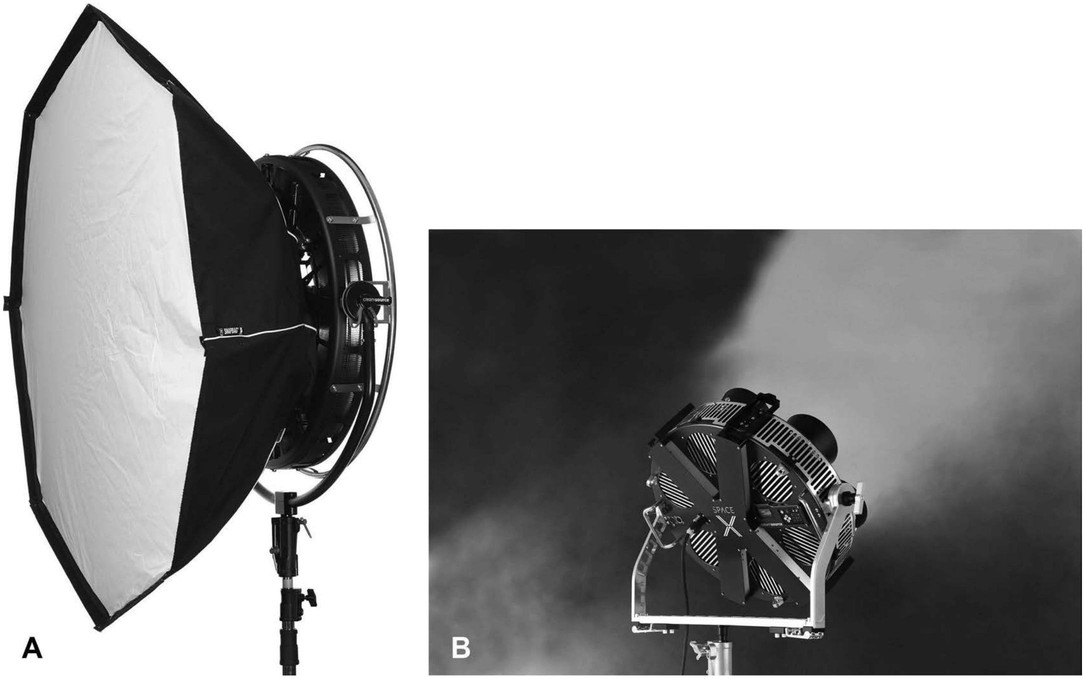


FIGURE 7.25

(A) The Creamsource Sky and (B) SpaceX from Outsight are circular in shape and have a six-light-engine configuration. They are designed as a replacement for a 5k space light, and can support a standard space light skirt. However, they have found use in a wide variety of applications—it is shown here with a SNAPBAG (DoP Choice)—because they are bright, 1200 W, and full color. The Creamsource Sky is passively cooled (no fans or moving parts to offend the sound department), and it is water resistant (IP65), perfect for rain shots. The SpaceX has quiet-running fans.

(*Courtesy Outsight, Creamsource*)

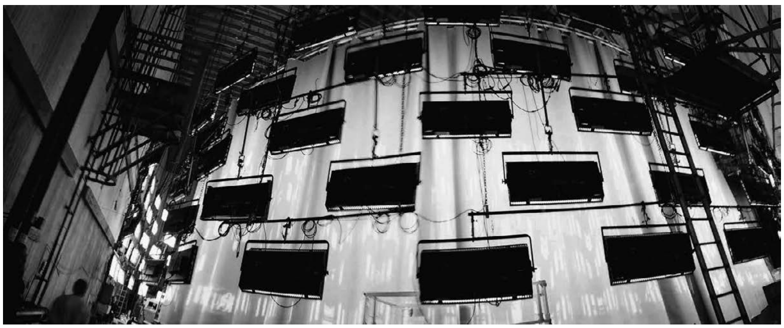


FIGURE 7.26

120 Image 80 fluorescent fixtures backlight a translight backdrop. The lights avoid the heat and massive power requirements that come with lighting a backing this size with incandescent lights.

(*Courtesy Mike Bauman*)

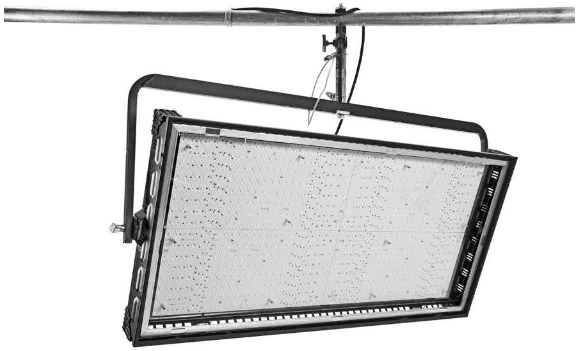


FIGURE 7.27

Kino Flo L80. Rugged metal fixture with traditional yoke for studio rigging. Full color. 2700–9900 K, 400 W, 54″ × 28″ × 6.5″.

(*Courtesy Kino Flo, Inc.*)

ARRI SKYPANEL®

SkyPanel is among the most commonly used and has the most comprehensive feature set of current full-color LED fixtures. It serves as an instructive example.

Establishing base settings

When the lights are first received from the supplier they should be reset to default settings and then set up for the new show. The sidebar shows one rigging gaffer's setup list for SkyPanels.

SKYPANEL SETUP CHECKLIST (EXAMPLE)

1 Factory reset. This resets all the fixture settings to default settings.
2 Bring manual dimmer to 3 percent. Leaving the light manually set to 3 percent during rigging makes it is easy to identify lights not receiving DMX once the board is connected.
3 Double check firmware version. Version should be the same for all lights.
4 Set DMX start address.
5 Set DMX Mode.
6 Double check it is set to Hold Last Look.
7 Set the dimming mode to Low End Mode.
8 Select Calibrated Color if in RGBW mode, otherwise this is automatic.

The settings can be entered manually using the fixture's control interface. Once you make the assignments in one fixture, you can save the fixture settings to a USB stick and load them into other fixtures (but you still need to check each one's firmware version).

When pre-rigging fixtures without a control console, for fixtures that have RDM like SkyPanels, you can use a device like DMXcat® to restore factory defaults, check software version, assign DMX address and mode using the DMXcat® RDM Controller app. The DMXcat® is a Bluetooth dongle that plugs directly into the DMX port on the fixture, so settings can be loaded from a compatible phone (see Chapter 12). Depending on the fixture manufacturer's RDM profile, you may be able to view and set other parameters. For example, ARRI's RDM commands enable the user to set Dim Curve and Low End Mode.

Settings menus

On the SkyPanel manual interface, the blue knob labeled INTENSITY/SELECTOR has two functions. When the fixture menu is closed, it controls intensity. If you push MENU, then the blue knob scrolls through fixture menu options. Press the blue knob again to open sub-menus and to select/confirm selected parameters. Press BACK to step back one step in the menu. Press MENU to close the fixture menu. Table 7.3 provides some of the most commonly needed menu paths.

Table 7.3 Commonly used menu paths for ARRI SkyPanel series—Firmware 4.4

Setting	Menu path	Default setting
Factory Reset	MENU/Factory Reset/	No (abort action)
DMX start address	MENU/DMX Settings/DMX Address/001–512	001
DMX Mode	MENU/DMX Settings/DMX Mode/	P1
DMX loss of signal behavior	MENU/DMX Settings/DMX Loss Behavior/	Hold last command
Wireless DMX (if supported)	MENU/DMX Settings/WDMX Settings/WDMX State/	OFF
Call up a PRESET	Press PRESET/Rotate blue knob to scroll/ Press blue knob to select.	
Store a PRESET	Select color to be stored/Press and hold PRESET/Rotate blue knob to select slot/Press blue knob to save/Press BACK to close.	
Dimming curves	MENU/Light Control/Dimming Curve/	Exponential (fine control at the low dimmer levels)
Fan Mode (all models except S360)	MENU/Fan Mode/	Variable (except S360, which is temperature regulated)
Optimal low-end dimming vs. flicker free	MENU/Light Control/Special Modes/Low End Mode	OFF (flicker free)
Calibrated Color	MENU/Light Control/RGBW Color Space/	Direct Control (optimizes brightness)
Highspeed Mode	MENU/Light Control/Special Modes/High Speed Mode/	Highspeed mode is OFF
Master/slave	MENU/Light Control/Master-Slave Mode/	OFF
Display illumination	MENU/Display Setup/Display Illumination	Always ON

Note: The above is provided as an example. Menu items may change or move with firmware updates.

Light operation

Intensity. Make sure the fixture menu is closed (press MENU to enter and exit menu mode). Use the blue knob (left) to adjust intensity.

Color Mode. Push the MODE button to toggle between operation modes: CCT, HSI, GEL, Source, RGBW, and X/Y mode. Use the other two knobs to adjust the parameters in each mode (Figure 7.28 and Table 7.4).

FIGURE 7.28

SkyPanel control panel. CCT mode is selected. The current functions are displayed: Color temperature and green/magenta shift.

Table 7.4 Selecting colors

Color mode (Press MODE repeatedly to select)	I/S knob (Blue knob)	Center knob	Right knob
CCT	Intensity	Color Temp	Green/Magenta
HSI	Intensity	Hue angle	Saturation
GEL	Press to open gel library	Color Temp (3200 K or 5600 K)	Best color/Brightest
	Turn to select gel. BACK to select a gel	Lee/Rosco	Gel Category
Source	Press for list of sources. Turn to call up different sources. Press again to choose selected source		Source Category
RGBW	Adjust intensity of selected color channel		Select color channel (red, green, blue, white)
X/Y	Adjust coordinate (0.0000 to 0.8000)		Select X or Y

Table 7.5 Lighting effects menu of ARRI SkyPanel Series—Firmware 4.4	
Setting	**Menu path**
Turn ON/Select Effect	MENU/Lighting Effects/Rotate blue knob to select effect category/Rotate right knob to scroll options/Press right knob to select.
Adjust Parameters	Use center and right knobs to adjust parameters shown on screen.
PAUSE/ACTIVATE	Pause and activate the effect by pressing blue knob.
Additional parameters	When "Press" is displayed, additional adjustments are available by pressing MODE and holding for 1 second.
Turn OFF	MENU/Lighting Effects/OFF

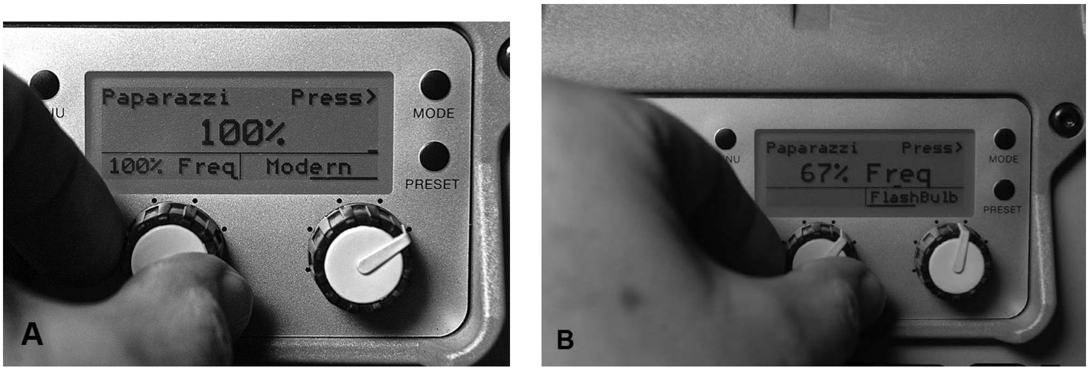


FIGURE 7.29

SkyPanel effects interface. The Paparazzi effect category has been selected. The *frequency* of flashes is adjusted using the *center knob*. The type of Paparazzi flash is selected by scrolling and pressing the *right knob*. The word "Press>" on screen indicates there are additional parameters available by pressing MODE button. (B) Press and hold the MODE button to reveal additional parameters, color temperature, *center knob*, and + Green, *right knob*.

Presets. Push PRESET to see a list of ten available factory presets plus ten user-defined presets. Scroll the list with the blue knob. Press the blue knob to select a preset. Hold the PRESET button down to set a new preset (like programming a new station on a car radio).

Effects. Push MENU, then scroll down using the blue knob to Lighting Effects. Select it by pressing the blue knob (Figure 7.29). Menu functions are shown in Table 7.5.

For further information, consult the manufacturers' user manuals. They contain detailed descriptions of every function and are available for download from manufacturers' Web sites.

LED TUBES

LED tubes, or *linear LEDs*, are among the most commonly used forms of LEDs after panels. Ever since Kino Flo developed film-friendly fluorescent tubes in the 1980s, gaffers have used bare tubes as accent lights in sets, lighting bottles behind a bar, for example, or placing them in soffits. While fluorescent tubes are feather light, and can be held in place with tape, LED tubes vary in weight, but can generally be held in place with purpose-made clamps, Velcro, or zip-ties. At this writing, there are a variety of different tubes on the market, many of which are designed with slightly different intentions, so distinguishing their attributes helps us see which applications work best for each type. LED tubes range from simple and inexpensive to more complex, full-color tubes, to pixel tubes that perform all kinds of color and lighting effects.

Single- and bi-color tubes

Quasar Science is a Los Angeles-based company founded by lighting technicians. Accordingly, their cornerstone products are primarily intended to provide high-CRI and brightness for lighting a subject, and their initial objective was to avoid unneeded control electronics in favor of a light that is lightweight, self-contained, simple to operate, and inexpensive. Their first products were small lights that are easy to hide on set, Q-Lion tubes. These are powered from an internal battery, come in 7″, 12″, and 24″ lengths, and have a strong magnet which securely holds the light to any ferrous metal surface (Figure 7.30). They can be dimmed in steps using a selector on the light.

Based on the same principle of simplicity, Q-LED T8 and T12 tubes in 2′ (15 W) and 4′ (30 W) lengths use the standard G13 medium bi-pin base (the standard connector on T12 fluorescent tubes) powered directly with 120 V (the power supply is internal). The tubes are available in 3000 K or 5600 K. A bi-color arrangement can be created by alternating warm and cool tubes and powering them from separate dimmer circuits. Similar tubes are available from Sourcemaker, Colt, and others.

FIGURE 7.30

Quasar Science Q-Lion kit with 7″, 12″, and 24″ tubes. Tubes have internal lithium-ion battery with 4-hour battery life running at 100 percent. The lights are single color (3000 K or 5600 K) with a high CRI. They can be set to one of five brightness settings (press on/off button multiple times to toggle through settings). Magnets at the ends attach the light firmly to anything metal. A ⅜-in. threaded hole in one end accepts baby pins to be attached. Kit includes multi charger, individual chargers, baby pins.

(*Courtesy Quasar Science*)

Q-LED T12 tubes are standard 1.5″ diameter, and can be snapped into standard fluorescent clips, which you can fasten to a baby plate to mount it to a C-stand. Modern Studio Equipment, Matthews, and others make single and double T12 clip plates. Matthews Studio Equipment makes the MyWay two-bank and four-bank plate which integrates with Matthews versatile MyWay rigging system.

The Q-LEDs have the same length as fluorescent tubes and are used as a replacement in practical fluorescents on set, which enables more versatility for dimming, while remaining color accurate. To use the tubes in an existing fluorescent practical fixture the fixture has to be rewired to by-pass the fluorescent ballast. The ballast can be wired-up again after production so the fixture may be resold.

LED tubes are also used to create an even backlight on a translight using a ladder of tubes supported by a lightweight structure, like fabric or thin wire (Figure 7.31). Tube arrays make a good source for evenly lighting large overhead diffusion to imitate sky light.

A number of LED tubes are designed to be dimmed externally using a phase control dimmer, including the Q-LED from Quasar Science, as well as similar tubes from Colt, and Sourcemaker. There are some tricks to dimming LED tubes this way. See Chapter 15.

Quasar's bi-color tube, the X-Crossfade, adds a thumb wheel on the end of the tube to select a color temperature (2000–6000 K). Again, these tubes are dimmable by external dimmer and come in

FIGURE 7.31

Quasar Science 4-ft. tube ladders lighting a translight. The tubes are controlled on dimmer packs.

1′ (15 W), 2′ (25 W), 4′ (50 W), 6′ (75 W), and 8′ (100 W) lengths. They are connected by a single G13 medium bi-pin on only one end of the lamp, which delivers 120 VAC.

Quasar also makes fully digital tubes with internal dimming, an on-board control panel plus DMX. XMD Crossfade LEDs are bi-color CCT with plus/minus green adjustment. (They should *not* be dimmed using an external dimmer.) They are powered using a Neutrik TRUE1 locking connector that plugs into one end of the tube and they can be operated off of any voltage 100–265 VAC (or 10–26 VDC via a little locking barrel connector).

The other end of the tube accepts a RJ-45 connector which delivers the DMX control signal. A 5-pin XLR to RJ-45 adapter can be used to plug it into a typical DMX cable. A bank of these tubes can be jumpered together and controlled as a single unit by setting one tube as to "lead" and the others as to "follow." The XMD crossfade tubes come in 2′, 4′, and 8′ lengths.

Full-color tubes

The dominant full-color tubes at this writing are: Rainbow (Quasar Science), FreeStyle (Kino Flo), LightBlade (NBC Universal), Titan (Astera), and Voyager (Digital Sputnik). Although similar in many ways, each one has a unique approach and a slightly different role in the gaffer's lighting arsenal.

Rainbow and LightBlade

Quasar's Rainbow series are full-color linear LEDs, similar in most respects to the XMD Crossfade model, but with the addition of full color. They provide manual and DMX control over intensity, CCT, hue, saturation, and lighting effects. In addition, each tube has built-in LumenRadio CRMX wireless DMX. One tube can independently control any number of others (Figures 7.32 and 7.33). They are available in 2′ (25 W), 4′ (50 W), and 8′ (100 W) lengths.

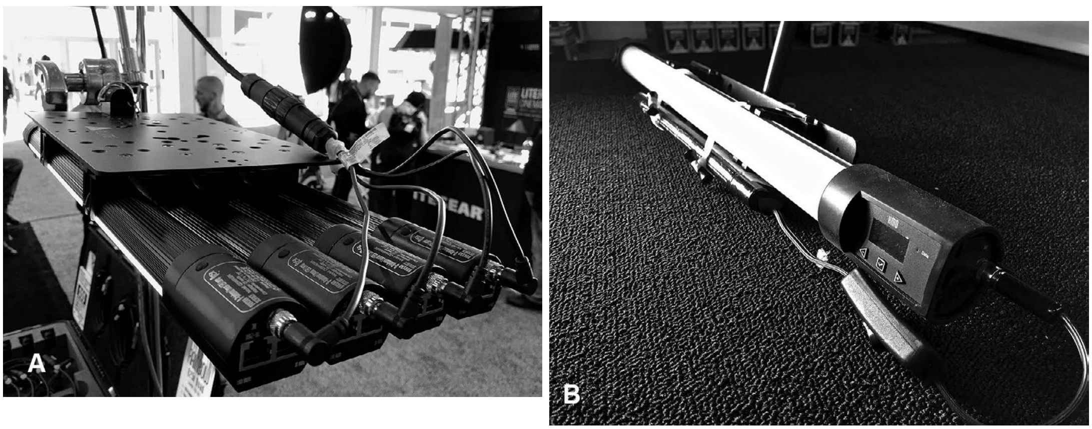


FIGURE 7.32

(A) Four Quasar Science Rainbow, Q25R, tubes mounted in a Matthews MyWay™ plate. (B) A Quasar Science Rainbow tube mounted in a Matthews MQ mount for attachment to a C-stand. With built-in CRMX wireless DMX control and a portable battery bundled to the tube with Bongo ties, this unit is completely self-contained.

(*Courtesy Quasar Science*)

FIGURE 7.33

The 10-tube framed array (4′ × 24′) in the background is controlled from the Rainbow tube in the foreground using lead/follow. Both are the same aqua color.

LightBlade is an 80 W 24″ and 48″ (R, G, B, WW, CW) tube from NBC Universal in collaboration with Cineo. Edge fixtures are a modular system to hold two or four LightBlades. LightBlades have a ⅜-in. 16 thread mounted in the ends for easy, almost invisible mounting. It is controlled externally via DMX/RDM (RJ45 connector).

Kino Flo FreeStyle tube

Kino Flo's full-color 4′ tubes are designed to run off the FreeStyle control/power supply and used in or out of the FreeStyle 4 fixture, which is similar to the traditional Kino Flo four-bank fluorescent fixture. These tubes are much lighter than other LED tubes because the power supply and control circuits are mainly in a separate FreeStyle 4 power supply (100–240 V). The tubes use Kino Flo's True Match® LEDs (R, G, B, WW, CW) enabling all of Kino Flo's color control and effects features (described previously) as well as wireless and wired DMX control. The tubes are also distinguished by a narrow channel along the back of the fixture that provides a versatile system for mounting the tubes (Figure 7.34) and is integrated with Matthews MICROGrip system. Unlike other tubes, FreeStyle tubes emit light from the tube in 310° degrees (most tubes are 180°), which enables them to use a reflector for greater lumen efficiency. Reflectors are available for use in or out of the FreeStyle fixture. FreeStyle head cable uses Kino Flo's own 8-pin locking connector type.

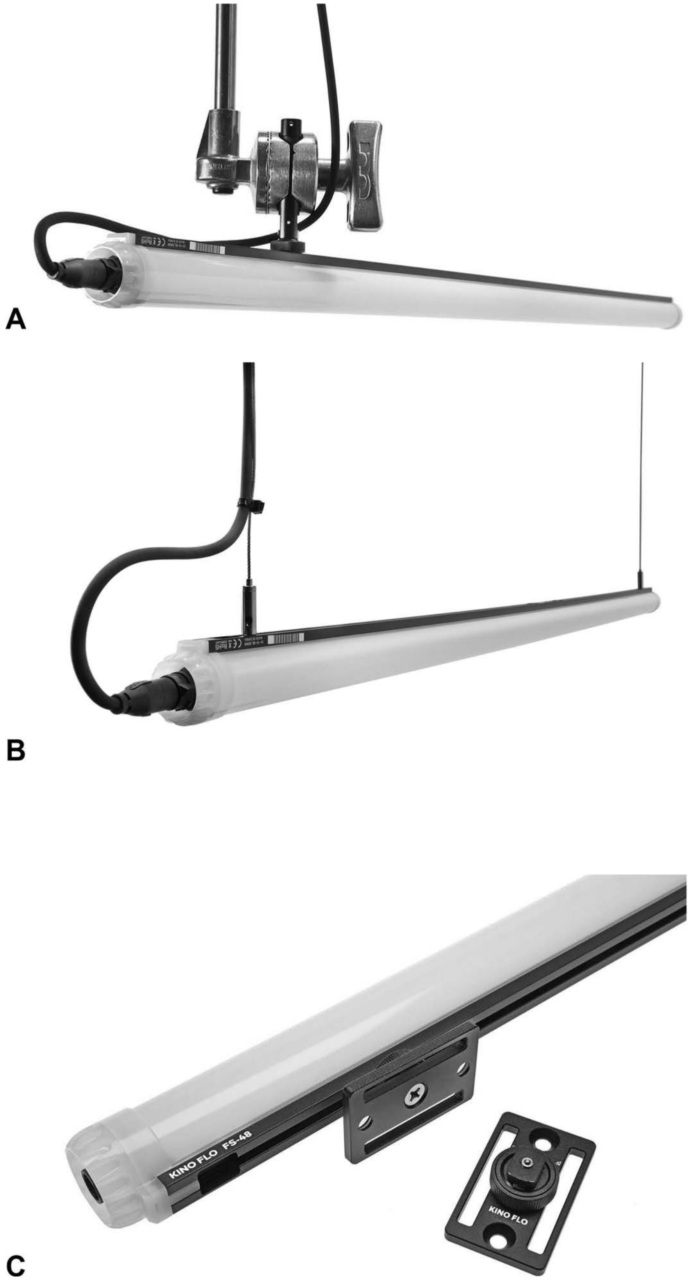


FIGURE 7.34

(A) FreeStyle T44 tubes have a slotted back rail for mounting. (B) A clean look for on-camera applications (with or without reflector). (C) Screw plate.

(*Courtesy Kino Flo, Inc.*)

Pixel tubes

When a light provides separate control of different sections, the sections are often referred to as *pixels* (in reference to pixel mapping). Pixel tubes can create programmable, repeatable stepping effects between the pixels. The effects can create nice off-screen lighting effects like police flashers that flash first at one end and then the other.

Pixel effects also make for visual interest as an on-camera element. For any tube, the challenge for on-camera lighting effects is that tubes are too bright, and colors quickly wash out. To some extent, the tubes can be dimmed, but if you are shooting at 800 ASA at an f/2.8 or f/4, they are still too bright. DPs often opt to use ND 3 or ND 6 gel on the tubes to optimize their appearance.

Astera

Astera tubes, the 4-foot Titan, 2-foot Helios, and 8-foot Hyperion, have been a game-changing light (Figure 7.35). Astera's LEDs, which also includes AX-series full-color wash lights, are conceived as a completely wireless and self-contained system that is easy to deploy indoors or outdoors. All their lights have internal batteries with a 20-hour maximum run time. You can actually preprogram a predetermined run time and the light adjusts its maximum light output to achieve it.

Astera lights are rated IP65—meaning they can be exposed to jetting water from all directions (see Appendix E for explanation of IP ratings).

They are full color (R, G, B, Mint, Amber). The tubes have an extremely broad color range, with CCT from 1750 K to 20,000 K with high CRI. The Titan has 16 individually controllable pixel sections. Helios has eight. Hyperion has 32.

Astera comes from the event world, so many of its built-in effects are designed to be visually appealing to look at. However, on a film set, Asteras are used for all manner of on-camera light effects. For example, one feature film created the appearance of moving headlights outside a pebbled glass window, by sequencing Astera Titans lined up end-to-end and programming a white light to streak down the line of tubes, from one tube to the next. It is also easy to sequence the tubes for offscreen effects where the light moves, such as to simulate lights passing outside a vehicle, for poor man's process shots, for example.

The Titan tubes each provide full-function control from a manual digital interface on the back of the fixture. Astera's have built-in CRMX wireless DMX receivers. An entire system of Astera lights can be controlled from their custom app. Astera's wireless transmitter, the Astera Box, communicates via Bluetooth with an iOS or Android device. The Astera Box communicates with the lights via CRMX. The Astera Box can also be fed DMX from a console. In addition to providing intuitive color/brightness pixel control, the Astera app also performs system monitoring of settings, battery levels, and radio signal strength during use. It even tells you if a light is manually moved or switched off. With their internal battery, Titan tubes are the heaviest of the tubes we've talked about.

Voyager

Digital Sputnik's Voyager (Figure 7.36) is another full-color (R, G, B, A) linear pixel LED with internal battery and wireless control that is underwater-rated (IP68). At this writing, the battery has a 2-hour run time. The 2′ Voyager tube (20 W) has 39 individual pixels, and the 4′ tube (40 W) has 83. Digital Sputnik has an iOS- or Android-compatible control app for the Voyager. The app is designed to shorten setup time and streamline effects creation. Through the app, not only are the lights automatically

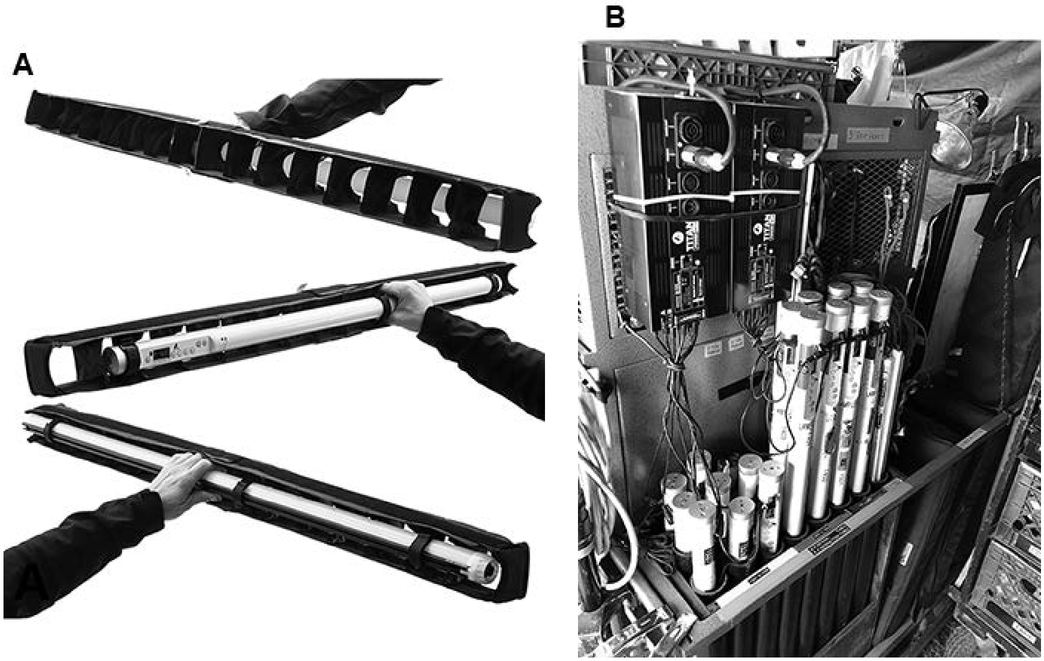


FIGURE 7.35

(A) Astera Titan tube with Snapgrid from DOp Choice (Courtesy DOp Choice, Inc.). (B) Astera tube storage cart and charging station. The drawers on the other side of this cart hold Astera Lightdrops, LiteRibbon, Lume Cubes, Cintennas, DMXits, accessories, Astera-sized snapgrids, and sundry other LED-related paraphernalia.

(*Courtesy Mike Ambrose*)

FIGURE 7.36

Digital Sputnik Voyager pixel tubes.

(*Courtesy Digital Sputnik*)

discoverable, but they actually map themselves in the application. From there, each light can be selected, adjusted, and sequenced with the touchscreen display.

The design of the Voyager makes inserting ND or gel easy, because the diffusion tube is actually open on the ends, so the gel can be slid inside, preserving the tube's sleek outside appearance.

RIBBON AND TILES

One of the truly game-changing applications for LEDs has been the ability to build them into sets and use them to fabricate custom lights and fixtures. LED ribbon creates a flexible linear light source. The ribbon can be as narrow as 10 mm, and only a couple millimeters thick. It comes on a reel containing 16 ft. of ribbon and has break points positioned every few LEDs, enabling it to be cut to any length (Figure 7.37). The ribbon has an adhesive back, so with its tiny size and low weight, there are all kinds of unique opportunities to hide lights inside sets, display shelves, inside practical fixtures, tucked in soffits, used to emulate instrument lights in a vehicle or aircraft. Ribbon can be integrated into props like lanterns and candelabra, and costumes like full-face helmets. The use of LEDs in sets has changed the way sets are lit. With white, bi-color, or full-color LEDs built in, the set lights itself and offers an endless variety of possible moods and looks (Figure 7.38).

In addition to being built into sets, LED ribbon and tiles can be mounted to flat stock such as foam-core or corrugated polypropylene stock, enabling the gaffer to fabricate feather-weight light sources in whatever size is called for. They can be mounted anywhere—such as flush to the ceiling or wall, against the ceiling of a car, or against an instrument panel. Ribbon can be bent to curve with the surface

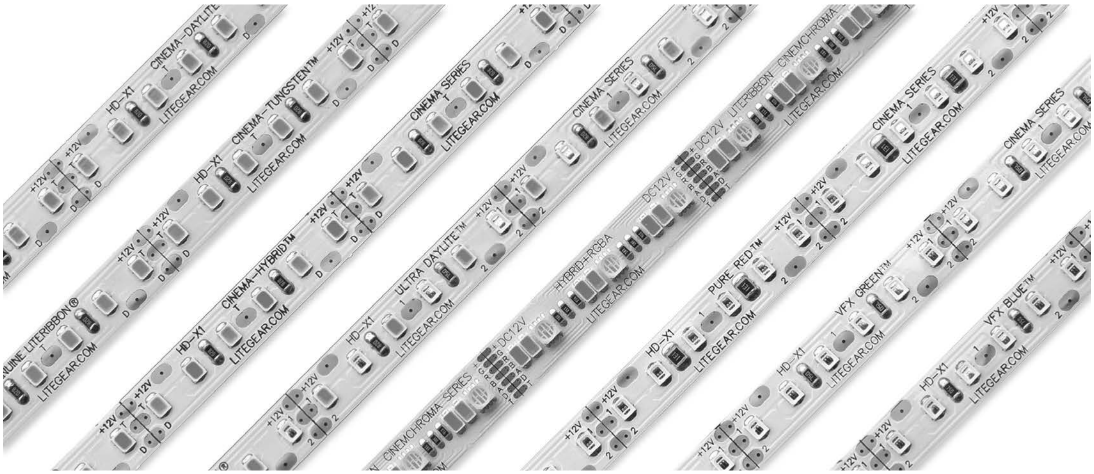


FIGURE 7.37

A sample of a few variations of LiteGear LiteRibbon. From left to right: Cinema Daylight X1, Cinema Tungsten X1 (available in 2600 K, 3000 K, 4000 K, and 6000 K), Cinema Hybrid (available in various bi-color combinations), Cinema Ultra Daylight, Hybrid+RGBA (the works), Pure Color (red, blue, green, amber, blacklight blue, and other colors), VFX Green, and VFX Blue.

(*Courtesy LiteGear*)

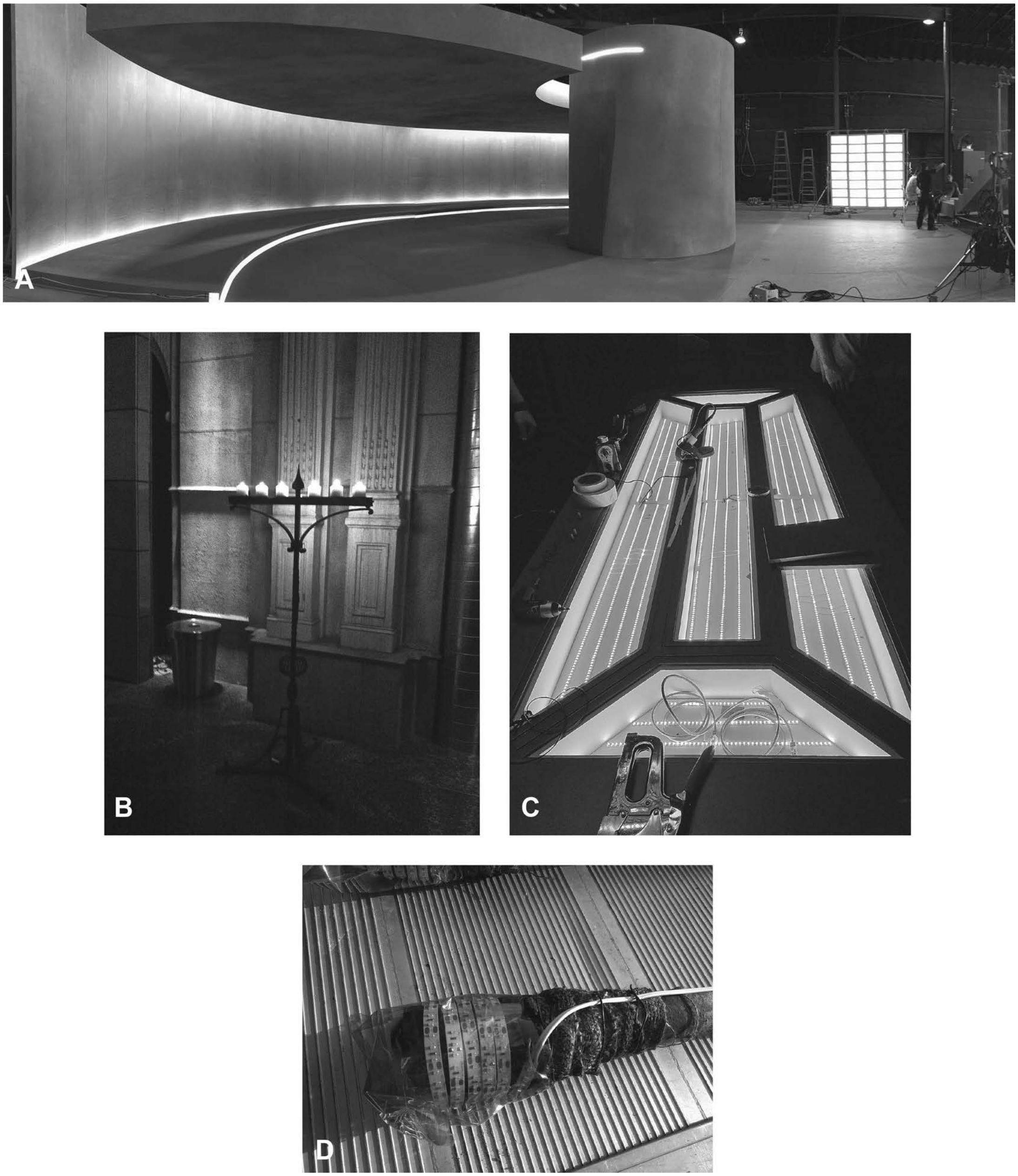


FIGURE 7.38

(A) LED ribbon integrated into the floor and ceiling of a set, (B) hidden on the back side of a candelabra, (C) illumination light table, and (D) wrapped to make a hand-holdable medieval torch.

(*Courtesy Mike Bauman*)

they are mounted on—into a circle as small as a 1-in. radius. It is ideal for lighting curved soffits and surfaces, which are awkward to do with 4-foot fixtures.

LiteGear has been the pioneer for this application of LEDs and has developed a complete system of products that includes ribbon, cards, power supplies, controllers (DMX wired and wireless), and accessories.

Ribbon and cards are different from traditional lights in that they provide a lighting solution that the user integrates to suit their specific need. Accordingly, using the ribbon involves cutting and soldering wires to ribbon, using terminal boxes and special connectors, to create a custom system—working much closer to the actual electronics than set lighting or rigging normally does. We mentioned in Chapter 1 that on a big feature film, there may be a completely separate fixtures crew employed to install and network these types of integrated solutions. Some tips for soldering are given later in this section.

LiteCards are bi-color Hybrid, high CRI, light engines distributed on a sheet. Gaffers often use these to create custom light sources. They are so thin they take up virtually no space. The spacing of the emitters provides soft light without the need for an additional diffusion layer.

Ribbon

LED ribbon comes on a 5-m reel (16.4 ft.) that can be cut to length to suit the application at any of the indicated cut points. There are dozens of variations of LiteGear LiteRibbon from which to choose:

- All LiteGear's phosphor ribbon is available in tungsten (3200 K), daylight (5600 K) or hybrid (bi-color). The Cinema series is LiteGear's premium high-CRI, high-output white phosphor ribbon. The Studio series is more appropriate for high-volume situations. VHO Pro ribbon is LiteGear's original high-CRI, high-output ribbon available in either 120 or 60 LEDs per meter, in widths up to 6 meters.
- Chroma ribbon (RGB, RGBA, RGBW (daylight), RGBW (tungsten), and single-color ribbon in red, green, blue, and amber/yellow and many others. Chroma-Correct is propriety full-color ribbon that can also produce high-CRI white light.
- High density (120 emitters/m) vs. low density (60 emitters/m).
- Width variations: X1, X2, X3, and X6 where X1 is one row wide (10 mm) and X6 is six rows wide (60 mm).
- Other variations: low-cost versions, waterproof versions in each color, 120° beam angle, 80° beam angle, and a side-emitting type (light emits from the narrow edge of the ribbon), etc.

While RGBW ribbon gives the gaffer any color "just in case," gaffers rarely actually want or need every color. Often they really only need some flexibility within a particular range of colors. A simpler and more affordable solution may be to use a two-color ribbon. LiteGear has a few of these that give a range of hues between two color points. For example, daylight/blue ribbon creates any color in the blue range from daylight, to a saturated deep blue. Tungsten/orange ribbon creates any color in the warm range from 3200 K to orange. This gives the gaffer a simple way to tweak and create different looks within their chosen color range. Since it only uses two channels it uses a simpler, less expensive controller.

Power and control

Twelve-volt ribbon can be powered by a 6–12 V DC battery or a power supply. DC may be supplied from either an AC power supply, NiMH rechargeable battery pack, cigarette car battery adapter, D-tap battery adaptor (see Chapter 18), or a AA Alkaline battery holder. A single-circuit ribbon can be powered by a 9 V battery, which is ideal for portable situations, such as props or wardrobe, where anything bigger is a challenge to hide. Cinema series ribbon are available in 12 V or 24 V. The higher voltage reduces current by half, making long lengths easier to accommodate.

LiteGear supplies different types of dimmers and controllers for the number of circuits required. LiteGear makes single-channel and bi-color, flicker-free, manual dimmers and effects generating dimmers which are ideal for props, gags, and remote lights.

When ribbon is part of the set, a DMX dimmer is typically called for. DMX dimmers use RJ45 connectors for DMX in and out. CAT5 cable is a good way to run DMX for ribbon because it is cheap, can be cut to suit, and is available at any home-improvement store. (See Chapter 12 for wiring RJ45 connectors.) The DMX-controlled dimmers connect to a DC power source using ¼-inch barrel connectors. The ribbon connects to the dimmer via Phoenix connectors.

The wire is connected to the ribbon by soldering the wire to solder pads that are spaced at regular intervals. The ribbon has one copper contact pad for each color circuit, plus a common (+) pad, so a single-color ribbon has two solder pads, while Hybrid ribbon has three, (warm white (T), cool white (D) and a common (+)). RGB has four solder pads, RGBWA has six, and so on.

Wires can be soldered to the end of the ribbon, or at any solder point along its length. They can also be soldered to the back of the ribbon, which is handy so the wires can run out through a hole in the back of the supporting material. Phoenix-type connectors are simple to install with a screwdriver and can accommodate any number of circuits: Phoenix2 for single-circuit ribbon, Phoenix3 for two-circuit ribbon, Pheonix 5 or 7 for RGBW and other multi-circuit ribbon.

A five-meter length of 12 V LiteRibbon draws 8 A (24 V ribbon draws 4 A). The dimmers are specified by the number of circuits and amperage per circuit: 4 × 4, 5 × 8, 24 × 4, and others. DMX addressing the dimmers is either by an interface on the front of the dimmer or via dip-switches. It is good practice to label the dimmer with the assigned DMX address, and if dip-switches are used, cover the dip-switches with a piece of tape and mark which switches are in the ON position. (See Chapter 12 for more about DMX addressing and dip-switches.) Some dimmers provide a handy test mode when the DMX address is set to 000. The ribbon will flash to show the circuit is operating.

Housings and light sticks

LiteGear also supplies a range of extruded aluminum, linear housings with diffusion covers with a clean, finished appearance for applications in set decoration as an on-camera light element (Figure 7.38). With the aluminum housing with a frosted plastic cover the lighting crew can easily fabricate portable light sticks any length for 4 inches and longer. Much like Kino Flo's discontinued Mini- and Micro-Flo fluorescents, a light stick is handy for hiding in a set, or mounting above and below the matte box of the camera as a little fill light.

Soldering

For consistent, reliable results the following tools are recommended:

- Wire strippers (self-adjusting)
- Wire stripper/cutter
- Flush cutter
- Soldering iron (ideally with a temperature readout)
- Solder (lead-free recommended)
- De-soldering pump
- De-soldering wick
- Soldering iron tip cleaner
- Soldering iron tip tinner
- Safety glasses

Smoke absorber
Screwdriver
Weights
DC power supply
Test leads with mini-grabber

Use a soldering iron tip that isn't so big that you will inadvertently apply solder to adjacent solder pads or so small that you have a tough time quickly reflowing the solder and applying it to the pad.

Work area

Have a clean work surface that is relatively heat resistant and unable to conduct electricity. Use a fan or smoke absorber to filter the unhealthy smoke. When wiring lots of LEDs, you are going to need to test each one after putting it together. A reliable bench power supply can supply any DC voltage that's called for, which may vary depending on what ribbon you are wiring. It also provides built-in short circuit protection. Test leads that terminate in mini-grabbers are ideal for clipping to LED strips. Alligator clips are fine as well, but they are more prone to creating accidental short circuits since the contacts themselves are more openly exposed.

Soldering tips (courtesy of LiteGear)

You can find demonstration videos on YouTube that show good techniques for soldering to LED ribbon. The basic steps are as follows:

1. Peel back the paper backing of the LiteRibbon.
2. Secure the ribbon so it can't move. Weight it down.
3. Get your soldering iron nice and hot. The highest setting is recommended. Clean the soldering iron tip before use.
4. "Tin" the contact pads on the ribbon. Apply a dot of solder to each pad by applying the tip of the iron to the pad to get it hot, then briefly applying the solder to the sweet spot where the iron meets the pad. The soldering iron will do almost all the work. Some pressure on the copper pads helps transfer heat to the pad quickly so the solder more easily adheres to the pads.
5. Cut the insulation off the wire, leaving no more than ¼ inch exposed.
6. You may consider "tinning" the tips of the wire.
7. Secure the wire with a weight, aligning the ends with the pads. Apply the iron to the wire for a moment, pressing into the solder until the solder melts and the wire bonds to the pad.

Tips

- Keep the soldering iron at about 35° to 40° relative to the surface.
- Be sure not to inadvertently hit adjacent copper pads with the soldering iron.
- Keep your soldering iron tip clean. Solder buildup can run over into adjacent pads.
- Mistakes will happen! So, keep a de-soldering pump and de-soldering wick on standby.
- Once the solder has cooled, consider adding a dollop of hot glue or some heat shrink to the soldered connector to help act as a strain relief. This also provides some additional protection against short circuits. Keep in mind, the rest of the LiteRibbon contacts are still exposed.

Be very careful not to create a short between two pads. If the ribbon is connected to a dimmer or DC power supply with a short, it will burn out that dimmer circuit instantly. There is no overcurrent protection to protect the dimmer.

OTHER LED FORM FACTORS

Orbiter

The ARRI Orbiter is a 400 W (nominal), multi-purpose, full-color, LED light head with a small (1.78-inch) aperture that can create focused hard light using an array of available optical attachments (Figure 7.39). ARRI calls its twist/lock optical mounting system QLM for Quick Lighting Mount. The QLM can be fitted with:

- 60°, 30°, and 15° "open face" condenser optics;
- 35°, 25°, and 15° projection optics that can focus the beam edge, gobos, cutters and an iris; or
- a lantern-like "dome" attachment or softbox attachments.

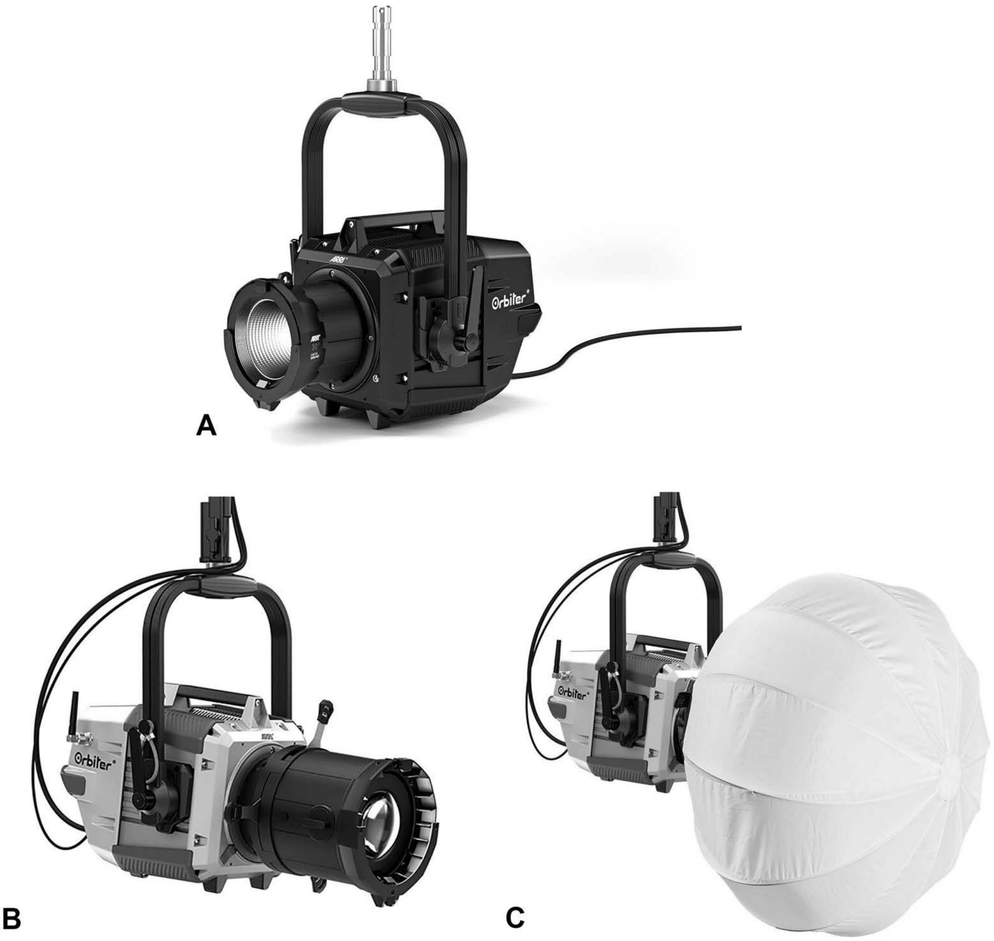


FIGURE 7.39

ARRI Orbiter (A) in black finish with 30° open face attachment, (B) with 35° projection attachment, (C) with dome attachment.

(*Courtesy ARRI, Inc.*)

Orbiter introduced the ARRI Spectra light engine, which comprises six colors (red, green, blue, amber, cyan, and lime green), providing a wide gamut of colors and enabling CCT white range from 2000 to 20,000 K. The light uses a mix of approaches within the electronic dimming that enables dimming down to 0 percent without an abrupt shut off at zero. The unit is a substantial 33 pounds, similar in size to a 2k Fresnel, uses a junior pin, and is weatherproof (can withstand rain or snow). The light's output depends on the optical attachment used, but it is capable of greater output than ARRI's L10 Fresnel.

Orbiter runs on ARRI's LiOS (Lighting Operating System) software which includes all the features that SkyPanels users are familiar with and more. This includes eight color modes: CCT, HSI, individual colors, x/y coordinates, gel mode, source matching mode, and effects, plus a color sensor mode. The on-board control panel can be removed from the back of the light, providing a tethered remote control that can just hang on the light stand for manual access. The light is equipped with a wireless DMX (CRMX) receiver and has inputs for DMX or Ethernet communication protocols. The light features three operational modes from which the user may choose to maximize either color performance, light output, or low noise.

The light has a powerful processor and a lot more memory than previous lights, putting in place the hardware needed for extensive software features and future development. The light also has optical and 3-axis accelerometer and magnetometer so it knows its tilt, roll, and heading and can provide this metadata, such as might be needed for special effects shooting. In color sensor mode it can measure the color and intensity of ambient light and can be programmed to match or respond to changes in ambient light and trigger a light cue from a change in ambient light. It has USB and SD card connectivity for loading firmware updates and color presets.

The power supply is internal. The light head takes AC power 100–260 V, 50–60 Hz, and can be battery powered at 48 V DC (via 3-pin XLR).

Automated fixtures

When planning the lighting scheme for a big set, an important question that affects the gaffer's ability to work quickly is the placement and focus of backlights, which is often impossible to predict with certainty. Because they typically are out of reach, adjusting the focus of backlights can be time consuming. As a solution, some gaffers have turned to automated lights, which can be refocused very quickly from the lighting console.

The SolaFrame fixture from High End Systems is a great example of the power of automated LED lights for this purpose (Figure 7.40). It has four motorized framing shutters to cut and shape the beam. It has rotating and fixed gobo wheels, CMY (cyan, magenta, yellow) color mixing and CTO color systems, 12°–40° zoom, animation effects plus iris and light frost, rotating prism, and other effects. There are five models of different wattages. The model called SolaFrame Theater does not have cooling fans, and it uses a special high CRI LED engine which may be most ideal for motion picture work. (Automated lights and remote yokes are discussed in greater detail in Chapter 20.)

Camera-mounted and small LEDs

There are many, many versions of small, battery-powered panels suited as an on-camera light, eye light, or as a small light that is easily hidden on set.

Lume Cubes are an example of tiny lights the are easy to hide. They are tiny 1.6-inch-square wireless, daylight, LED cubes that are waterproof and Bluetooth controlled via the Lume-X app. They

FIGURE 7.40

(A) High End Systems SolaFrame. (B) Automating the lighting helps make the work on the day flow efficiently. (*Courtesy High End Sytems, Inc., an ETC Company*)

have a 2.5-hour run time at 50 percent brightness. They are mountable in various ways including by a built-in magnet on the back, and they weight 2 oz.

Ring lights

A ring light is a donut-shaped light fitted to the camera lens so that the camera shoots through a hole in the center of the light (Figure 7.41). It is often used as a flattering, shadowless front light in the style of glamour stills photography. A ring light can be a good solution when the camera has to get very close to the subject and for macro photography. It helps fill the shadow made by the camera itself. In a close-up of a face, the reflection of the light in the subject's eyeballs is a distinctive donut-shape. In music videos and similar stylized shooting, you'll see all kinds of variations of this idea, with small LEDs used to make triangles, stars, and other attention-getting eye reflections.

Portable wall wash

Astera's AX3 Lightdrop is the smallest (15 W) of their series of small, PAR-like, totally self-contained, battery operated, wirelessly controlled, IP65 lights. These are great lights for uplighting architecture or trees. They are fast to deploy. Their clean shape, matte black finish, and lack of cables means they don't

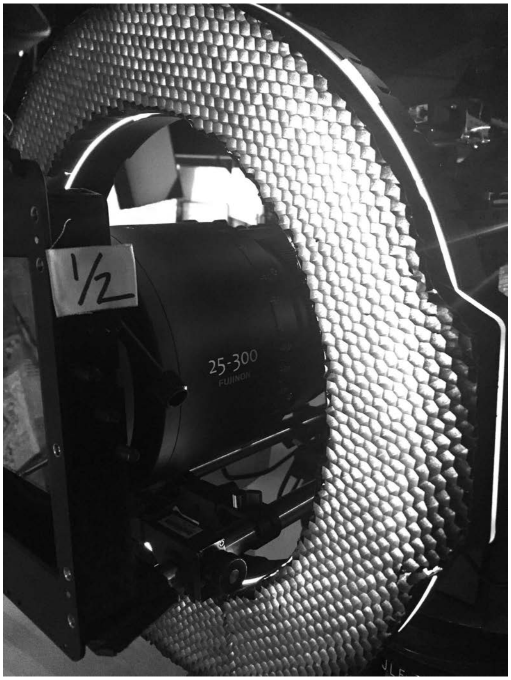


FIGURE 7.41

F&V Lighting Z720 Ringlight. 51 W, bi-color (3200–5600 K), four separately controllable quadrants, Wi-Fi capable, 10–16 V (a 14.4 V brick battery or two NP-F 7.2 V batteries), 290-mm diameter center opening for large lenses.

(*Courtesy F&V Lighting*)

necessarily need to be hidden from camera. The Lightdrop is an puck-like RGBW fixture, 7.4 inches in diameter, that weights only 1.4 lb. and has a built-in magnet on the back for easy attachment to metal. It lights upward sitting flat on its back, or angled using an adjustable foot. It has a removeable bracket that can serve as feet or as a yoke. It has a 13° beam angle and comes with 30°, 120°, and "Wallwash" diffusers as well as a diffuser dome that spreads the light 220°. The Wallwash diffuser covers a wall fairly evenly by creating a broad wash aimed at the bottom of the wall and a narrow beam aimed higher up. The PAR line-up also includes larger RGBAW units: 45 W, AX5 Triplepar; 60 W, AX7 Spotlite; and 135 W, AX10 Spotmax.

Punchy LEDs

Some of the early attempts at making a punchy, daylight LED resulted in poor color rendering and earned some lights a reputation for having a green or inconsistent color quality. This kind of light necessarily drives the LEDs harder and requires a heat management system, so they are not lightweight or small LED lights. However, there are now more LEDs on the market that start to compete with small HMIs and tungsten PARs for brightness and quality of light. Having green/magenta adjustability is helpful for these lights; otherwise, there's always gel.

Notable punchy lights include the Cinema Series lights (from Sturdy): JAB Variable (bi-color) JAB Daylight (Figure 7.42), JAB Hurricane (5600 K, IP65 waterproof rating, 212 W) and Punch (5600 K, 584 W). Much like a traditional PAR, these lights come with a set of diffusers to select the beam angle from 45° to 13°. The Punch, with no diffuser, can deliver 3716 fc at 10 feet (about the same as a PAR 64 with NSP lens).

Digital Sputnik's DS system comprises multiple 100 W, RGBW, full-color heads with a CCT range from 1500 K to 10,000 K. The heads have an innate 20º beam angle that can be modified with holographic diffusion panels to 34 º or 76º. DS-3 and DS-6 systems combine heads in arrays or in a spacelight configuration. The power supply has an interchangeable control module which can be either DMX/RDM or wireless Art-Net.

Digital Sputnik takes a scalable approach to wireless control that avoids the limitations of DMX. Each light module can act as a Wi-Fi access point and can act as a server for other DS lights. So, it has a built-in Art-Net node. This enables the heads to be networked, grouped, and controlled from the DS Control app without the need for a console. To control the lights wirelessly, select the light's Wi-Fi network (the serial number written on the DS unit) from your phone or tablet's Wi-Fi settings, and then launch the DS Control app. To control multiple DS heads, use the DS Control app to configure one

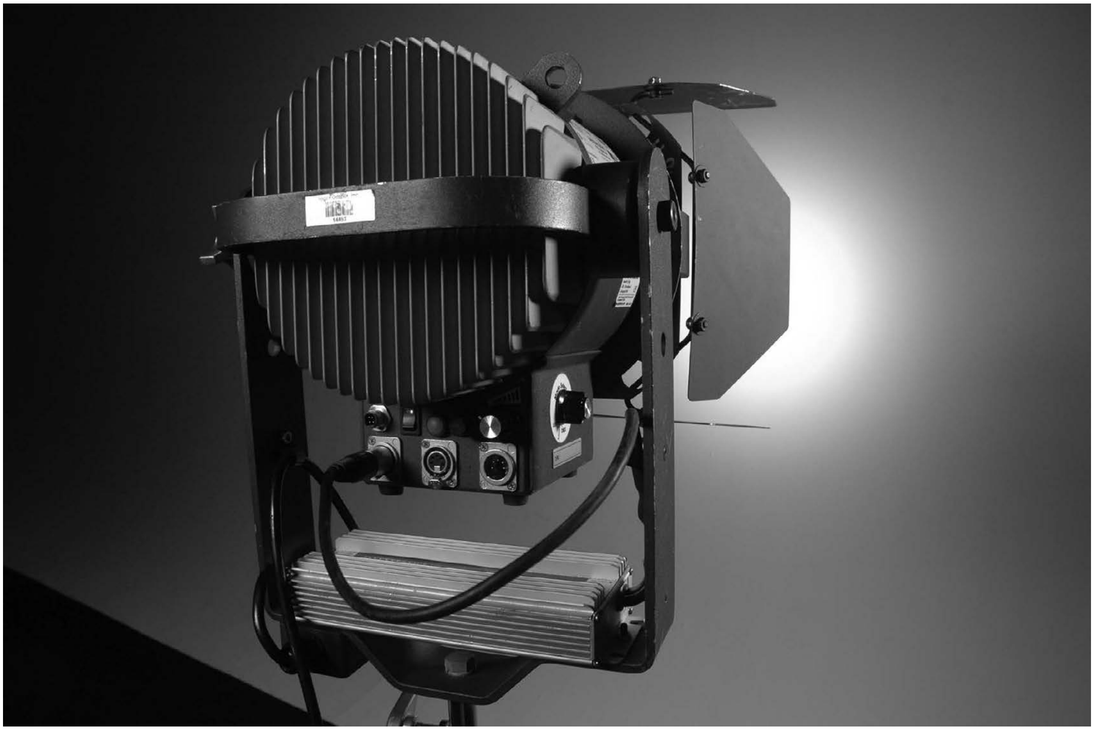


FIGURE 7.42

AAdyn Jab.

FIGURE 7.43

Three 100 W Digital Sputnik heads connected to the DS3 controller/power unit. The modular heads can also be controlled individually with a DS1 power unit.

(*Courtesy Digital Sputnik*)

head to be the Wi-Fi server (which it is by default), and the others as clients. Lights can be assigned different channel numbers to control them separately, and they can be grouped within the app to control them together. The app provides an HSI interface (hue, saturation, intensity) as well as gel color functionality, and other features.

Architectural

The P-10 by SGM is an example of a high-intensity RGBW color wash. With a typical power of 1150 W, the output photometrics are close to those of a 4k HMI par. It is capable of lighting large buildings, bridges, and structures, and also has a high degree of color control including whites (2000 K to 10,000 K with plus/minus green tuning) and a full color palette. It has an innate beam angle of 10° that can be spread with lens accessories. It is compact (28″ × 16″ × 8″) and is designed for outdoor use with an IP65 rating.

CHAPTER

Established lighting instruments

8

Every light has three distinguishing parts to its design:

- the source—the type of light engine or lamp such as tungsten halogen, HMI, fluorescent, or LED,
- the optical design used to project, refine, and shape the light,
- and accessories that control the light or adapt it to alternative uses.

We'll begin by discussing the innate qualities of two light sources, tungsten and HMI.

TUNGSTEN

An incandescent lamp creates light by running current through a tungsten filament. A tungsten light can be powered directly by either AC or DC electricity. Tungsten halogen lamps are available in a wide range of output up to 24,000 W, and have a color temperature around 3200 K.

Unlike HMI, fluorescent, and LED sources, incandescent light has a continuous color spectrum, meaning its spectrum has no gaps or distortions. It includes all colors. Reducing the applied voltage smoothly dims the lamp from 100 to 0 percent. Various types of dimmers are detailed in Chapter 15. As the light is dimmed it also warms in color temperature, turning gradually more and more orange. The color temperature decreases as voltage decreases.

Most tungsten lamps are effectively flicker free at any frame rate because the light output of the filament decays very slowly compared to the frequency of AC current. However, small tungsten lamps (less than 200 W roughly) are more responsive and may flicker when photographed at high speed using a non-flicker-free flame rate especially if dimmed using a phase control dimmer.

HMI AND OTHER METAL HALIDE ARC LAMPS

A metal halide arc lamp, commonly known as an HMI,[1] generates light by creating an electrical discharge between two electrodes held a short distance apart from one another within a quartz envelope. The lamp produces a color spectrum of daylight-balanced light; it has a correlated color temperature of 5600 or 6000 K, depending on the globe manufacturer. HMI (and similar lamps) come in a wide range of wattages from 125 W (and less) up to 24,000 W.

[1] HMI is the registered trade name of Osram for its discharge lamps; however, HMI has become the common name referring to discharge lamps of this type, regardless of manufacturer. The many other manufacturers and trade names are listed later in this chapter.

An HMI has almost four times the light output as a tungsten light of the same wattage, 85–108 lumens per watt of electricity, compared to 26–29 lumens per watt for tungsten halogen lamps. This is partly because an incandescent lamp expends 80 percent of its energy creating heat (infrared wavelengths), whereas HMIs convert that same percentage of their energy into usable illumination. HMI light fixtures are also able to focus the light from the small arc source more efficiently than can be done with a relatively large tungsten filament. As a result, the beam of an HMI is brighter yet not as hot as the tungsten equivalent.

The color spectrum of a metal halide arc is not continuous; instead it has a multiple-line spectrum (Figure 8.1).

An HMI light uses a separate power supply, commonly called the *ballast*, which connects to an AC power source and supplies current to the light head using a multi-wire head cable containing power, ignition, and control/safety circuits. The ballast powers the igniter circuit to initiate the arc and then regulates the power to the lamp head. An HMI package therefore has the following component parts (Figure 8.2):

- Head (the light)
- Two head extension cables (from ballast to head)
- Ballast
- Separate ballast cable in most cases (to power the ballast)
- Accessories (depending on the type of fixture: barn doors, scrims, gel frames, lenses)

HMIs generally run on AC power (some power supplies for 200 W lights like the Joker-Bug 200 can also run on 28.8 V DC), and they cannot be operated on a dimmer line. Solid-state ballasts can dim the light to 50 percent by controlling the current. Ballasts are DMX512 controllable, and can be operated in a flicker-free mode for off-speed or high frame rates. HMI operation and limitations are described in Chapter 9.

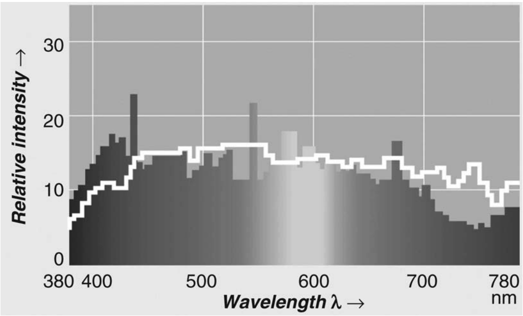


FIGURE 8.1

HMI lamp spectral power distribution. The white line represents the spectral distribution of actual daylight in Europe. The gray area shows the spectral distribution of an Osram 18 kW SE lamp. A multi-line spectrum shows a series of peaks distributed across the spectrum. These combine to make a reasonable approximation of daylight, with a high color rendering index of 95.

(*Courtesy Osram Corporation*)

FIGURE 8.2

K5600 Joker 1600 PAR head, head cable, ballast, ballast cable, lens set, Fresnel lens, lamp, barn doors, safety glass beaker and frosted beaker. (Nine-inch scrims not shown).

FRESNELS

The Fresnel (pronounced *freNEL*) (Figure 8.3) is characterized by its clean, hard shadows. It is a flexible light with optically adjustable intensity and field size using the flood/spot knob. At full flood a Fresnel produces a relatively wide, even field. Its clean beam makes it a good choice for lighting actors' faces, either directly or through diffusion.

The Fresnel was the workhorse of motion picture and television lighting throughout the twentieth century, which accounts for its wide availability and many accessories and variants (Figure 8.4). They were used in every way, for hard light and soft light. Today, LED softlights have taken over as the workhorse (see Chapter 7). However, the Fresnel still has no rival for creating pleasing, controlled hard light, and beautiful, clean, hard shadows. For a pattern on a wall, a splash of sunlight across objects, fabrics or textured surfaces, a clean, hard light is ideal. When you see sunlight streaming in through windows in a movie, odds are good that a 12/18k HMI Fresnel is sitting outside on the lawn

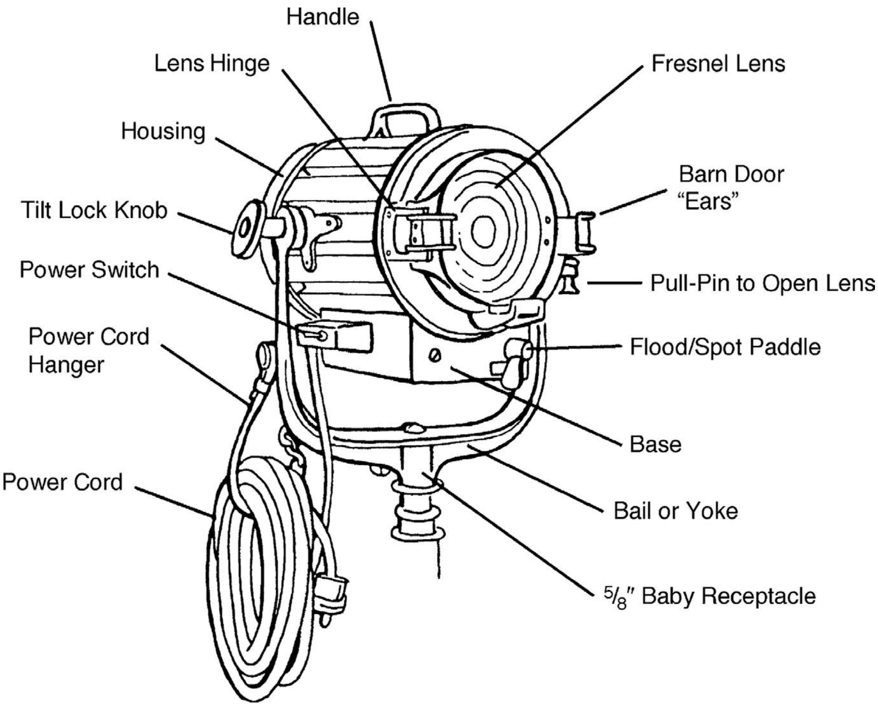


FIGURE 8.3

Anatomy of a Fresnel fixture.

(Figure 8.5). They are used to emulate sunlight, for key or fill on day exterior shots, or to cover wide exterior night shots from great distances.

Fresnels are available in standard wattages in tungsten and HMI, and there are LED Fresnels as well (Table 8.1). Our industry commonly refers to lights by their wattage as 1k, 2k, 5k, and so on. The letter k really means kW. A 1k is a 1-kilowatt (1000 W) light.

Flood/spot control

The light is named for its Fresnel lens, which refracts the diverging rays of light emitted by the lamp into a controlled beam of light. The Fresnel lens has the same light-bending characteristics as a standard plano-convex lens, but the Fresnel's design compresses the convex curve into jagged steps (Figure 8.6), making it lighter and thinner, so that it retains less heat. The back of a Fresnel lens is frosted or slightly pebbled. This helps maintain a very even beam and prevents the lens from actually projecting an image of the filament of the lamp.

Equally important, the fixture uses a *spherical* reflector. The reflector is really what gives the light its high level of control and even field characteristics, because the geometry of the reflector is such that light reflects straight back through the lamp (Figure 8.7). All light therefore emanates from the lamp center, which allows the Fresnel lens to control the beam cleanly.

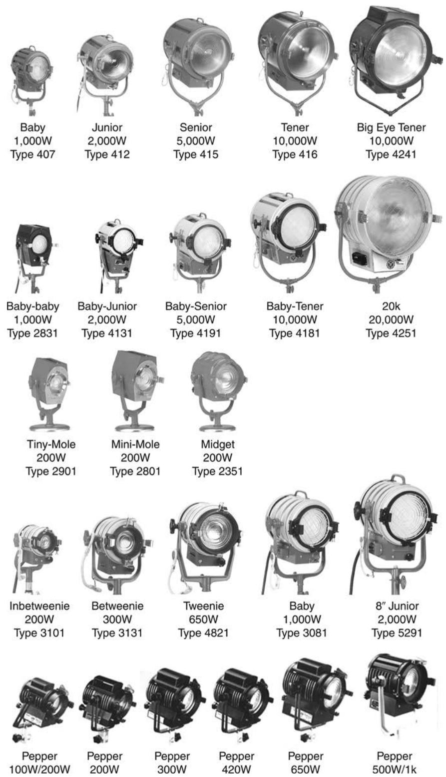


FIGURE 8.4

Fresnel fixtures come is all sizes from tiny 100 W fixtures to huge 24k fixtures.

(*Courtesy Mole-Richardson Company and LTM Corporation*)

FIGURE 8.5

A line of 18 kW HMI Fresnels surround a tiki hut.

(*Courtesy Mike Bauman*)

Table 8.1 Fresnel standard sizes

Approximate lens size (in.)	Tungsten	HMI	LED
2	150 W		
3–4	200 W 300 W		LitePanels Sola 4C
5	650 W (Tweenie)	200 W	ARRI L5 series, 115 W Mole Tweenie LED, 100 W
6–7	1k 2k (Baby Junior)	400 W 575 W	ARRI L7 series, 160 W Mole 6″ Vari-baby LED (250 W) Mole Baby LED 150 W Litepanels Solo 6C (104 W) D
7–8	2k (Studio Junior)	800 W 1200 W*	Mole 8″ Vari-Junior, 350 W Filex Q8 Travel, 340 W
10	2k (10″ Junior) 5k T5, Senior	1600 W 2500 W*	ARRI L10 series, 400W Mole 10″ Vari-Studio Junior LED, 480 W Mole 10″ Junior 400 W T or D LitePanels Sola 12, 346 W, D
14	5k (14″ Senior)	4k*	Mole Vari-senior LED, 900 W
14	10k (Baby-tener)		Mole Tener LED, 1600 W
20	10k (Tener Solarspot)		
24	10/12k (Big-eye tener)		
24–32	20/24k	12/18k, 24k	

* No longer manufactured. Possibly for rental.

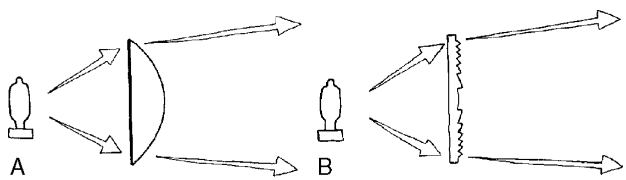


FIGURE 8.6

(A) A plano-convex lens pulls together the divergent rays of light. (B) A Fresnel lens has the same optical effect as the plano-convex lens, but it is cut away to reduce weight and heat retention.

Inside the housing, the globe and spherical reflector are mounted together and can be moved toward or away from the lens by an exterior adjustment knob. Moving the globe and reflector toward the lens *floods* the beam, increasing its spread and decreasing its intensity (Figure 8.7A bottom). Moving the globe and reflector away from the lens *spots* the beam, making it narrower and more intense (Figure 8.7A top).

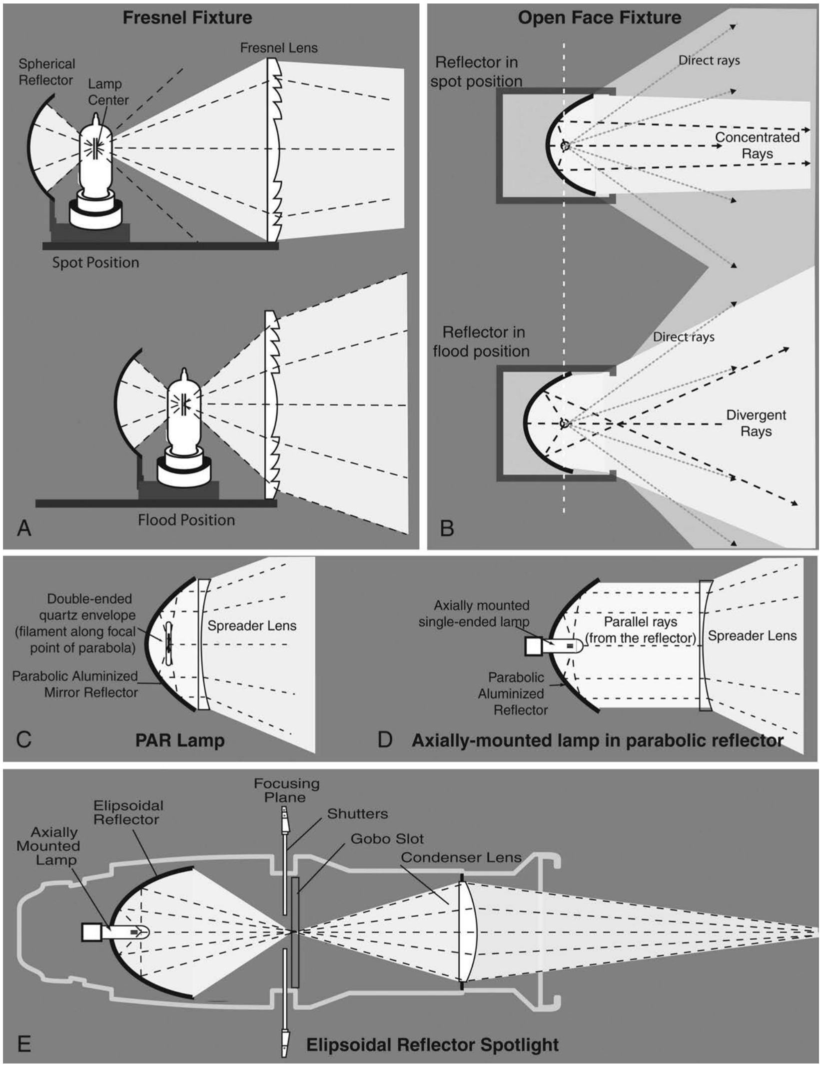


FIGURE 8.7

The design of the optical train—lamp, reflector, and lenses—affects the degree of control one has over the resulting beam as well as its efficiency and quality of the light. (A) Fresnel lights use a spherical reflector coupled with the Fresnel lens. (B) An open-face fixture comprises a simple lamp and reflector (which in this case has adjustable focus). (C) A parabolic reflector is used in PAR lamps and beam projectors to create a near-parallel shaft of light. (D) Many modern PAR fixtures employ an axially mounted lamp in a parabolic reflector. (E) The ellipsoidal reflector of a spotlight focuses all the light gathered by the reflector at a second position, where framing shutters, iris or gobo pattern can be inserted into the beam. Because they are inserted at this focal point, the beam edges and gobo pattern can be projected with sharply defined edges. The lens tube can be adjusted to focus the beam or to de-focus it, which gives it a softer edge that is easier to blend.

Tilt angle

Lamp manufacturers publish limitations on the angle of tilt at which a given light can be used based on the need for proper cooling of the lamp. Tungsten Fresnels should be hung with the base down. Each type of globe has a limit to the amount it can be tilted on its side without shortening the life of the globe. For example, a senior (a 5k Fresnel fixture) should burn with the lamp oriented within 45° of vertical. A 2000 W baby junior light hung at an extreme downward tilt will also melt the reflector. In practice, the tilt angle is of most concern for lights that have large, expensive lamps.

Fresnel beam

Figure 8.8 illustrates the terms *field* and *beam*, terms used in describing the photometric[2] qualities of a fixture. Figure 8.9 is a polar distribution graph that shows that varying the amount of spot or flood changes the manner in which intensity falls off toward the edges. At full flood, the beam is relatively even across a 40° sweep, then falls off quickly toward the edges. Fresnels are used in flood position a lot. The flood/spot mechanism is often used for little more than to fine-tune the intensity. Note that in full flood, the beam has no central hot spot; the field is very even. As the lamp is spotted in, the beam narrows and gets brighter in the center, falling off rapidly on either side. At full spot, the usable portion of the beam is narrow, around 10° typically. The term *throw* refers to the distance from the light to the subject. In spot position the light has a lot greater throw.

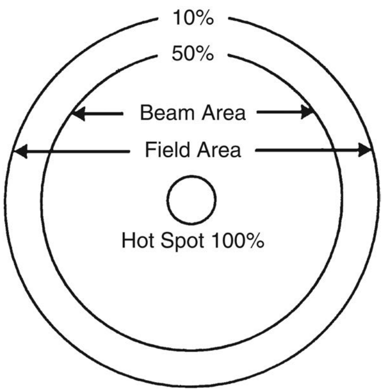


FIGURE 8.8

The field defines the "usable" light—the area of light that has an intensity of at least 10 percent of the peak value. Beam is defined as the "working light," the area of light that has an intensity of at least 50 percent of the peak value. The hot spot is the brightest spot within the beam. The terms beam angle and field angle refer to the angle, from the fixture, of the beam and field, respectively.

[2] Photometric data provided by a light manufacturer indicates the intensity of the light throughout its range of spot and flood. A typical Fresnel has a range from about 10° to 45° or 50°. Table A.2 gives the beam diameter at various distances for a given beam angle.

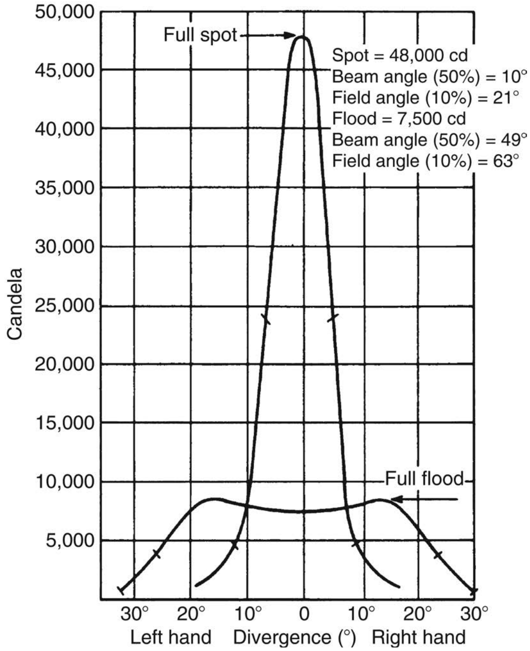


FIGURE 8.9

A polar distribution graph depicts light intensity across the diameter of the field of light. The upper tick marks denote the beam angle (the "working" light); the lower tick marks denote the field angle (the "usable" light). In the flood position, the light offers virtually even intensity across the wide spread of the beam; in the spot position, beam intensity falls off rapidly outward from the central hot spot.

Because of these characteristics, a spot beam is useful for scraping a streak of sunlight across a wall obliquely. With the beam center aimed deep across the set, the angle of the wall to the beam makes the streak almost even in brightness from near to far, creating the appearance that the source is actually much farther away than it is.

A Fresnel creates its hardest, most delineated shadows at full flood. The more spotted-in the fixture, the *less* sharp the shadow lines appear. In full spot position, rays from the Fresnel cross one another. This creates a fuzziness to any shadow cast from an object. To project a sharp shadow or make a silhouette (e.g., the classic gag of a silhouette cast on a closed curtain), use a light at full flood.

Photometrics, *beam angle*, and *field angle* are terms used in light manufacturers' sales literature; it is sometimes useful data to have during planning, but these are not terms you are likely to hear on set. In practice, however, lighting technicians use these concepts all the time. For example, say that a large room is to be lit using several lights spaced evenly along one wall of the room. To make the light intensity even across the whole room, the lights are set at full flood, and the edge of the beam of each light is feathered into that of the next. The beams overlap slightly at the 50 percent point, creating an even 100 percent intensity across the entire space.

Fresnel accessories

Fresnel lights should be accompanied by barn doors and a set of scrims in a scrim box or scrim bag. A typical equipment package also includes snoots for each size of Fresnel light.

Scrims

A scrim is a stainless-steel wire screen used to fine-tune the intensity of tungsten and HMI Fresnels. (LED versions have integrated dimmers and don't need scrims.) A single scrim has a loose wire weave, is identified by its green ring frame, and cuts the intensity of the light by approximately a half stop. A double scrim has a tighter weave, is identified by its red ring frame, and cuts the light by approximately one full stop.

STANDARD HOLLYWOOD SCRIM SET

1 single
2 doubles
1 half-single
1 half-double
1 gel frame

Half scrims affect just one half of the beam. A "bottom half-double" can be used to even out the intensity of the light as the subject moves closer to the fixture (Figure 8.10). It reduces the light falling on objects close to the light, bringing the light level down to that of objects farther from the light.

A gel frame can be used to hold gels or diffusion for short spans of time; however, because of the heat close to the lens, many lights melt gels mounted in the gel frame. Similarly, hot scrims melt the gel in a gel frame (and make a big gooey mess on the scrim). Therefore, gels and diffusion materials are often attached to the barn doors, spaced apart from the hot scrims.

Barn doors

Barn doors provide the most basic control over the placement of the edges of the beam. Because the doors are so close to the fixture, the cut is fairly soft (Figure 8.11). Barn doors typically have two large leaves and two smaller triangular ones. When the bigger doors are horizontal, they are said to be "Chinese"; when vertical, "American." By closing the two large leaves into a narrow slit and folding the small leaves out of the way, you can make a narrow slash. The slash can be horizontal—for an eye light, for example—or turned diagonally to make a slash across a background.

The most common way of attaching gel or diffusion to a Fresnel or open-face light is to clip it on with clothespins (Figure 8.12) or binder clips. Look out for light reflecting off the back of the gel and bouncing onto the walls of the set. Encircle the gaps in the barn doors with black wrap to block gel-reflection spill.

Don't be stingy with gel; cut a square of gel big enough that light does not leak around the side of the gel, causing spill. Placing the gel on the inside of the barn doors (Figure 8.12A) also prevents spill but puts more heat stress on the gel. Generally, this works well with Fresnel fixtures when they are flooded out. When using a dense gel, a particularly hot fixture (PAR or open face), or when the lamp is spotted, the gel is liable to lose color.

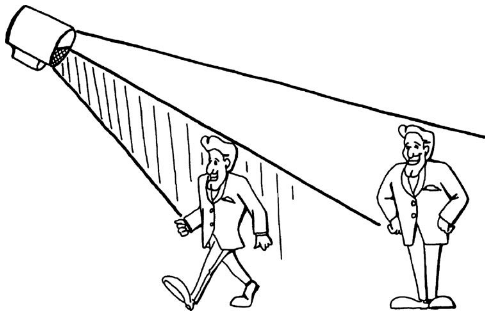


FIGURE 8.10

A bottom half-scrim is used to even out intensity as the subject moves closer to the light fixture.

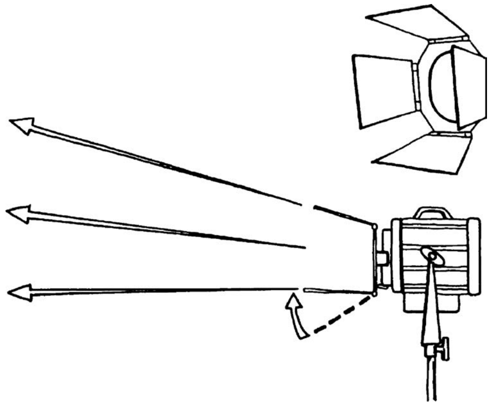


FIGURE 8.11

Barn doors contain the light, putting a straight edge on the beam.

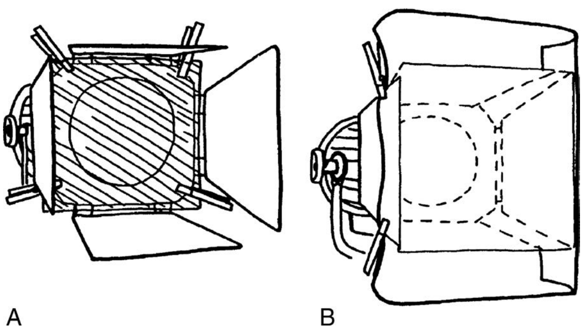


FIGURE 8.12

Gel and diffusion can be attached either inside (A) or outside (B) the barn doors.

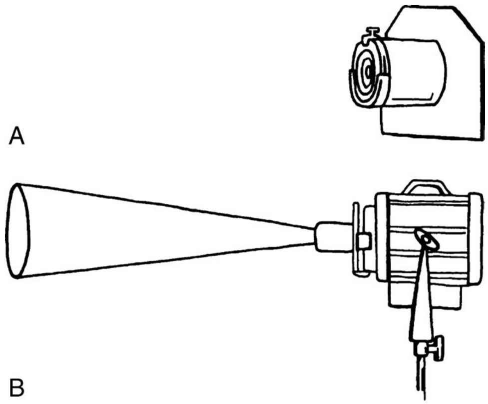


FIGURE 8.13

(A) A snoot with multiple aperture rings allows some flexibility in beam width. (B) A snoot confines the beam to a narrow circle.

Snoot

When a very confined, narrow, circular beam is desired, replace the barn doors with a snoot. Snoots come in various sizes, from wide (called a *top hat*) to very narrow (*stovepipe*). Some snoots are fitted with four rings with different aperture sizes so that you can adjust the beam width (Figure 8.13). You might use snoots if you wanted to light a set with small pools of light—lighting tables in a café, for example.

20k and 24k tungsten lights

20k and 24k lights are typically powered through a stand-alone dimmer. A dimmer is used to bring the lamp up to intensity more slowly than a switch does. These large lamps have a very high inrush current when started cold. The inrush current is hard on the lamp, and the lamps are expensive.

Lamps are available in various voltages: 208, 220, 230, and 240 V. It is important to match the lamp to the voltage of the system you are using. A 208 V lamp will be stressed if 240 V is applied to it. Conversely, a 240 V lamp running on 208 V will not have as much output and will have a warm color temperature. There are DPs who like to use a 230 V lamp on a 208 V system because they like the “warm look.” In fact, this is exactly the same thing as using the correct lamp and dimming it to 87 percent (but just keep that to yourself).

PAR LIGHTS

A parabolic optical design means the lamp filament is placed at the focal point of a polished aluminum parabolic reflector. Consequently, light is projected outward from the reflector in a column of parallel rays. The beam may then be widened by a selected spreader lens (Figure 8.14). This optical design

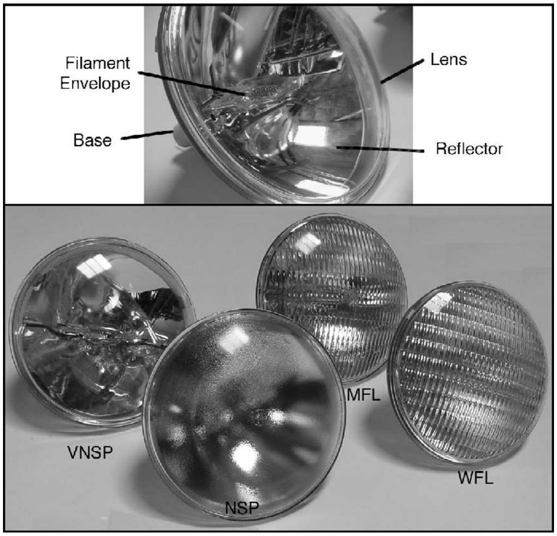


FIGURE 8.14

Anatomy of a PAR lamp. The lens types from left to right are very narrow spot (VNSP), narrow spot (NSP), medium flood (MFL), and wide flood (WFL). (Extra-wide flood, XWFL, is not shown.)

enables a very punchy, bright beam with more light output per watt than any other light. A single 1k PAR with a very narrow spot lens is as bright as a 10k Fresnel, but with a much smaller beam size.

There are three distinct light designs that are commonly called PARs:

1. A fixture having a single PAR lamp (PAR can, Molepar, etc.).
2. An array of PAR or FAY lamps (Maxi-Brute, nine-lite).
3. A fixture having a parabolic reflector with a bi-pin lamp that is axially mounted through the back of the reflector.

In the late 1960s and into the 1970s, Mole-Richardson Company developed a large range of light fixtures for our industry, grouping 1k PAR 64 lamps and 650-watt PAR 36 lamps (FAY) together in arrays to make relatively inexpensive, yet powerful lights. Around the same time, PAR lamps were built into “cans” and became the central fixture of the rock and roll industry.

PAR lamps

All of the optical parts of a PAR light are contained within the PAR lamp itself. The filament envelope, lens, and reflector are one permanently sealed unit, like an old-fashioned car headlight (Figure 8.14).

PAR lamps are available in a variety of sizes, the two most commonly used in our industry are 8-in. diameter PAR 64 lamps (500–1000 W) and 4½-in. diameter PAR 36 lamps (650 W, designated FAY). PAR lamps are named by the diameter of the lens in eighths of an inch. For example, a PAR 64 is 8 in. in diameter (64/8 = 8 in.). For any size PAR light, there may be a variety of different lamps: a range of spreader lenses, wattages, and color temperatures. The most common size is the 1000 W PAR 64.

(See also Tables B.4, B.5, and B.6.) Medium flood and wide PAR lamps tend to have an elliptical beam rather than a circular one. The lamp can be turned in its fixture to orient the beam for the coverage required.

For an even narrower, very intense beam, an aircraft landing light (ACL) can be fitted into standard PAR 64 housings. ACL lamps operate on 28 V but can be wired in series in gangs of four and connected to a 120 V circuit.

PAR cans

PAR cans are simple, lightweight, inexpensive, maintenance-free lights with no moving parts, made for the heavy-duty life of the concert tour (Figure 8.15). Their design is as simple as they come—a PAR lamp mounted at the back of a coffee-can-like cylinder that works as a snoot and has a gel frame slot at the front. PAR cans generally do not come with scrims; they typically are run on dimmers. The gel frame of a PAR 64 is typically 10 in. in diameter and any 10-in. scrim (Mighty-Mole) fits the slot.

PAR cans come in many sizes. The 1k PAR 64 is the most useful for lighting; the smaller PAR 56, 46, 38, 36, and 16 sizes are sometimes used as on-camera set decoration, as venue lights, and to light artwork or architecture.

ETC makes an efficient alternative called the Source Four PAR (Figure 8.16).

PAR cans are the workhorse of rock-concert lighting, because they can drive light through even the most saturated gel colors. Narrow-beam PARs can pound light onto a performer or produce strong

FIGURE 8.15

PAR cans come in black, white, or chrome finish.

(*Courtesy Mole-Richardson Company, Los Angeles, CA*)

FIGURE 8.16

ETC's Source Four PAR can accept a 575 W lamp or 750 W lamp with output superior to any 1k PAR lamp. Spreader lenses (VNSP, NSP, MFL, WFL, XWFL). Optional accessories include top hat snoot (gel extender), concentric ring snoot, and barn doors.

(*Reproduced by permission of Electronic Theatre Controls, Inc.*)

shafts of light in the atmosphere. The wider-beam PARs fill the stage with a wash of color. In motion picture and television work, narrow PARs are often used to splash a bright streak of sunlight across a part of the set or to bounce light. Because the narrow spot globes are so punchy, PARs are ideal for creating a strong water reflection effect (e.g., the moving light off a swimming pool). They can also throw light long distances, which is handy, for example, for lighting foliage or buildings at night. The light they produce is hard and unpleasant when used directly on faces, but bouncing a PAR onto a light-colored surface near an actor can create a beautiful glowing light.

PAR arrays

Arrays of PAR lamps (Figure 8.17) are available with 1, 2, 4, 6, 9, 12, 24, and 36 lamps. The most common is the nine-light PAR 64 fixture known as the Maxi-Brute (Figure 8.17B). *Mini-brute* or *nine-light* refers to the smaller PAR 36 nine-light (Figure 8.17D).

Large PAR arrays can put out a lot of raw light. They can be used to light large spaces at night or bounced into a 12′ × 12′ white griffolyn for soft fill. A nine-light works well as a bounce fill light, because you can adjust the intensity quickly by snapping lamps on or off. On a sound stage in large exterior sets, PAR arrays can create a dominant direction of light to simulate sunlight.

PAR arrays are designed in rows, or *pods*, of three to six lights. The pods are mounted into a metal frame. Usually, the pod can be swiveled and tightened with a knuckle at one end. This affords them some versatility. The pods can be individually focused—splayed out to cover a large area or focused to concentrate light in a smaller area. Additionally, the gaffer can have the fixture fitted with any kind of PAR lamps, from wide flood to very narrow, or can use a combination, as desired. One may even choose to mix color temperatures by including dichroic lamps. Relamping a large PAR array is time-consuming—something you want to take care of well ahead of time.

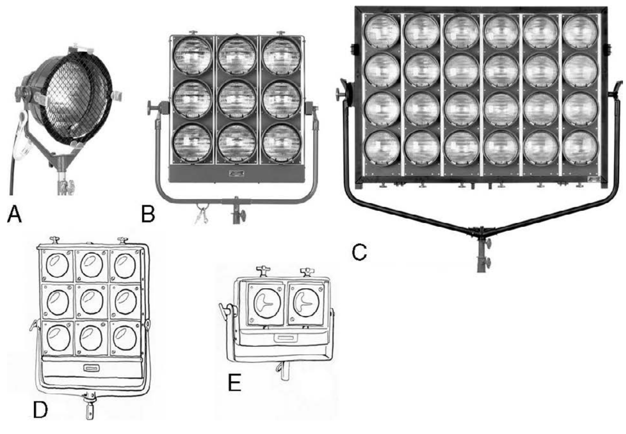


FIGURE 8.17

(A) Molepar fixture. (B) Maxi-Brute with three pods of three lamps each. The two outside pods can be panned individually. (C) Moleeno and similar Dino light arrays have 24 or 36 lamps. Because they can be lamped with any of the lenses shown previously PARs offer a lot of flexibility and punch. (D) The nine-light FAY uses individually switchable PAR 36 lamps (650 W). (E) Two-light FAY.

Axially mounted PAR fixtures

A sealed beam PAR lamp is inherently limited in wattage. It wasn't until lighting manufacturers turned their attention to the problem of creating HMI PARs that a solution was found for making punchy tungsten and HMIs in wattages of more than 1200 W. The solution is to mount a single-ended lamp in a parabolic reflector, with the lamp protruding through the center of the reflector mounted on the same axis as the reflector. This design enabled tungsten PARs (2k, 5k, 10k, and 12k) (Figure 8.18), and HMI PARs like K5600's Joker series (200, 400, 800, and 1600 W) and ARRI's M-series PARs (800, 1200/1800, 2500/4000, 9000 W, and the ARRIMAX 12/18 kW) and Mole-Richardson's Daylite PAR series (575, 800, 1200, 1800, 2500, 4000, 6000 W, and 12/18 kW).

PAR fixtures generally control the beam angle using a set of interchangeable spreader lenses. ARRI's M-series PARs do not have spreader lenses. Instead the beam is adjusted from about 20° to 60° using a flood/spot knob. Accessories include scrims and barn doors.

1800 W HMI PARs are the brightest lights that can be plugged directly into a 20 A wall outlet without overloading the circuit breaker. Similarly, two 800 W PARs can be plugged to a single outlet. ARRI's M18 power factor corrected electronic ballast is specially designed to remain below the 20 A breaker threshold to avoid nuisance trips.

A

FIGURE 8.18

Mole-Richardson makes Tungsten PARs at 2 kW, 5 kW, and 12 kW. The 12 kW Tungsten PAR shown here uses 208 V power, drawing about 57 A per phase. It comes with a set of five interchangeable lenses and has brightness equivalent to a 20 kW Fresnel.

(*Courtesy Mole-Richardson Co., Los Angeles, CA*)

The optical efficiency of 18k HMI PAR fixtures make them the most powerful of all the HMIs. They are more compact and lightweight than the large Fresnels—50 to 80 pounds lighter than the Fresnel counterpart, so it is possible to mount several of them onto the basket of a Condor without exceeding the maximum weight capacity.

Figure 8.19 shows 12k PARs on a feature set. Among tall downtown buildings in Los Angeles, the DP and gaffer maintained a consistent backlight all day long by lining up nine 12k PARs on a rooftop 400 ft. from the set.

The ARRIMAX (Figure 8.20), currently the brightest of all HMIs, has some unique features worth noting. It has two interchangeable reflectors, a standard reflector (which provides a flood/spot range from 15° to 60°) and a spot reflector (8°–15°). Both can yield tremendous light output; with the spot reflector the light is capable of providing a working f-stop (52 fc) from 500 ft. away. At 40 ft., it is as bright as the sun on a clear day (8400 fc). With the flood reflector, you can get 60 fc at 150 ft.

Joker-Bug

Also worthy of special note is K5600's Joker-Bug lights (200, 400, 800, and 1600 W), which are small fixtures designed with a range of accessories (Figure 8.21) that enable some surprising applications:

- A daylight lamp base for a Source Four ellipsoidal spotlight
- A highly directional PAR light
- A fabric soft box
- A lantern light

FIGURE 8.19

12k PAR fixtures line the roof of a downtown building giving an edge light to actors 400 ft. away and nine stories below. At that distance, the eight fixtures acted as a single source and did not cast multiple shadows.

(*Courtesy Mike Bauman*)

FIGURE 8.20

As the sun sets, an ARRIMAX 18/12 is already burning, extending the daylight for a few more precious minutes.

(*Courtesy Mike Bauman*)

- The Kurve parabolic reflector soft box with a round front, 3, 4.5, or 6 ft. in diameter (soft boxes with round-fronts—sometimes called Octoboxes—make circular eye reflections, a cross-over from still portrait and fashion photography)
- The Softube is a 45-in. long by 6-in. wide white translucent tube that attaches to the front of the Joker-Bug light.

The Bug 400 can be adapted to the Source Four ellipsoidal spot by removing the Source Four lamp housing and inserting the "bug-a-beam" adapter. The result is a daylight-balanced ellipsoidal spot with four times more brightness than normal. The short-arc MSR lamp is well suited to the task; the Source Four's beam is clean, sharp, and free of color fringing.

In Joker mode, the light is a small PAR fixture, very bright for its size. The spreader lenses allow wide control (a punchy 5° beam to a generous 55° spread). In the Bug mode, the "beamer" (the front housing containing the reflector) is removed, leaving only a bare omnidirectional lamp held in a UV-protective beaker. (Note that the Joker-Bug does not have a separate UV protection circuit; it operates with just three wires.) The Bug is used to illuminate a Chimera light bank or china lantern. The lamp can be oriented in any position. For lantern applications, the clear beaker is exchanged for a frosted one, which helps diffuse the source. Both the 200 and 400 Joker-Bug can run on battery packs using the Slimverter power supply, making the 400 one of the brightest hand-holdable portable lights available. They can also be run on any type of AC power.

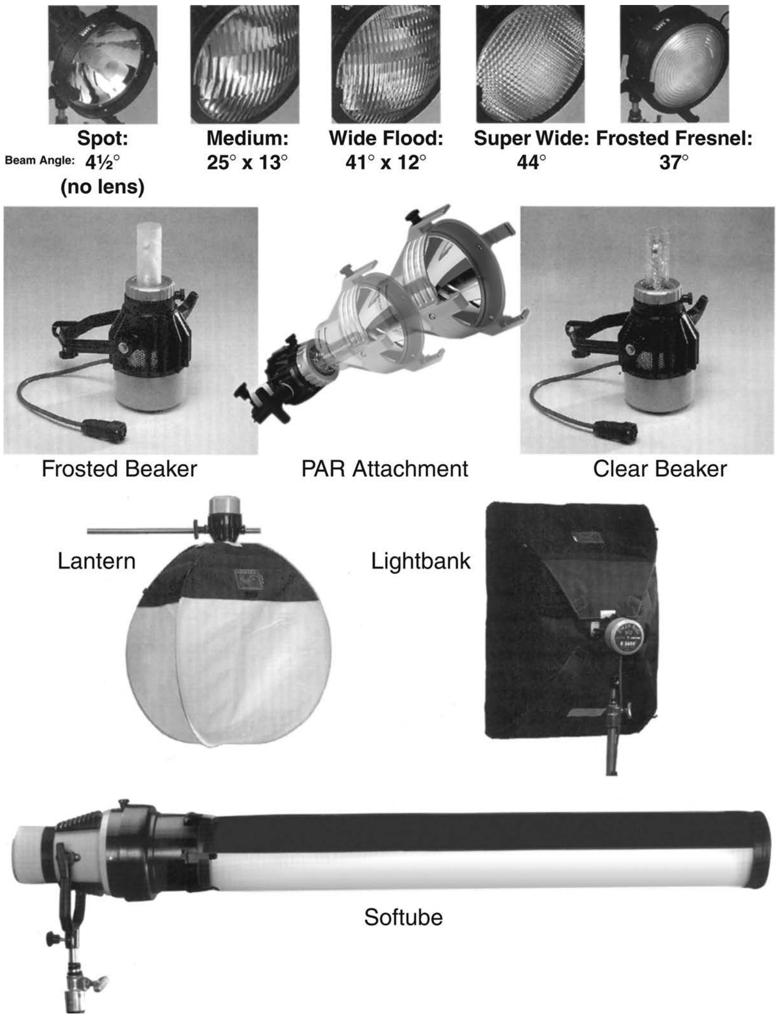


FIGURE 8.21

The Joker 800 in its many forms: PAR, bare beaker, lantern, chimera, Softube.

(*Courtesy K5600, Los Angeles, CA*)

ELLIPSOIDAL REFLECTOR SPOTLIGHTS

The ellipsoidal reflector spotlight (ERS) has long been the dominant light fixture used to light stage productions. It is also known as an *ellipsoidal*, or *profile spotlight*, or by trade names such as *Leko* and *Source Four*.[3] Ellipsoidal spotlights (Figure 8.22) were originally designed to give the theater lighting designer the strong throw, completely even field, and the control needed to light specific areas of the stage, blend the beam edges of adjoining areas seamlessly, and shape the beam to cut light from spilling where it is not wanted. Naturally, these fixtures are often employed when filming stage performances, but their special qualities are also very handy in other situations. An ERS can make a hard cut where there is no room to make a hard cut with a flag. For example, when an actor answers her front door, she is basically up against a wall with no space to fit a fixture to light her face. She can be lit easily with an ellipsoidal spotlight aimed into a piece of white show card taped to the inside wall beside the door. An ellipsoidal can make the hard cut necessary to prevent direct light from hitting anything but the card.

An ellipsoidal spotlight is able to project a beam that can be shaped by shutters, an iris, and a gobo pattern (Figure 8.23A). The shape of the beam is determined by the shape or pattern in the gate aperture (Figure 8.7E). The pattern can be brought into sharp or soft focus by sliding the lens barrel forward or backward.

The four cutting *shutters* (top, bottom, left, and right) can be pushed into the path of the beam to shape the beam edges into a square, rectangle, keystone, or whatever shape is needed. Immediately in front of the shutters is the *gobo* slot. The gobo pattern holder fits into this slot. Hundreds of gobo pattern templates are available, including a wide variety of window and Venetian blind patterns, foliage patterns, clouds, cityscapes, stars, flames—practically anything you can name (Figure 8.23B). Gobos are also available that are made of glass enhanced with color. Gobo manufacturers (like Rosco, Apollo, GAM, and many others) often provide materials on their Web sites showing the many extraordinary effects that can be created by layering color and gobo effects. The entire barrel section of the light fixture can be rotated to help in aligning shutter cuts or gobo patterns.

A second larger slot accommodates an iris, gobo rotator, or other accessories. The iris handle closes the leaves of the iris, shrinking the radius of the field.

The Source Four may be used with any one of many interchangeable fixed-focus lenses as shown in Table 8.2. Source Fours are also available with a permanently fitted zoom lens, which allows quick adjustment of the beam diameter and intensity. The narrower the beam angle of the lens, the greater the throw and intensity and the smaller the field. If you needed to project a gobo and fill a screen with only limited space, you could use the 50°, 70° or 90° lens to do so. On the other hand, if the light has to work far away from the performer, or if the beam has to be small and intense a 19°, 14°, 10°, or even a 5° can be used. To provide a point of reference, Table 8.2 shows the distance at which the field diameter will be 8 ft. across, and also gives the beam center brightness at those distances. You can calculate the field diameter at any distance using the multiplier in the right column.

The original ERS was a tungsten light of course. Being such a useful light, the Source Four was later adapted and fitted with an MSR (Medium-Source Rare-Earth) daylight lamp (Joker-Bug and others), creating a daylight-balanced light source with all the same control qualities of the Source Four except dimming. With the development of LEDs, a wide variety of full-color and white-tunable LED ellipsoidal spotlights came onto the market and have all but eclipsed the traditional tungsten light.

[3] Leko is the trademark of Strand Lighting but is widely used to refer generally to ellipsoidal spotlights. Source Four, made by ETC, is the most common ERS.

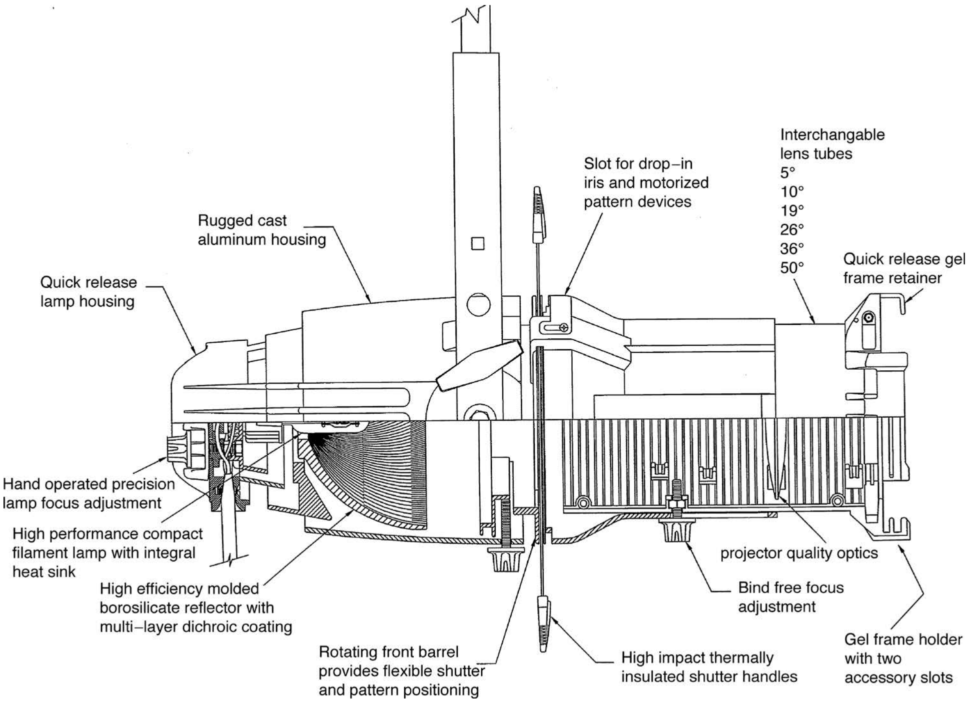


FIGURE 8.22

A cut-away view of the Source Four. The design is characterized by sharp shutter cuts without halation, even distribution of light through the field. 575 W or 750 W lamp.

(*Reproduced by permission of Electronic Theatre Controls, Inc.*)

Gel frames, gobo pattern holders, and irises are fairly standard accessories for film work. Other accessories include:

Donuts and hats—sharpen gobo patterns and clean up color fringes at the beam edge (at the expense of some light output).
Enhanced definition lenses—project detailed patterns cleanly like company logos.
Follow spot yoke and operating handles—adapt a Source Four into a balanced and smooth-operating poor man's follow spot (Figure 8.24A).
Gobo rotators—spin the gobo.
Motorized iris control—opens and closes the iris.
Linear gobo effects—flames that lap upward, rain or snow falling, ripples, or clouds (Figure 8.24B).
Color scroller—changes gel colors.
Pan/tilt automation—moving mirror or pan/tilt head.

Devices like gobo rotators and motorized irises are controlled via DMX512 and may require 24-volt power via Power/DMX.

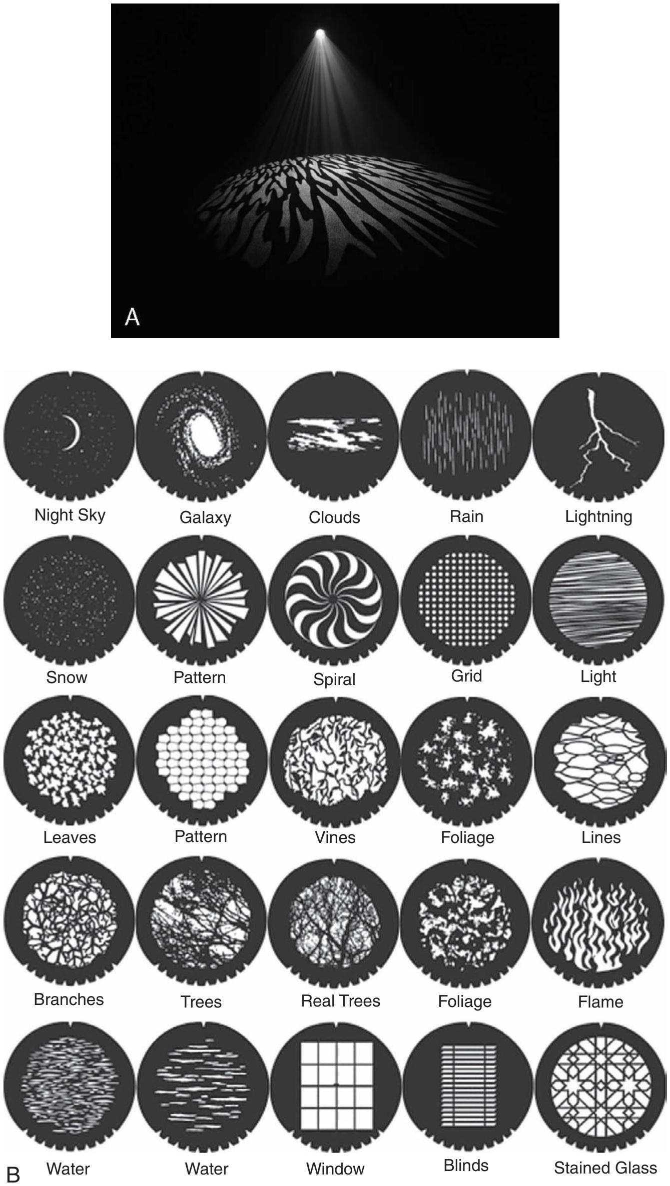


FIGURE 8.23

(A) The gobo pattern not only projects a pattern, but also breaks up the beam, which will be visible if there is a little smoke, fog, or atmosphere in the air. This photo shows one of the standard gobos of a Mac III Profile moving light. (B) This figure shows a small sample of the literally hundreds of gobo templates available.

(*A Courtesy Martin Professional*)

(*B Courtesy Lee Filters*)

Table 8.2 Source Four lenses and field diameter

Field angle (degrees of spread)	Equivalent lens diameter and focal length	Distance to achieve 8-foot field diameter/beam center brightness (fc) (HPL 750 W lamp)	Multiplier (to determine field diameter multiply by distance)
5°		66 ft. / 308 fc	0.12
10°		42 ft. / 444 fc	0.19
14°		30.7 ft. / 428 fc	0.26
19°	6 × 16	25 ft. / 392 fc	0.32
26°	6 × 12	17.8 ft. / 557 fc	0.45
36°	6 × 9	13 ft. / 534 fc	0.61
50°	4½ × 6	8.6 ft. / 616 fc	0.93
70°		5.7 ft. / 685 fc	1.40
90°		4.2 ft. / 619 fc	1.88
15°–30° Zoom			
25°–50° Zoom			

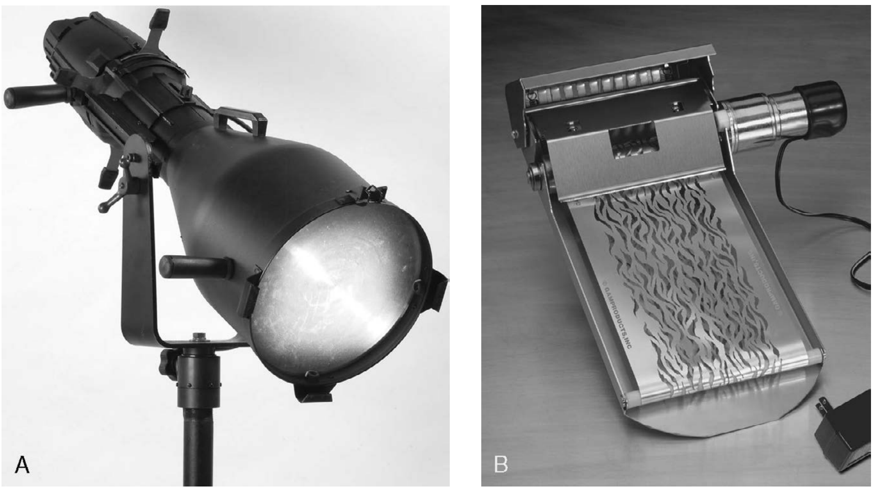


FIGURE 8.24

(A) A Source Four retrofitted for use as a fully functional follow spot, including a heavy duty follow spot yoke with professional pan bearings, handles for front and back of the fixture, and even a mini boomerang color changer or manual color scroller (not shown). The back handle acts as a counterweight for the color changer. (B) Film/FX scrolling gobo pattern.

(*A Courtesy City Theatrical, Inc.*)

(*B Reproduced by permission of GAMPRODUCTS, INC., Los Angeles, CA*)

DEDOLIGHTS

Dedolights are tiny low-voltage lights, capable of precision lighting work (Figure 8.25). The lights were originally designed by German cinematographer, Dedo Weigert, to fulfill his own exacting requirements. The projection attachment allows extremely precise control of the beam. It can be shuttered in on a beer label, for instance, providing a hard edge cut with no color fringing or softness around the edges. The lights are designed to provide exceptionally even light across the field, a high degree of control over all stray light, and a variety of projection attachments. The special lens assembly gives the fixtures punch for the long throw and an unusually wide range of adjustment. The DLH2 model ranges from 40° in full flood to 2.5° in full spot. A 100 W Dedolight has roughly the same light output as a 300 W Fresnel. The lights are so small, lightweight, and unobtrusive that they can easily be hidden in the set.

Dedotec makes tungsten, daylight, and LED light kits. The LED versions are 20 W, 40 W, and 90 W LED heads with 4°–50° spot/flood control, in tungsten, daylight, and bi-color versions.

BEAM PROJECTORS

The beam projector (BP) has been around since before movies were invented. In 2000, Mole-Richardson redesigned the BP in large sizes, both tungsten and HMI, for use in motion picture work, and they have proved to be a valuable tool (Figure 8.26).

The lamp in a BP is set in front of a large parabolic glass mirror, which fills the back of the unit. Fins or channels in concentric circles around the lamp cut side spill. The resulting beam is a straight, almost parallel column of light, similar to that of a xenon unit, but not quite as sharp. A flood/spot knob widens or concentrates the beam slightly (5°–15°) by sliding the lamp base relative to the mirror. BPs are all about showing shafts of light in the atmosphere, diffusion fog, special effects smoke, or dust in the air, which give the shafts shape. Unlike a xenon, however, BPs are available in tungsten, which can be controlled and cued easily on a dimmer.

FIGURE 8.25

The refined beam of a 100 W tungsten Dedolight.

(*Courtesy Dedotec USA, Inc., Lodi, NJ*)

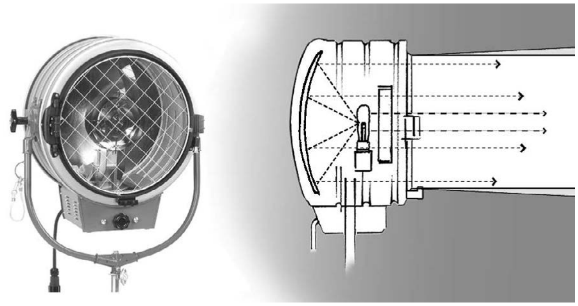


FIGURE 8.26

Beam projectors. The fixtures come in several sizes: an 18-in. fixture, either 2k tungsten or 1.2k HMI; a 24-in. fixture, either 5k tungsten or 2.5/4k HMI; and a huge 36-in. fixture, either 10k or 20k tungsten or 12k HMI.

(*Courtesy Mole-Richardson Company*)

AREA LIGHTS AND BACKING LIGHTS

Space lights

Tungsten space lights and their predecessor, chicken coops, are overhead lights, typically hung throughout a large set to fill the space with a general soft baseline illumination. A traditional space light (Figure 8.27B) consists essentially of six 1k nook lights configured like spokes of a wagon wheel, pointing down into a silk cylinder. At the bottom is a round diffusion ring to which a diffusion material and gel can be clipped.

There are a number of LED versions built on the same principle, most using the standard-size cylindrical lantern attachment: the SpaceX and Sky by Creamsource, Space Force, shown in Figure 8.28 by Chroma-Q™, Vari-Space by Mole-Richardson, the DS series (Figure 8.29) by Digital Sputnik. Most of these are designed to also be used in multiple ways in addition to overhead.

"Super" or "Maxi" versions of tungsten coops and space lights are redesigned to use PAR lamps in place of the original lamps. Super Coop (Dadco), Maxi Coop and Maxi Spacelite (Mole-Richardson), Top Light (Finnlight), and Mac Tech 6 and Mac Tech Spacelight (B&M) are examples of overhead lights employing PAR optics to increase the downward light output within a diffused source (Figure 8.27C). These lights are four or five times brighter directly below the fixture than a normal space light of the same wattage. The lights are brighter because they act less like a lantern and more like a directional source.

Backing lights

When lighting backings, translights, scenic paintings, and backdrops the goal is to light it evenly from side to side and top to bottom. Backlighting is typically done by hanging evenly spaced lights behind the translight with some sort of broad, even source such as the following:

- LED panels or LED ladder lights (Chapter 7).
- Fluorescent banks such as Kino Flo's Image 80.
- Skypans.

FIGURE 8.27

(A) The chicken coop. (B) Space lights are available with either a single 60 A connector or Socapex connector, that allows individual control of all six lamps. Space lights are available in a 2k version (two 1k lamps), a 6k version (six 1k lamps), and a 12k version (six 2k lamps). (C) The Super Coop employs six 1000 W PAR 64 lamps, and two diffusion layers to create a very strong downlight.

(*Courtesy Mole-Richardson Company, Los Angeles, CA*)

FIGURE 8.28

Chroma-Q™ Space Force. The face of the light is diffuse and acts as a single source so the light does not need a silk, but it can be ordered with a full range of skirt and silk accessories. The head weighs 18 pounds and can be rigged from a simple three-leg bridle, suspension hanging bracket, or yoke mounted. It is a bi-color light (2800 K to 6500 K) and, at 333 W, can be as bright as a traditional 6 kW space light. It does not have fans. It has complete onboard controls as well as DMX and can be ordered with a wireless DMX (LumenRadio) receiver.

(*Courtesy Chroma-Q*)

A skypan is simply a big, white pan reflector with an exposed tungsten lamp mounted in the center (Figure 8.30). The light can be made softer and more even by employing a frame of diffusion. The gel frame fits into a metal skirt that attaches to the face of the light.

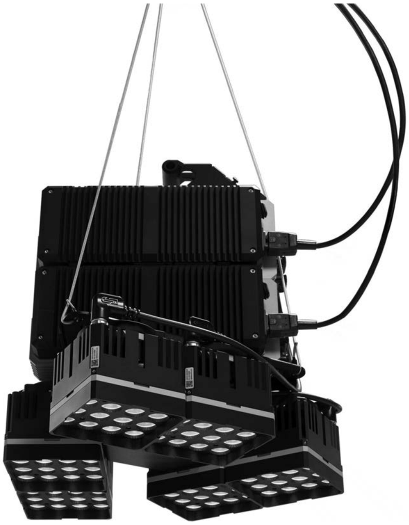


FIGURE 8.29

Digital Sputnik's DS series heads can be ganged together as 3- or 6-module space lights or like a PAR array with 3, 6 or 18 heads.

(*Courtesy Digital Sputnik*)

Cyc strips

A *cyc strip* is a row of lights placed at the bottom and/or top of a backdrop (Figure 8.31). To illuminate a vertical surface evenly top to bottom, the strips have asymmetrical optical elements that concentrate the light where the beam has a longest throw. The term *cyclorama* (or cyc) refers to a seamless wall used as a backdrop. The term is borrowed from theater where a seamless canvas, muslin, or scrim material is commonly used behind the sets, often to create a skyline, and lit with cyc strips. In film and television, we commonly use an *infinite cyc*—a permanent hard wall built with a curve at the bottom that seamlessly transitions into the floor so there is no visible line at the base of the wall. A white cyc is commonly used to create a "limbo" set. It may also be painted blue or green for shooting foreground elements for matte photography.

Today, color LED cyc lights have replaced the traditional tungsten strips. There are many versions of theatrical color washes for uplighting a cyc or mounting to batten. Chroma-Q's Color Force™ and Studio Force™ fixtures use RGBA color mixing, provide a smooth even wash and high intensity (Figure 8.32). The Studio Force™ fixtures are designed specifically for film applications and have tuneable white (2800–6500 K with plus/minus green control) as well as full color. The Studio Force™ also has an onboard control interface and is available with film accessories like egg crate louver, barn doors, top hat, and soft box kits. The lights have theatrical grade dimming, meaning they can be dimmed to blackout smoothly. These lights are available in 1 ft. (150 W), 4 ft. (550 W), and 6 ft. (800 W) lengths.

FIGURE 8.30

Skypans backlight a translight backdrop. They are available as 2k, 5k, 10k, or 20k.

(*Photo by Mike Bauman*)

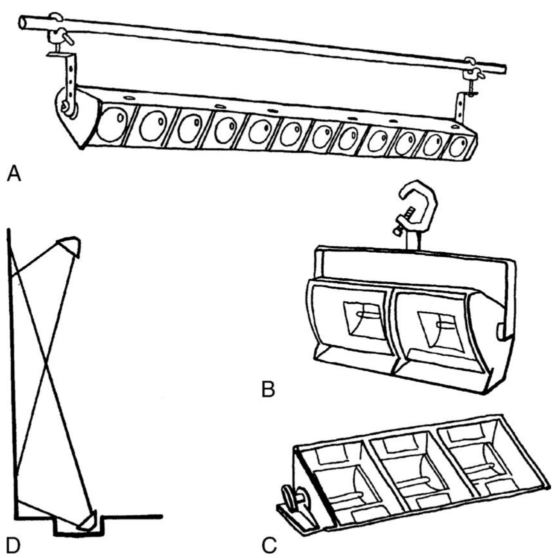


FIGURE 8.31

(A) Border light. (B) Cyc light for hanging on batten, (C) ground row, (D) the typical method of lighting a cyc evenly from top to bottom.

The angle of the strip and its distance from the *cyc* is critical for achieving even lighting from top to bottom. See manufacturer recommendations for best results. When a cyc is lit from both top and bottom, the cyc can take on a gradation of colors from top to bottom—simulating a sunrise, for example.

FIGURE 8.32

Chroma-Q Studio Force™ and accessories.

(*Courtesy Chroma-Q*)

OPEN-FACE LIGHTS

Tungsten

As the name implies, open-face lights have no lens. They are simpler, less expensive, and less refined than Fresnels. The beam is not directed and even like a Fresnel; it splays out in all directions from the lamp and the reflector, creating a double shadow line. Open-face lights make good bounce lights or can be handy for lighting elements of the background set. To be used for lighting actors, a medium to heavy diffusion is needed to blend the source and take the garish curse off the light.

Note that open-face lights tend to burn very hot and can melt a foamcore bounce board or destroy a flag if it is placed too close to the light. Think twice before rigging a light close to set pieces and allow ventilation above the fixture.

Figure 8.33 illustrates some open-face lights with which a lighting technician must be familiar. The Blonde (2k) and Redhead (1k), shown in Figure 8.33, have a crudely adjustable reflector for flood/spot control and come with barn doors and a scrim set. Open-face lights tend to spill light everywhere. To compensate, they need large barn doors. They are lightweight, durable lights with a relatively high intensity per watt.

HMI "open-face" lights

The ARRI X series (discontinued but still available for rent) and Desisti Goya lights are "open-face" HMIs featuring a very broad beam (almost 180°). They have only UV-protective glass in front of the lamp and reflector, but no lens (Figure 8.35). The UV glass can be clear or frosted. Their beam is broad and unfocused. They can be oriented in any direction including pointing straight down as an overhead soft light (through heavy diffusion) or straight up for architectural lighting. They cast a hard shadow. They were manufactured in sizes of 200 W, 575 W, 1200 W, 2.5k, 4k, and 6k.

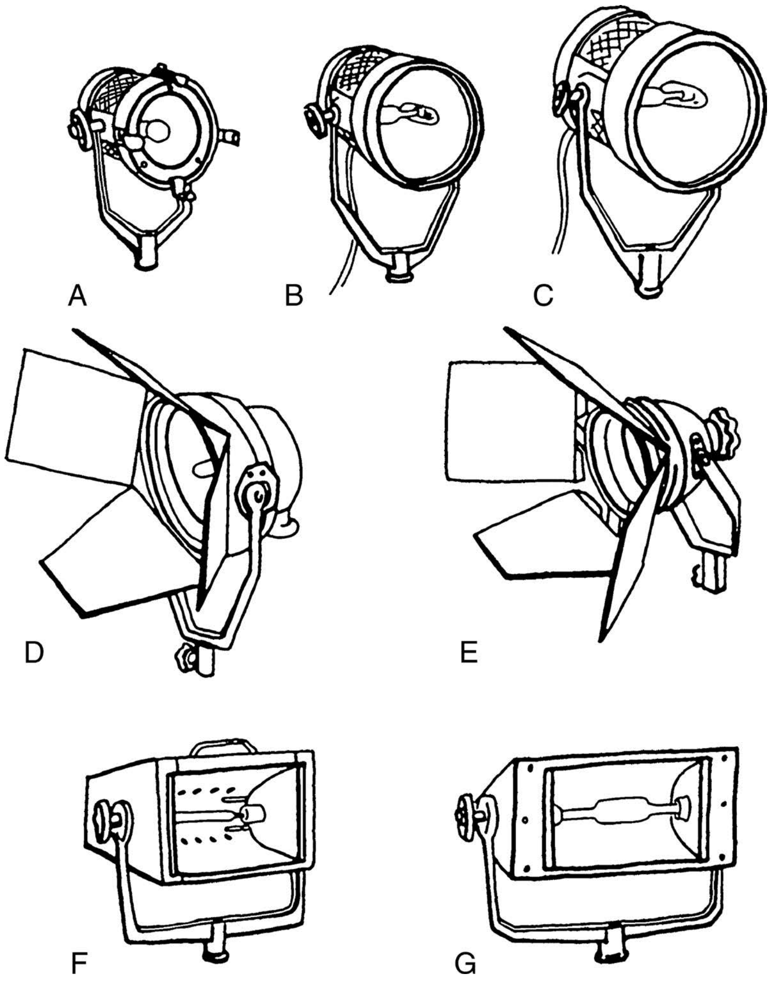


FIGURE 8.33

Open-face fixtures: (A) 650 W teenie-weenie, (B) 1k Mickey, (C) 2k mighty, (D) 2k blonde, (E) 1k redhead, (F) 1k broad, (G) 1k or 2k nook light.

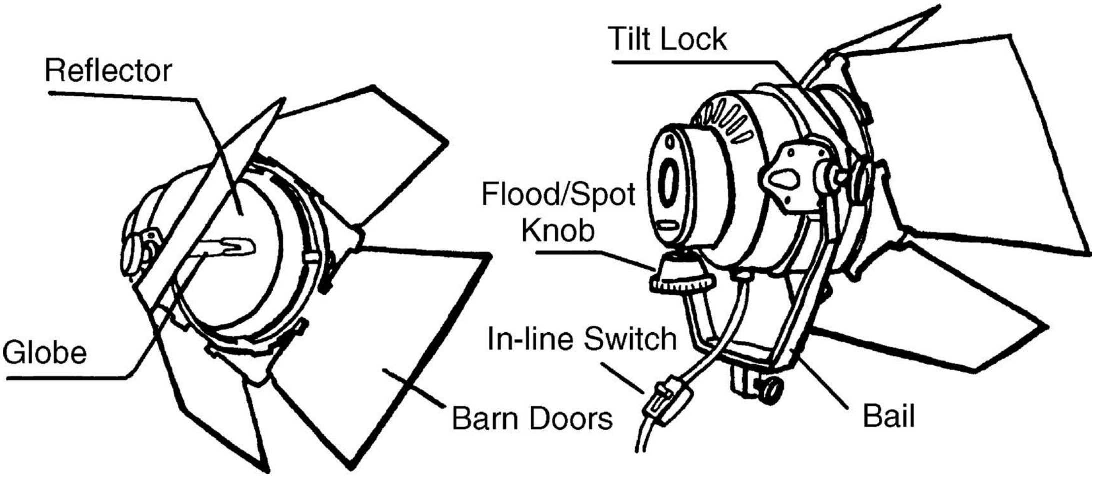


FIGURE 8.34

Anatomy of a blonde 2k open-face fixture.

FIGURE 8.35

The ARRI X 40/25 light is an open-face light, with clear or frosted UV protective glass.

(*Courtesy ARRI Lighting*)

TUNGSTEN SOFT LIGHTS

The original tungsten soft lights (Figures 8.36 and 8.37) use tubular tungsten halogen globes directed into a white concave reflector. Because it is indirect, bounced off a diffuse white surface, and exits through a relatively large aperture, the resulting light is soft and has a wide, even, uncontrolled spread.

2k, 4k and 8k soft lights have multiple 1k tungsten globes, each switched individually to increase or reduce the light's intensity. Figure 8.37 shows the egg crate and snoot, which can also be used to contain and control soft light. A gel frame is also a standard accessory. Soft lights do not generally have scrims, but you can improvise by inserting a baby scrim between the base and the white reflector surface, sandwiched with the egg crate and held in place with a grip clip.

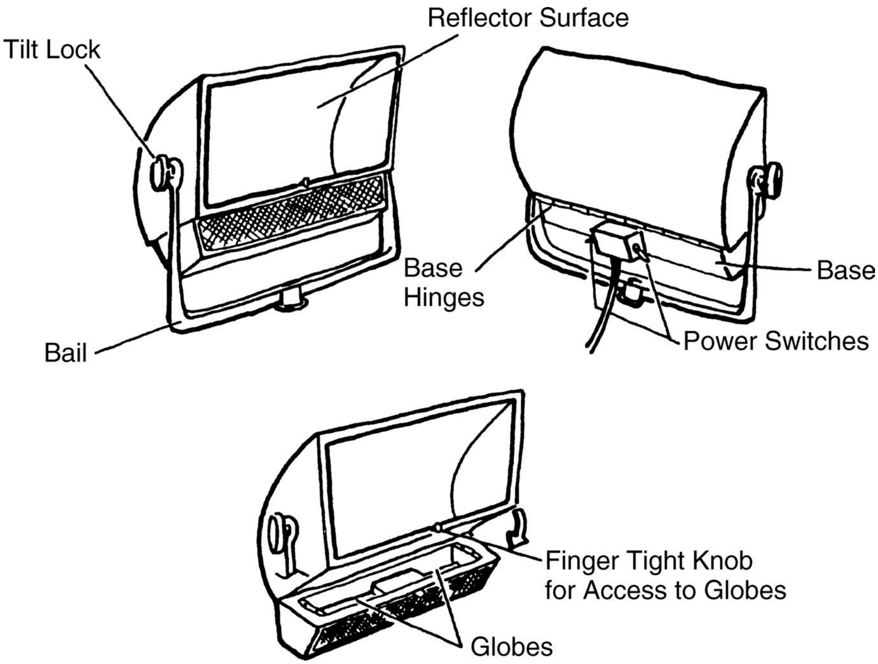


FIGURE 8.36

Anatomy of a 2k zip soft light.

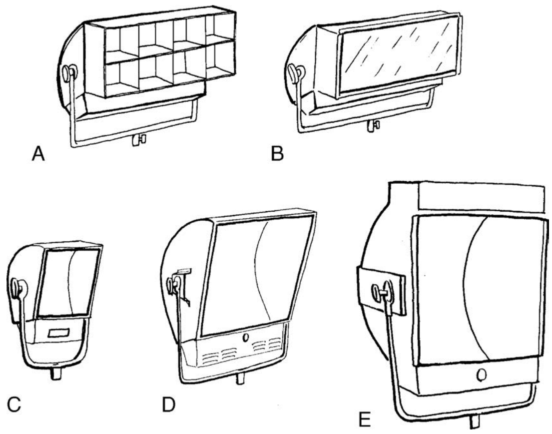


FIGURE 8.37

Soft lights and their accessories. (A) Egg crate: this black, metal grid helps control spill. It is a good idea to keep an egg crate with each soft light because they are used frequently. (B) Diffuser frame (shown here placed on the front of a snoot): this square gel frame fits in the front of the unit to hold colored gel or diffusion. (C) 750 W zip. (D) 4k soft. (E) 8k Softlite.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

CHAPTER

Operating HMI lights

9

HMI LAMPS

Large HMI lamps should be removed for transport. Since the lamp is mounted horizontally, it can easily be cracked by vibration or a bump in the road or by being set down hard. Be especially careful with large SE lamps. Keep in mind that these lamps are hand-made, not machine-manufactured. At this writing, a single-ended 18k lamp goes for about $2,400. In a Fresnel fixture, the single-ended lamp is mounted vertically and is not subject to as much strain.

To install a lamp in an HMI, first disconnect the head cable from the light head. Never open the light when the head feeder is connected. De-energizing at the ballast does not provide acceptable protection because the circuit breakers could be 25 feet away and not under the lamp operator's sole control.

Most par fixtures have a lamp-lock lever or knob on one side of the fixture. Turning this knob counterclockwise 90° releases the lamp from the base. The tightness of the base can be adjusted in the shop. On ARRI M-series pars the lever is under a protective cap that you slide to access the lever. Proper adjustment allows for some expansion of the lamp pins when hot. A base that is too tight puts stress on the lamp base and can cause lamps to crack with expansion.

The design of some par fixtures may require handling the lamp by the glass during certain stages of installation or removal. Hold the glass with clean cotton gloves or a clean rag. Care must be taken to avoid breaking the glass where it attaches to its ceramic base. Do not wiggle the globe across the axis of the pins; any stress across the axis can very easily snap the quartz.

A single-ended lamp base not *fully* inserted into the socket can cause a costly meltdown. 12k/18k lights can have extremely high ignition voltage. If the pins are not fully inserted, at high voltage electricity will arc between the pins of the lamp, with potentially expensive consequences.

ARRIMAX

There are a couple of extra steps to know when lamping an ARRIMAX. Follow these steps:

1. With the light in a stable position, and the head disconnected from the ballast, first turn the focus knob to place the reflector in the spot position (Figure 9.1A).
2. Open the lens door by pressing the door latch on the front righthand side of the face of the light, 4 o'clock position (Figure 9.1C).
3. Open the side cover by pressing the release knob on the rear of the housing (Figure 9.1B)
4. The lamp-lock lever is located inside the cover. Release the lamp by turning the lamp-lock lever counterclockwise to the horizontal position.

5. ARRI designed a ceramic feeler into the lamp socket that is connected to an indicator located beside the lamp-lock lever. When the lamp is fully seated, the indicator lines up with an arrow to give the operator positive confirmation that the lamp is fully seated. Regardless of which light you are lamping, be sure that the pins are fully inserted into the socket before locking the lamp.
6. Make sure the lamp is centered in the reflector.
7. Tighten the lamp-lock lever (clockwise to vertical position).
8. Close the side door. Close the lens door. It should latch with the click.

The 12k/18k single-ended lamps are manufactured in two base sizes: G38 or G51; 12k single-ended lamps use the G38 base. To accommodate this, some manufacturers use dual-size sockets that can take either size of lamp. For large single-ended lamps, some manufacturers specify that the rod should be oriented above the envelope; others say that it should be below the envelope. Osram says it doesn't matter which way it is installed. You just have to read the instructions that come with the lamp.

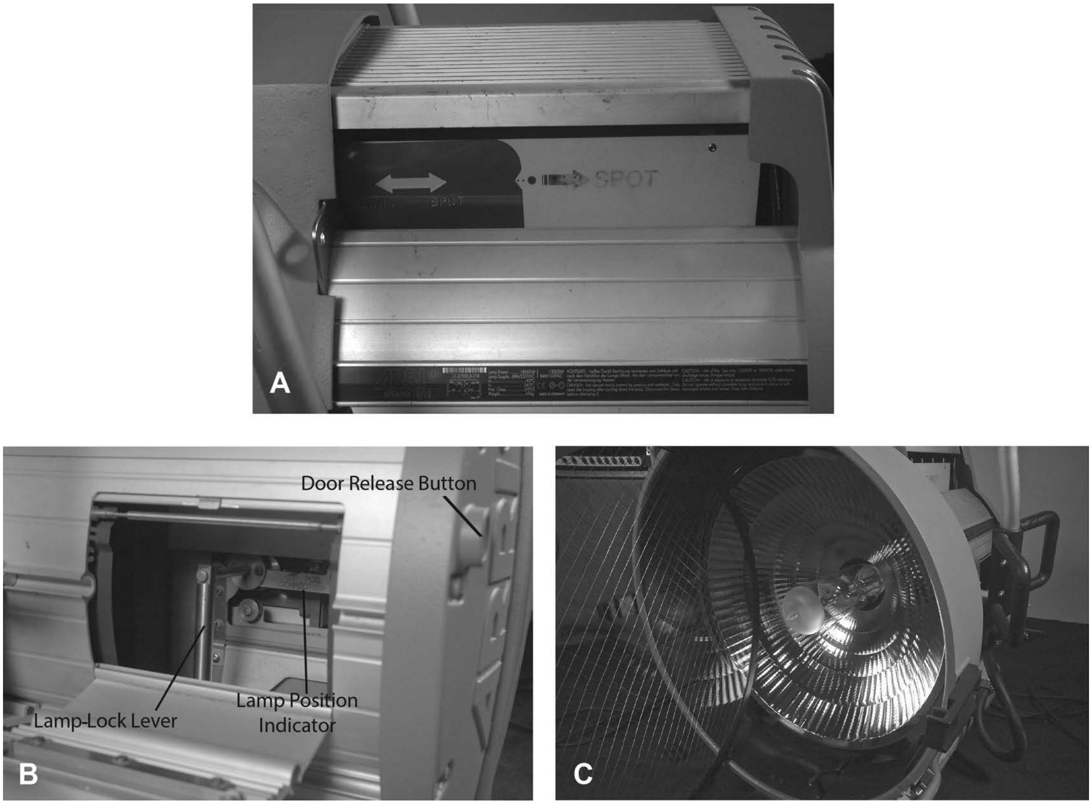


FIGURE 9.1

Lamping an ARRIMAX. (A) Flood/spot indicator shown in the flood position. (B) The lamp-lock knob is inside the side door. (C) UV glass door, reflector, and lamp.

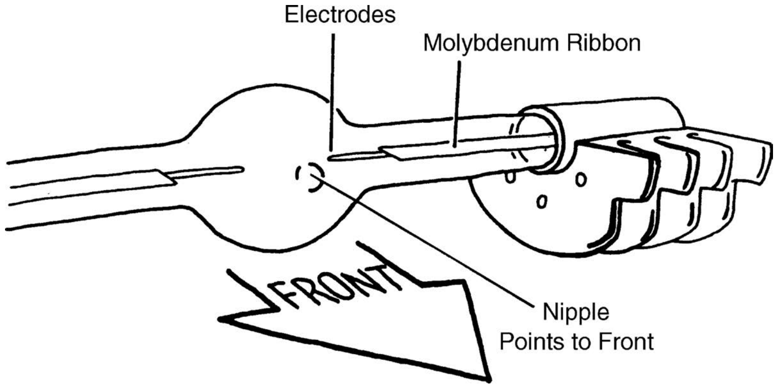


FIGURE 9.2

Installation of a double-ended HMI globe. Note that the ribbon is horizontal, and the nipple is oriented outward (it may also be oriented upward). Connections are tight. Note that some manufacturers make different installation recommendations; check the documentation that comes with the lamp.

Double-ended lamps

Some lamp manufacturers specify that double-ended globes should be installed with the molybdenum ribbon horizontal so that it does not block light returning from the reflector (Figure 9.2). Some specify the orientation of the nipple of the quartz envelope. Take a look at the manufacturer's recommendations for installation.

Other notes about HMI lamps

In cold weather, the abrupt change of temperature when lamps are shut down can cause lenses to crack. You can avoid this by lengthening the time during which they cool down. Do this by adding scrims to the light a minute or two before shutting off the light. The hot scrims help slow the cooling of the lens when the light is shut off.

For safety reasons, manufacturers recommend that globes not be used for more than 125 percent of their rated service life. As the bulb ages, changes in the quartz glass envelope make the globe increasingly fragile.

Most HMI Fresnel and par fixtures that use single-ended globes have a good range of tilt. Lights under 4k can generally be pointed straight up or down. Fixtures 4k and over are generally limited to 75° up or down from horizontal. Double-ended HMI lamps generally are assigned a more restrictive range of up/down tilt and also have restrictions on how much they should be operated tilted sideways—usually plus or minus 15 degrees left and right.

NORMAL HMI OPERATION

Before connecting the head feeder, check that the lamp is installed and seated properly. Do not turn on the light without a lamp installed. The ballast circuit breakers should be off, or the ballast unplugged while connecting or disconnecting head cables and when plugging the ballast into power. This protects the front-end electronics from inrush current.

VEAM head cable connectors[1] use a threaded collar that twist-locks onto the receptacle. Use the keyway to orient the plug into the socket. The VEAM connectors for 575, 1200, and 2500 W are identical, except that the keyway is oriented differently. To tell the cables apart, some rental houses color-code the connectors or cables as follows:

Green	575
Yellow	1200
Red	2500
Blue	4k

As with all connectors, the head cable connectors are a possible point of failure and must be treated respectfully. Be sure to tie a tension relief so that the weight of the head cable does not pull on the connector, especially with larger lights that have heavy head cables.

Many electronic power supplies provide dual outputs so that they can be used with more than one wattage light (see sidebar).

COMBINATION BALLASTS

- 575 W, 1.2k
- 575 W, 800 W, 1200 W, 1800 W
- 1.2k, 2.5k
- 1.2k, 1.8k
- 575 W, 1200 W, 2.5k, 4k
- 2.5k, 4k
- 4k, 6k
- 6k, 9k
- 6k, 12k
- 6k, 9k, 12k, 18k
- 12k, 18k
- 12k, 18k, 24k

When a ballast has two output sockets, both are continually energized when the ballast is powered and on. Some manufacturers provide a flip-flop flap that covers the unused socket. You can also tape over the unused socket.

To ensure reliability, HMI manufacturers recommend that no more than 150 feet of feeder cable be used between the head and ballast. The success of employing more than two 50-ft. head feeders at a time will depend mostly on the condition of the cables and the connectors. Connectors impose resistance. The more connectors there are, and the worse shape

[1] VEAM connectors are used in North America. In Europe, HMIs typically use Schaltbau connectors.

they are in, the less likely it is that the ballast will succeed in striking the light. For long runs, reliability is better using 100-ft. head cable in place of two 50-ft. cables together (special order item). A single 200-ft. head feeder cable in good condition will work reliably (special order item).

Striking

Once the head cable is connected to the head and ballast, plug in the ballast and switch on the circuit breakers. Indicator lights on the ballast will light to show that you have power to the ballast. Some ballasts also indicate that a ground is present. This is labeled "PE" for Phased Earth on ARRI-style ballasts (see Figure 9.3).

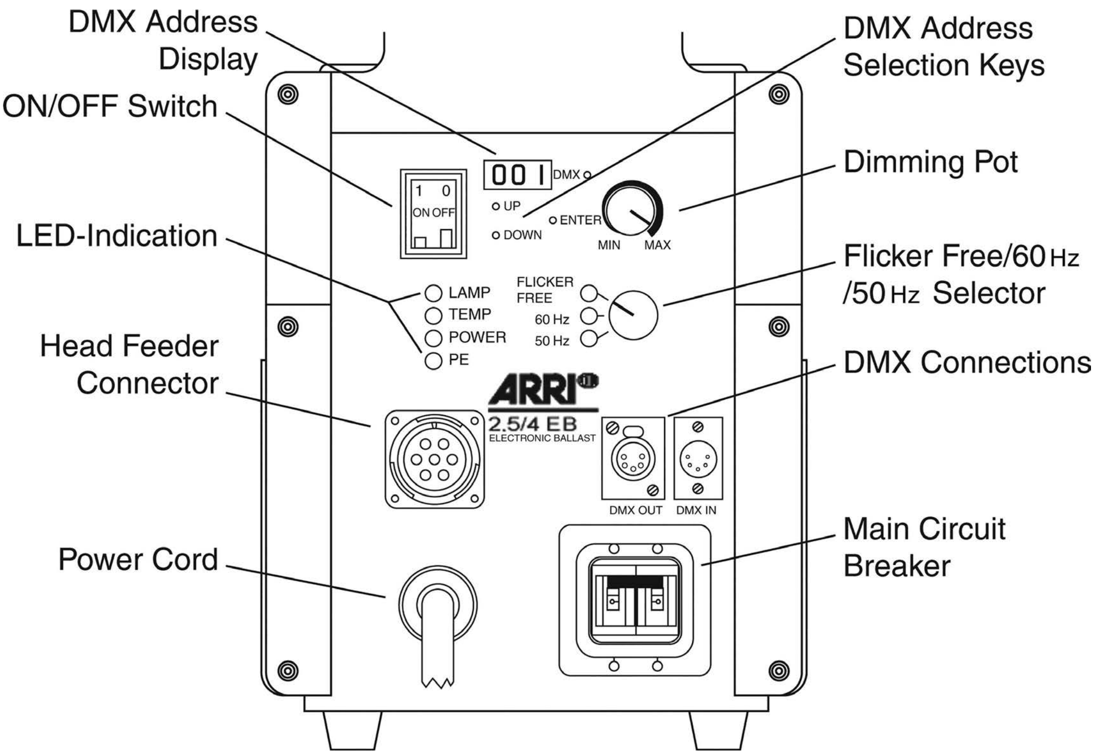


FIGURE 9.3

An ARRI 2.5/4 kW electronic ballast with DMX. A three-position knob selects 50 Hz, 60 Hz or "flicker free." The dimmer pot can dim the lamp to 50 percent.

With 12k and 18k Fresnel lights, place the bulb in the full spot position before pushing the ON switch. This backs the bulb away from the lens, to reduce the risk that the lens could crack from thermal shock. It also reduces the chance of shattering the lens in the (rare) event that the globe explodes during warmup. When 12k or 18k bulbs do explode, they often go within the first 5 or 10 minutes of ignition or reignition.

Before pushing the ON switch, call out "Striking" to warn people that the light is about to be ignited. When you press the ON switch, an electronic ballast may take 5–10 seconds to charge the capacitors, then the ballast briefly sends an ignition charge to the head, and this makes a sparking sound. The igniter circuit provides a brief ignition charge (about 0.5 seconds). The ignition voltage is very high: anywhere from 4500 V for a 575 W lamp to 20,000 V for an 18k lamp (and up to 70,000 V for hot restrike). The ignition charge establishes the arc between the electrodes in the globe. Once the flow of electrons is initiated, the ballast brings the voltage down to the operating level and regulates the current.

Once sparked, it takes a couple minutes for an HMI to come up to its nominal brightness. From a cold state, it takes 1–3 minutes for the substances in the globe to vaporize. At the same time, lamp voltage, lamp current, luminous flux (brightness), and color temperature all settle to their nominal values.

With some older ballasts, reigniting a globe that is hot from recent use can be unreliable. Hot gasses inside the globe are under great pressure, creating very high resistance. To overcome this resistance and ionize the gas between the electrodes, a much higher ignition voltage is necessary. The electronics of newer ballasts take this into account and have better hot restrike performance; often, however, an older magnetic ballast cannot produce sufficient voltage and you have to wait until the lamp has cooled (2 or 3 minutes) before you can restrike. This process can be hastened by opening the lens door to provide extra ventilation.

DMX512-controlled ballasts

Ballast manufacturers offer DMX512-controllable versions of their ballasts. The units can be turned ON and OFF and dimmed to 50 percent remotely. An HMI cannot be dimmed lower than 50 percent. With high-frequency ballasts you can also control the frequency remotely. Be sure to obtain the correct DMX personality from the manufacturer for the particular make and model. See Chapter 12 for a description of DMX and fixture personalities.

When controlling the ballast on DMX, the ballast must be switched on *from the console*. The dimmer pot on the ballast does not respond when the ballast is controlled remotely. You can disengage DMX512 and regain local control by selecting address 000.

UV protection and the safety loop circuit

Direct light from an HMI lamp contains a dangerous amount of ultraviolet light. Once the light passes through a piece of UV-protective glass or bounces off the inside of the fixture, the UV is diminished below a safe threshold. However, the amount of UV in direct light from the lamp itself is high enough to cause a bad sunburn very quickly. UV can cause retinal burns if a person looks toward a light that is not UV-protected even for just a few seconds.

All HMIs have UV-protective glass and almost all include a safety circuit that prevents the light from operating if the lens door is open or the lens is missing. The safety circuit should never be deliberately defeated. An actuator rod is depressed when the lens door is closed; this closes the safety loop switch, allowing the lamp to fire. If the light does not strike or shuts off when pointed downward it is likely that the lens door is not fully shut or the actuator rod is not closing the switch.

Even with these protective measures, exposure too close to an HMI light or for too long a period of time can cause injury. Harmful exposure to UV from a light is a product of three factors: time, distance, and intensity. Manufacturers publish minimum safe distances. This distance is based on eight continuous hours of exposure to a particular light fixture. The distance is the same as the clearance distance recommended between the light and combustible materials. This information may be printed on a metal plate attached to the fixture.

If a person has to be placed at a distance closer than the prescribed minimum, then the time must be reduced in inverse proportion to the increased intensity. In situations where UV exposure could be a problem, it is possible to use a higher-quality UV glass (special order item). There have been instances where spectators watching filming stood too close to large HMIs and later sued the production over UV exposure. Do not permit people to stand too close to HMI lights. Advise someone in the AD's team if measures need to be taken to enforce this. Cast, crew, background artists, and production staff may not be aware of these issues. This is an area where the gaffer may need to provide the necessary guidance before and during production.

A damaged or modified fixture that leaks direct UV radiation can, and has, caused skin burns, retinal burns, and even skin cancer. If prolonged proximity is unavoidable, as when operating a 12k or 18k in a Condor, and you start to feel some burning on your skin, block radiation from the fixture and have the fixture replaced ASAP.

Color temperature

There are a number of factors that affect and change the color temperature of HMI lamps: the make and model of the globe, its hours in service, whether exiting conditions are conducive to proper lamp cooling, the type of ballast used, dimming, and voltage regulation by the ballast. These factors may make one light slightly warmer or cooler in color temperature or slightly more magenta or green.

Color temperature can be checked using a spectrometer (Chapter 6). Meters like the Minolta Color Meter IIIF are not capable of reading color consistently and accurately when measuring discontinuous sources such as metal halide discharge lamps, fluorescents, and LEDs. Both Minolta and Philips have released explanations of this, and they do not themselves recommend this practice.

Measure the color temperature of each lamp with the dimmer set at full, before production starts to see where the color temperature has settled for that particular lamp. Marking this on the head enables the crew to more easily track individual lights that may need correction with gels (Chapter 6).

When an HMI globe is brand new, it often shows a very high color temperature (10,000–20,000 K). This is sometimes accompanied by some arc instability, causing flicker. You may want to "burn in" the globe, if it is brand new. During the first couple hours of use, the color temperature comes down quite quickly to the nominal value (5600 or 6000 K) and the arc stabilizes.

Constant-power electronic ballasts regulate lamp power in such a way that color temperature remains constant as the electrodes age. When a fixture is dimmed on an electronic ballast, the color temperature rises slightly (goes bluer) as the voltage is reduced to 50 percent. With magnetic ballasts, the color temperature decreases over the life of the globe at the rate of 0.5–1 K/hours depending on conditions. The color temperature decreases because as the gap between electrodes increases, more voltage is required to maintain the arc, and as the voltage increases, the color temperature decreases.

Operating conditions

For reliability, attention should be given to providing adequate operating conditions for the ballast. A modern electronic ballast will turn itself off to protect itself from permanent damage in a range of adverse situations.

- Ambient temperature range. For example, the ARRI EB Max 1.8, operating range is −4 °F to 122 °F (−20 °C to 50 °C). Many ballasts have a max temp of 112 °F. It is not hard to reach these temperatures in the summer in the sun when the ballasts are sitting on a hot surface. The ballast will reset automatically, but only after it has cooled below the shutdown threshold.
- Place the ballasts in shade or create shade for them (but don't inhibit the free flow of air in doing so).
- Maintain airflow around the ballast. Do not allow ventilation on back and side heat sinks and air slots to be obstructed. If the ballasts are in a place where there is little circulation, use a fan or AC duct to force air across the ballasts.
- Do not stack the ballasts one on another; the lower ballast will overheat the upper one.
- If the ballast is sitting on the ground, the temperature of the ground should be less than 122 °F. Do not place on a hot surface like cement, because the heat sinks will work in reverse. Place the ballast up on an apple box.
- Do not shine HMIs or other hot lights directly on the ballast. Do not place it in direct sunlight.
- Protect the ballast from precipitation and liquids.
- Care and forethought are required in cold temperatures too. When a ballast has been outside in cold temperatures and is brought inside, moisture will condense on internal electronics. It is recommended that the ballast be given a couple of hours to acclimate before it is plugged in. If the ballast has condensation internally and is then taken back out in freezing temperatures, the condensed moisture will freeze and can literally freeze and lock up the relays.

Troubleshooting

LED indicator lights or self-diagnostic messages on a ballast's LCD display are helpful features (Figure 9.4). In the event of a shutdown, the microcontroller identifies the problem: an overheated power module, improper input voltage, a short in the output circuits, current on the ground wire, a misconnected cable—everything but a readout of the gaffer's blood pressure. If the ballast shuts off, don't be in such a rush that you forget to check the display before rebooting the ballast. It is important to note that if the ballast indicates an error, it does not mean that the ballast is necessarily faulty. These ballast diagnostics will look for problems throughout the system.

On Power Gems ballasts, a message will be displayed on the LCD alongside a flashing red light. Power Gems ballasts also keep an internal log of fault codes the ballast experiences, as well as run times. To access the ballast's internal log, either hold down the blue button (marked "Full") for 5 seconds or use an infrared datakey. On ballasts with the blue button, the up/down buttons can be used to move through the memory.

If the light goes out after operating for several minutes:

- The lamp itself may be faulty or at the end of its service life.
- The ballast's protective circuit will shut off the light if exposed to extreme ambient temperatures or direct sunlight in hot conditions. The free inflow and outflow of the cooling air might also be restricted.

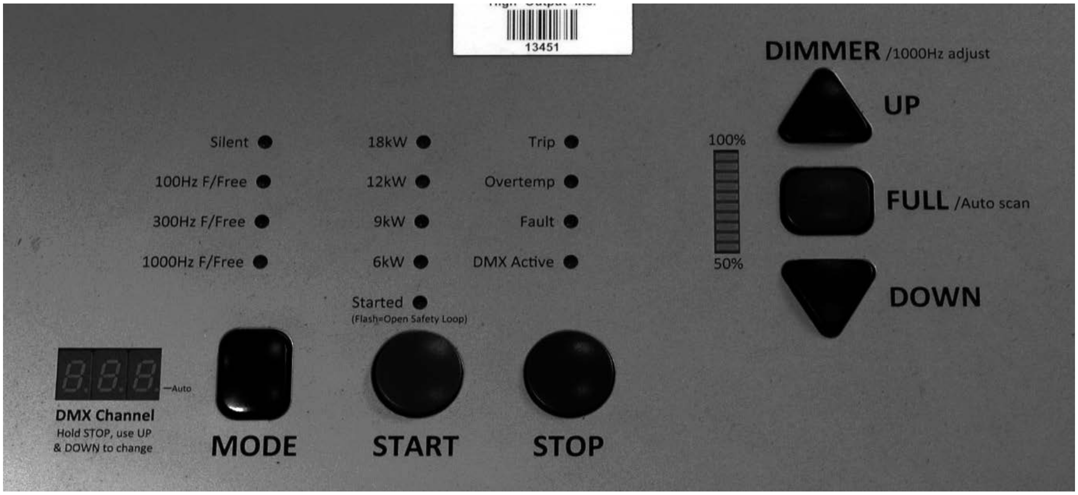


FIGURE 9.4

Power Gems display on their 6/9/12/18 kW high-speed ballast. The left column of LEDs show mode (silent, or flicker-free speeds at 100 Hz, 300 Hz or 1000 Hz). The ballast is auto sensing and shows the connected lamp wattage (18, 12, 9 or 6 kW). The third column helps diagnose why the light has turned off or is not responding. It includes circuit breaker trip, overtemp, fault (in wiring), and whether a DMX signal is present. To set the DMX channel, hold down the STOP button and use the UP/DOWN buttons to set the address.

- The ballast's protective circuit will shut off the light if it is subjected to voltage drop-out, voltage spikes, or low voltage. Switch the ballast OFF and ON again; it should start up as normal.
- The ballast's protective circuit may shut off the light if it senses earth leakage of lamp heads or head to ballast cables. Test the ballast with a known good lamp head. If cables are suspect, they should be exchanged with known good cables.

If the light will not turn on:

- Lens door may not be fully shut, or safety circuit may not be closed.
- There are three potential points of failure: the ballast, head, and head cable. A shorted head, or head cable, can blow the output transistors of the ballast. If you suspect a head may be faulty, do NOT connect it to another ballast.
- To check if a ballast is good, run it with a known good lamp head and known good head to ballast cable. Use the process of elimination to determine if the head or head cable is faulty by demonstrating that the other parts are not.

According to one account, a bad head feeder (and one very determined electrician) once shorted out 13 ballasts in a row. In some cases, the ballast continues to work even though internal parts are damaged. The result is that other parts overheat and short out, and the repair bill and turnaround time keep going up.

Power

Constant power ballasts

Most modern electronic ballasts are *constant power*, meaning they regulate not just lamp current but lamp power, enabling the ballast to compensate for changing lamp voltage as a lamp ages and for voltage loss in long head cables. *Constant power* means that the lamp has a stable, optimal color temperature that remains uniform regardless of lamp age or line voltage.

To determine the maximum amperage draw of a constant power ballast at a given line voltage, check the operation manual and find the ballast *maximum line power*. For example, for the ARRIMAX 12/18 kW ballast, max line power is listed as 19,600 VA. Divide this figure by the line voltage to get the required current.

$$\frac{19{,}600\ VA}{190\ V} = 103.1\ A \qquad \frac{19{,}600\ VA}{208\ V} = 94.2\ A \qquad \frac{19{,}600\ VA}{240\ V} = 81.7\ A$$

Note that low line voltage (190 V is generally the lowest voltage at which the light can operate) results in higher than usual current, which could overheat connectors and other parts.

Electronic ballasts have a wide tolerance for voltage and hertz rate discrepancies. Typically, ballasts will accept a line voltage from 90 to 125 V and 190 to 250 V. The amount of current a ballast demands will vary with the voltage provided to the ballast (see sidebar).

The line frequency can vary as much as 10 percent from one cycle to the next with no adverse effect on operation. However, in general, it is good practice to ensure proper voltage to HMI ballasts. In situations where line voltage is low, current can become unexpectedly high, especially with the bigger lights (Figure 9.5).

Power factor correction

Any electronic power supply, whether for an HMI, LED, or fluorescent light, has some innate, undesirable electrical characteristics. These can be cleaned up if the equipment has a power factor correction (PFC) circuit. Having power factor correction is especially advisable when the lights make up a large portion of the load such as when HMIs are powered by a small Honda generator, or when lots of HMIs are being used.

Ballasts without PFC use electricity inefficiently (65–75 percent efficiency is typical) and can create high spike currents that adversely affect the power supply or generator and can even damage them. Poor power factor creates current on the neutral in the distribution system. A PFC ballast realigns the waveform, returning it to as much as 99 percent efficiency, and inducing a smoother waveform. ARRI uses the phrase *active line filter* (ALF) to denote PFC plus line filtering. A full explanation of power factor and its effects in the distribution system is provided in Chapter 17.

European electrical codes require the use of PFC, but PFC is not required in the United States. For ballasts 6k and lower, manufacturers offer PFC as an option. However, because of the added cost,

FIGURE 9.5

24 kW HMI Fresnel. Because the lamp voltage is higher, the current through the head cable is roughly the same as that of an 18 kW light, so the 24 kW head and 18 kW head can use the same head cables. However, it is critical with these high currents that the voltage to the ballast be correct as the ballast is designed to protect itself from excessively high current.

(*Courtesy Ron Dahlquist, Dadco/Sunray MFG*)

weight, and complexity, the rental house may not stock PFC ballasts, at least not exclusively. The gaffer or best boy must specify that PFC ballasts are required when ordering the equipment. All manufacturers now include PFC on ballasts 9 kW and larger. For these high-current units, PFC becomes not just desirable but necessary to protect the electronics from extremely high currents and overheating.

Cueing for HMIs

Having an HMI come on or turn off on a cue presents a greater challenge than other types of light because of the necessary warm-up time. To work around this, a dowser unit (DMX512-controlled shutters) can be used to block the beam during the warm-up period, and open and close on cue. HMIs are commonly controlled this way in opera and theater lighting. The ON/OFF cues have to be arranged so that heat will not build up and warp the shutters, which will happen if they are left closed for too long. The lighting console programmer typically programs the light ignition cue a short time before the lighting cue to open the shutters. DMX512-controlled shutters and color scrollers are helpful accessories when this kind of control is required.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

CHAPTER

Stands and rigging

10

Lighting technicians find themselves having to hang lights in all kinds of places, so naturally, over the years, ways have been devised to secure a light almost anywhere. People are constantly inventing and reinventing these devices. The basics are described in this chapter; check manufacturers' Web sites for the most up-to-date information (ARRI, Matthews, Norms, American, Modern Studio Equipment, Versales, The Light Source, City Theatrical, and many others; see also Appendix F).

Lights are typically mounted in one of three ways. The smaller movie lights (baby 2k and smaller) have a ⅝-in. receiver that can be mounted on a ⅝-in. "baby" pin. Larger movie lights have 1⅛-in. pin which fits into a 1⅛-in. "junior" receiver on the stand or rigging hardware. Concert and theater venue lights may be delivered with a pipe clamp bolted to the yoke. This can be removed and replaced with a baby receiver for stand-mounting if necessary. Accordingly stands and rigging hardware are identified as either "baby" or "junior."

STANDS

A wide range of light stands are available. Stands may be made of aluminum, which is lightweight, or steel, which is stronger. Stands of both types come in various heights: two-riser, three-riser, and "low-boy."

Baby stands

Figure 10.1 shows some of the standard baby light stands. The most versatile baby stand for location work is a steel three-riser stand with a mountain leg. Loosening the T-handle on the top collar and pulling up can quickly retract the legs. The legs have a wide base for stability, and the mountain leg makes it easy to level the stand when it is placed on uneven ground, on a stair, over the edge of a curb, or leaning against a set wall (Figure 10.2).

Rolling stand

Baby rolling stands are convenient when working in the studio on a level surface. Most rolling stands have brakes that snap into a locked position.

Low stands

When you need a light placed low, a mini-baby (22–50 in.) or preemie (31–70 in.) stand comes in handy. Table 10.1 lists the basement and top floor for many common stands.

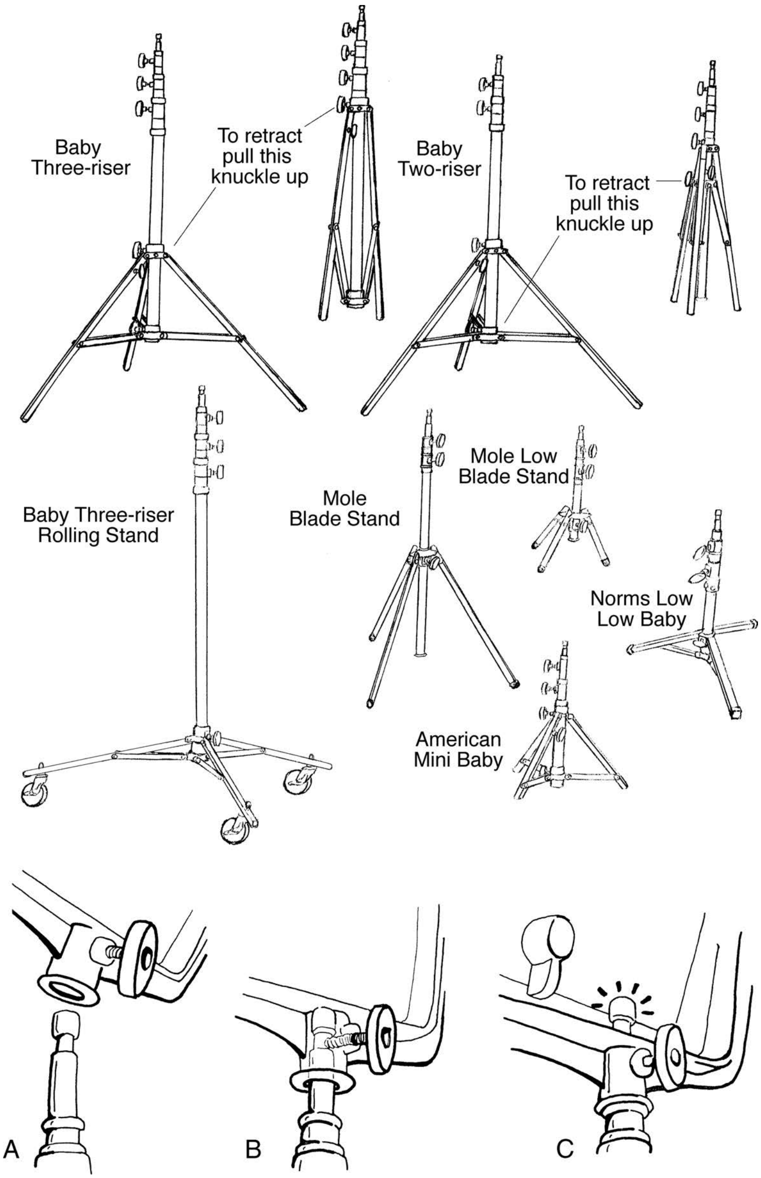


FIGURE 10.1

To retract the legs of most stands, loosen the upper tie-down knob and pull the legs up and in. With some stands, the legs retract by loosening the bottom tie-down knob and sliding that collar upward. A ⅝-in. baby pin inserts into the receptacle on a fixture (A). When mounting the light, the pin should be flush with the receptacle and not stick through. This assures that the T-handle engages the indent of the pin (B). Also, some lights (notably the baby junior) do not tilt properly if the pin sticks through (C).

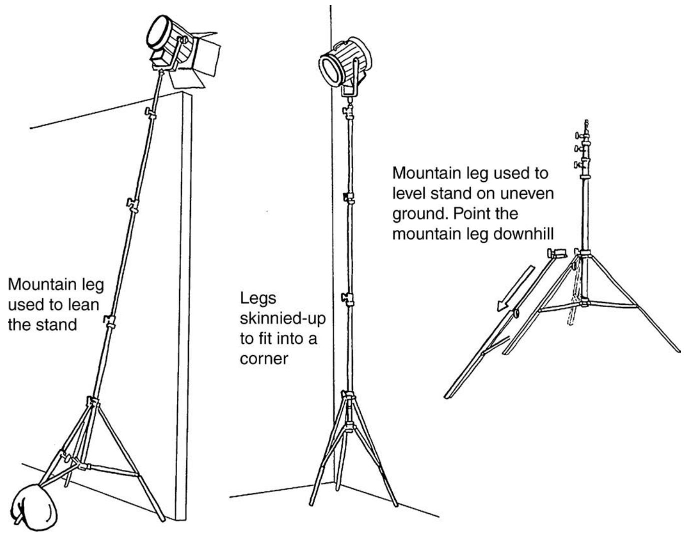


FIGURE 10.2

Alternative stand configurations.

Junior stands

Combo

The junior combo stand is so named because it was designed to handle both lighting units and reflector boards. Larger fixtures, Studio 2k and larger, have a 1⅛-in. junior pin. A typical two-riser combo has a maximum height of 11 ft. A three-riser combo has a maximum height of 14 ft. Figure 10.3 illustrates the junior stand and some common stand accessories: the baby pop-up pin, the angled drop-down offset, and the baby pin adapter.

Low boy

The minimum height of a typical combo stand is 48 in. If the light must be lower than that, you need a low boy junior stand, which has a minimum height of around 33 in. If you need to mount a light lower than 33 in., you have to under-hang the light from an offset or use a turtle stand or T-bone.

T-bones and turtle stands

A T-bone is simply a metal T that sits flat on the floor, providing a low position for larger lights. It has a junior receiver (Figure 10.4). A T-bone can be nailed or screwed into place. A turtle stand is nothing more than three legs joined in the center to a junior receiver. Matthews's C+ stand has removable legs, which serve as a turtle stand. The riser section of the C+ stand can be used as a stand extension. Matthews and other manufacturers also make wheeled turtle stands. Matthews calls theirs a *runway stand*.

Table 10.1 Stands

Name	Type	Risers	Minimum height	Maximum height	RM leg	Brand
Low baby stands						
Low blade stand	Al	2	15″	38⅞″		Mole
Mini-preemie	St	2	20″	39″		Matthews
Preemie baby	Al	2	31″	5′10″		Matthews
Mini-baby	St/Al	2	22″	50″	X	American
Low low baby	Al	2	20″	3′3″		Norms
Low hefty baby	Al	2	33″	5′7″		Norms
Baby stands						
Steel maxi	St	3	34″	10″		Matthews
Beefy baby standard	Al	2	37″	8′3″		Matthews
Beefy baby, 3-riser	Al	3	45″	1′	X	Matthews
Baby, 2-riser	St/Al	2	40″	9′4″	X	American
Baby, 3-riser	St/Al	3	44″	12′5″	X	American
Baby light, 2-riser	Al	2	44″	9′4″		Norms
Baby light, 2-riser	St	2	52″	10′6″		Norms
Hefty baby, 2-riser	Al	2	47″	9′10″	X	Norms
Hefty baby, 3-riser	Al	3	50″	12′10″	X	Norms
Baby light, 2-riser	Al	2	44″	9′4″		Norms
Baby light, 2-riser	St	2	52″	10′6″		Norms
Hefty baby, 2-riser	Al	2	47″	9′10″	X	Norms
Hefty baby, 3-riser	Al	3	50″	12′10″	X	Norms
Low junior stands						
Runway base only		0	11″	11″		Matthews
Low boy	St	2	33″	6′9″	X	Matthews
Low boy	Al	2	37″	6′9″	X	Matthews
Low combo, 1-riser	St	1	29″	4′0″	X	American
Low combo, 2-riser	St	2	32″	5′6″	X	American
Low combo, 2-riser	St	2	33″	5′7″	X	American
Low boy		2	36″	5′8″	X	Norms
Rolling folding stand	St	1	22¼″	32″		Mole
Junior stands						
Combo	St	2	48″	11″	X	Matthews
Sky high	St	3	52″	14″	X	Matthews

Table 10.1 Stands

Name	Type	Risers	Minimum height	Maximum height	RM leg	Brand
Mombo combo	St	4	76″	27″	X	Matthews
Light duty combo	St	2	48″	10′5″	X	American
Heavy duty, 2-riser	St	2	50″	11′3″	X	American
Heavy duty, 3-riser	St	3	51″	14′3″	X	American
Alum combo, 2-riser	St/Al	2	48″	10′3″	X	American
Alum combo, 3-riser	St/Al	3	51″	13′9″	X	American
Mombo combo	St	4	5′8″	23′5″	X	American
Standard		2	54″	11′2″	X	Norms
Sky high		3	58″	13″	X	Norms
Sky high	Al	3	61″	13″	X	Norms

Notes

RM leg stands for Rocky Mountain leg. St/Al means the stand has steel legs and aluminum risers.

Mombo combo

A mombo combo is a very substantial four-riser steel stand with a very wide base (no wheels), which allows a maximum height of more than 26 ft.

Offsets, side arms, extensions, and right angles

Offsets

Figure 10.5 shows various types of baby offsets that can be used to locate the head out from the stand. They are useful when some obstruction, such as furniture or a set piece, prevents the stand from being placed under the light. Note that an offset or side arm puts the stand off its center of balance. Use sandbags on the legs as counterweights.

Risers

Risers come in many sizes; typical sizes are 6, 12, 18, and 24 in. A riser is a handy piece of hardware when a light mounted to a plate or clamp is not quite high enough. A 36-in. junior stand extension essentially adds an additional riser to a stand. It can also be inserted into the receiver on the dolly or the crane when a light is to ride.

Using stands

See Chapter 2 for the checkout procedure for stands.

- Remember: "Righty tighty, lefty loosey." The T-handle tightens when turned to the right (clockwise) and loosens when turned to the left.

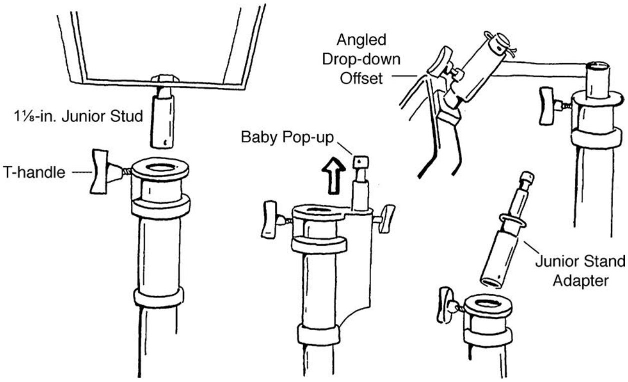


FIGURE 10.3

The 1⅛-in. junior pin fits into the receptacle on the stand. The T-handle should engage the indented part of the pin. Some stands have a baby pop-up, which allows the junior stand to support either a baby or a junior fixture. An angled drop-down offset allows a light or reflector to hang lower than the lowest height of the stand. The 45° angle holds the light away from the stand. In the absence of a baby pop-up, a junior stand adapter can be used.

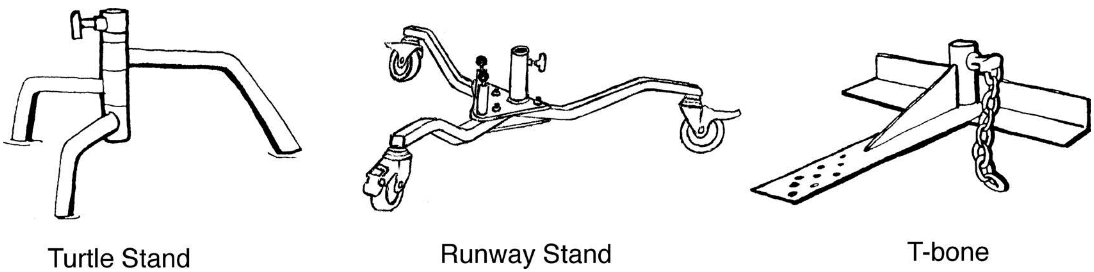


FIGURE 10.4

Three ways to place a light near the ground. A T-bone can be nailed or screwed into place in green beds or on parallels.

- Extend the top riser first. If you extend the second riser first, you will raise the first riser out of your reach and look like a bonehead. However, if the light is heavy for the stand, you can add strength to the stand by not using the first riser or using only part of it.
- Bag any raised stand. A good rule of thumb is one sandbag per riser. If the light were extended all the way up on a three-riser stand, you would use three bags. Place the sandbags on the legs so that the weight rests on the stand, not on the floor.
- Get help when needed. As a rule, use two people to head up any light 10k or larger. Depending on the height of the stand and the awkwardness of its position, heading up an 18k or Dino can require three or four people. Don't hesitate to round up the other electricians and grips when you need them. A heavy light can get away from you and cause injury and damage. Lifting equipment is not a contest; the lighting crew works as a team.

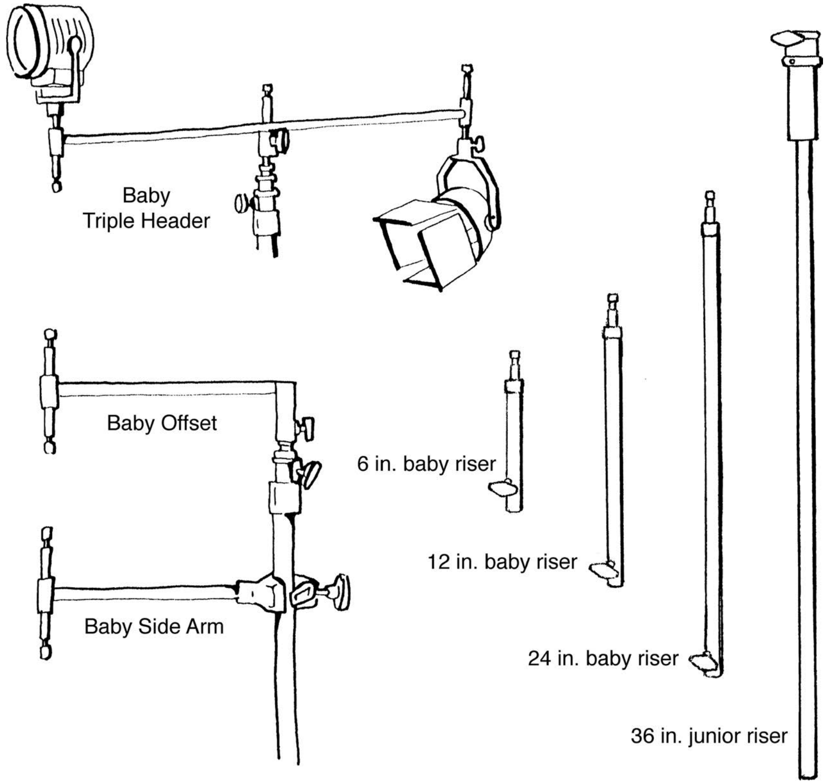


FIGURE 10.5

Offsets, side arms, double headers, and triple headers are available in baby and junior sizes.

Crank-up and motorized stands

Crank-up stands provide a mechanical advantage needed for raising heavy lights. Table 10.2 gives the weights and weight capacities of crank-up and motorized stands. They have a chain-, cable-, or screw-driven telescoping extension system with a crank and clutch so that the crank does not reverse and spin out of control under weight. Do not crank up a stand without some kind of weight on it, as this can cause problems in the inner mechanisms. The Avenger stands have a number of notable features, including a very safe gear system (Figure 10.6).

The Cine-Vator, Molevator, and similar motorized stands power the telescoping mechanism with an electrical motor that is operated by a single up/down toggle switch (Figure 10.7).

- When rolling a large light on a crank stand or motorized stand, push the stand from the back with the swivel locks *unlocked* on the two rear tires and the front tire *locked*. Steer by pushing the back wheels left or right. This way you are less likely to catch it in a rut and tip over the whole stand.

- When the stand is in place, prevent the stand from rolling by swiveling each wheel straight out from the stand and locking each swivel. Additionally, wedges in the tires and cup blocks under the tires prevent them from turning (grip department).
- Before raising the stand, make sure it is totally leveled with cup blocks, wedges, and apple boxes, if necessary (grip department).
- Use your strong arm to turn the crank to raise and lower the light. Never release the clutch without having a good grip on the crank. A properly adjusted crank should not spin when the clutch is released. However, they often do. If the crank gets away from you, there is a good chance you will not be able to get hold of it again before the lamp hits you in the head. There is also a good chance you'll hurt yourself trying to grab hold of the spinning crank. If you lose control, let go of the clutch and get out of the way of the light.

Table 10.2 Weight capacities of crank-up and motorized stands

	Floor	Ceiling	Capacity	Type
American				
Roadrunner 220	4′2″	11′3″	220 lb. (100 kg)	Crank
Big Fresnel Lamp Stand (BFL)	4′2″	12′6″	300 lb. (136 kg)	Motor
Avenger				
Long John Silver Junior, 3-riser	4′0″	11′0″	265 lb. (120 kg)	Crank
Long John Silver, 4-riser	5′9″	18′8″	264 lb. (119 kg)	Crank
ARRI				
Baby 2-section Supercrank	3′2″ (97 cm)	5′5″ (165 cm)	220 lb. (100 kg)	Crank
Short-base 3-section Supercrank	4′8″ (153 cm)	11′3″ (345 cm)	154 lb. (70 kg)	Crank
2-section Supercrank	4′10″ (147 cm)	7′7″ (232 cm)	198 lb. (90 kg)	Crank
3-section Supercrank	5′5″ (165 cm)	11′5″ (348 cm)	176 lb. (80 kg)	Crank
4-section Supercrank	5′11″ (182 cm)	15′7″ (477 cm)	154 lb. (70 kg)	Crank
5-section Supercrank	7′9″ (237 cm)	20′4″ (620 cm)	154 lb. (70 kg)	Crank
Matthews				
Lite Lift	4′1″	8′6″	85 lb. (38 kg)	Crank
Crank-O-Vator	4′11″	12′	150 lb. (68 kg)	Crank
Low Boy Crank-O-Vator	3′2″	5′5″	150 lb. (68 kg)	Crank
Super Crank	5′9″	12′6″	200 lb. (90 kg)	Crank
Cine-Vator	4′6″	12′	300 lb. (136 kg)	Motor
Mole-Richardson				
Folding Crank-up Litewate Stand	4′5″	10′	—	Crank
Molevator	5′1″	11′1″	250 lb. (113 kg)	Motor

FIGURE 10.6

Avenger Long John Silver (shown here) and Long John Silver Junior (by Avenger Lighting) are high-capacity crank stands with some unique features. The Junior version has a loading height of 48 in., significantly lower than most crank stands, making it much easier and safer to head up big heavy lights. The taller version of the Avenger is a four-riser light stand with a maximum height of almost 18 ft. 7 in., making it the tallest of its type. The Avenger stands feature leg pistons that help in folding and unfolding the stand, which is quite heavy. Unlike other crank stands, it has a leveling leg. The winch-type crank provides two crank handles, so the user employs both hands to crank. The gear box is designed so that all the risers work simultaneously and has a manual safety block, as well as an internal one, and internal friction, which greatly reduces the danger of the crank getting away. The wheels also have very good brakes and the wheel swivels lock in a variety of positions.

(*Photo by Damon Liebowitz*)

Grip stands

For the most part, the grip stands are used for flying overhead sets and setting flags, nets, diffusion frames, and so on. However, in special situations, they are needed as light stands.

C-stands

Q: How do you drive an electrician crazy?
A: Lock him in a small room with a C-stand.

FIGURE 10.7

A Cine-Vator stand. These stands can handle the heaviest lights made (up to 300 lb.). The motor is usually 115 V AC (at about 6 A) but can be 115 V DC, 220 V AC, or 220 V DC.

(*Courtesy Matthews Studio Equipment, Burbank, CA*)

The Century stand, or *C-stand*, is a versatile, all-purpose rigging gadget that is the centerpiece of the grip's equipment. Its components are like the parts of an erector set, and setting C-stands is a little appreciated art form. Given enough time and enough C-stands, a grip could build a scale model of the Eiffel Tower. C-stands are very handy for rigging small, lightweight lights, like LEDs, especially when the light needs to be cantilevered out on an arm (Figures 10.8 and 10.9).

Knowing the proper technique will save you much embarrassment; grips like nothing better than to heckle an electrician who is making a mess of a job with a C-stand:

- Place the longest leg under the extended arm. This helps stabilize the stand. Always sandbag the legs when putting weight on an extended arm (Figure 10.8A).
- Work with gravity, not against it. When you are standing behind the stand with the arm pointing away from you, the knuckles should be on your right. In this way, when weight is put on the arm, gravity pulls the grip head clockwise, which tightens it. If the knuckle is on the left, the weight will eventually loosen the knuckle, and the whole rig will collapse.
- Avoid configurations in which the back end of the arm sticks out, especially at eye level; it could hurt someone. There is almost always an alternative configuration that eliminates the hazard. If it's unavoidable, place a tennis ball or Styrofoam cup on the end of the arm so people will see it.
- Place the sandbag on the top leg so that the bag's weight is on the leg and not resting on the ground.
- Always place the C-stand on the "off-camera side" of the light—the outside, as viewed from the camera. This helps keep grip equipment out of the movie.

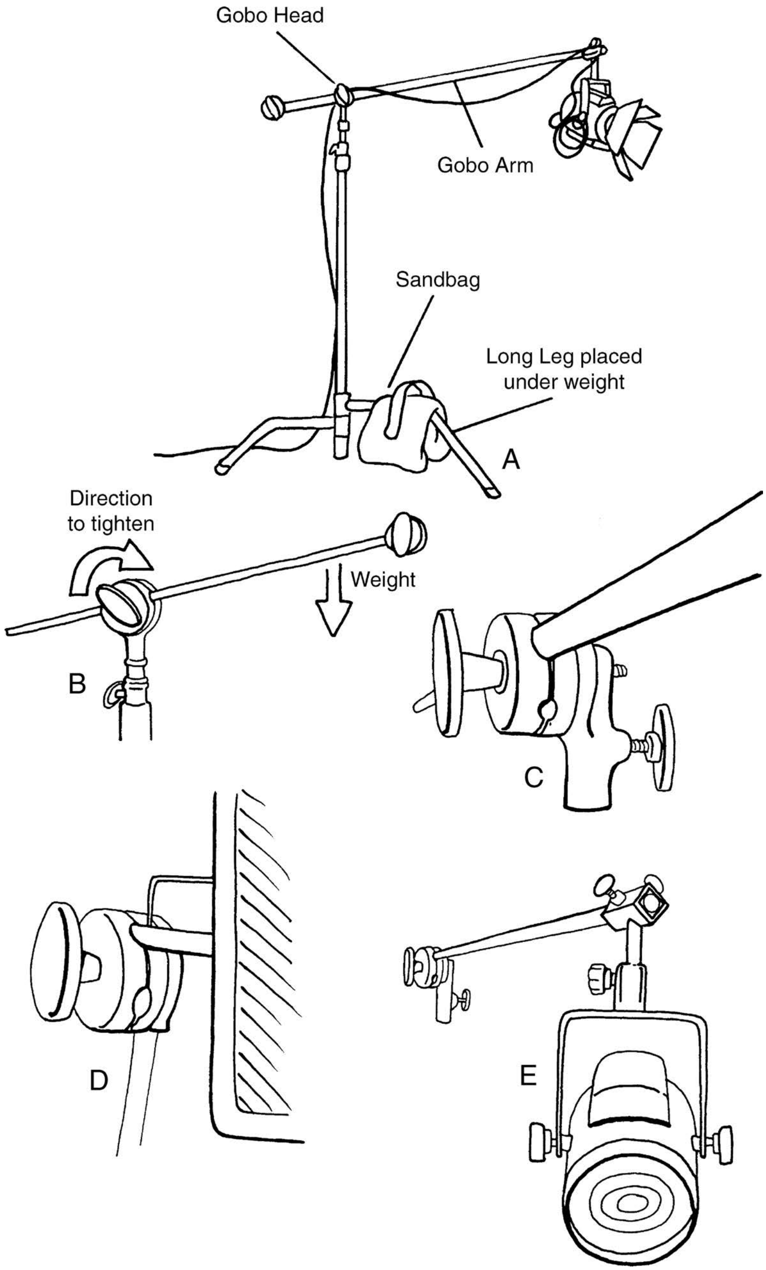


FIGURE 10.8

(A) C-stand supporting a light fixture. (B) Orient the knuckle so that gravity tightens it ("righty tighty"). (C, D) The grip head accepts various sizes: a ⅝-in. hole for the gobo arm or a baby pin, and a ⅜-, ½-, or ¼-in. hole for nets and flags. (E) The light fixture shown uses a bar clamp adaptor (used on furniture clamps) to attach to the gobo arm.

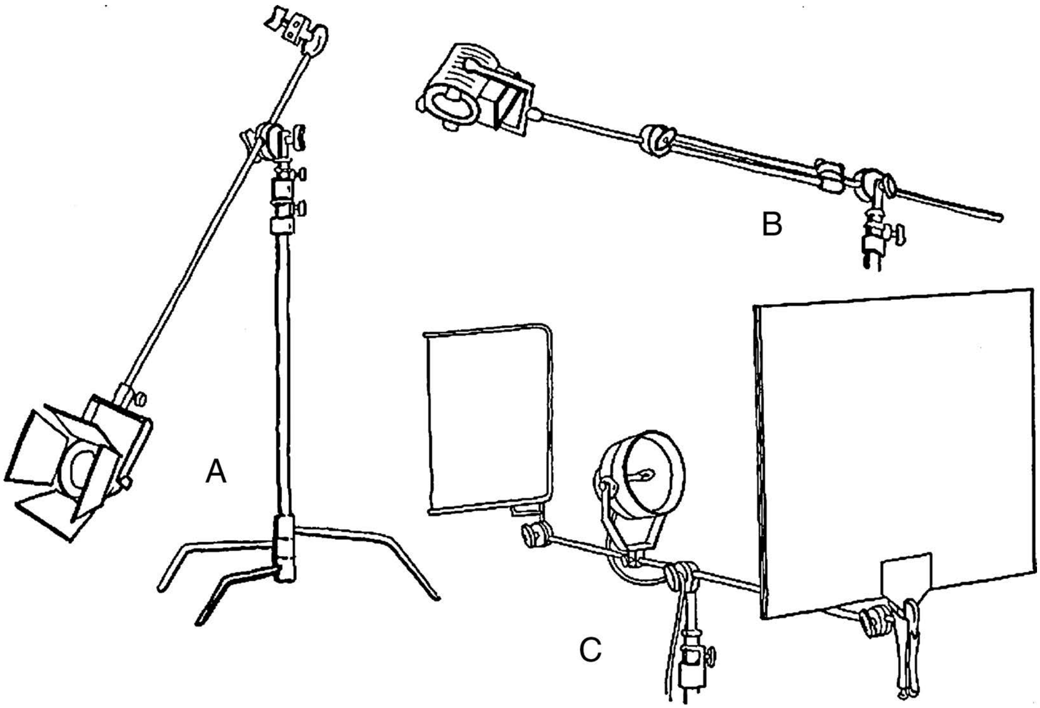


FIGURE 10.9

Some special uses for C-stands: (A) to place the light in a low position; (B) to arm the light out over the action (here, two gobo arms coupled together); (C) to work with a bounce card rig like this, which uses a single stand to support the light, bounce card, and a net.

Medium, hi, and hi-hi rollers

A medium roller stand is slightly taller than a junior combo, about 14 ft. maximum, and has wheels, which makes it easy to move around. The wheels have brakes that should be locked once the stand is placed. In addition to a junior receiver, roller stands typically provide a 4-in. grip head for mounting overhead frames, large flags, and other grip gear. A hi-hi roller is especially useful when height is required; it has a maximum height of 20 ft.

Booms

Boom poles allow a fixture to be cantilevered over or behind the actors in places where it could not be mounted by other means. These are best used for lightweight fixtures such as extending a lantern light out over an acting area. Booms vary in size and strength. The small ones mount on a baby stand and provide about a 4-ft. arm with almost as much counterweight length. The larger ones mount on a junior stand, have more length and more counterweight, and provide either a junior or a baby mount for the light. Sandbags can be added for additional counterweight.

Stand maintenance

Modern stands are made of stainless steel and aluminum. Stainless steel stands are more weather-resistant. A well-made stand will not rust or corrode. When stands get muddy, they should be cleaned so that dirt does not get inside, between the risers. Wipe each riser down with a rag or towel. If a riser starts to bind, lubricate it with silicone spray.

Occasionally, the Allen screws that secure the bonnet castings and the riser castings to the tube parts of a stand get loose and the castings come off. It is a simple matter to push the castings back into place and tighten down the Allen screws. Be sure to keep the castings tight. If the casting comes off while you are raising a light, the riser will separate from the stand and you'll wind up balancing the light on the riser like an acrobat with teacups (except that a 4k PAR costs a little more than a teacup when it shatters on the ground).

RIGGING HARDWARE

Nail-on plates

A nail-on plate, also called a wall plate or pigeon plate (Figure 10.10), mounts to a surface with screws. Use a cordless electric drill with a Phillips bit and wood or drywall screws. The plate can be mounted to a horizontal surface, a wall, or a ceiling, but be sure that you are screwing into something solid. If you are screwing into a set wall (usually ¼-in. plywood), place a piece of cribbing on the other side of the wall to give the screws something to hold to.

The grips usually prepare several apple boxes with nail-on plates. When mounted on an apple box, a nail-on plate provides a stable lighting position that is handy for setting a light on the floor or on a counter top.

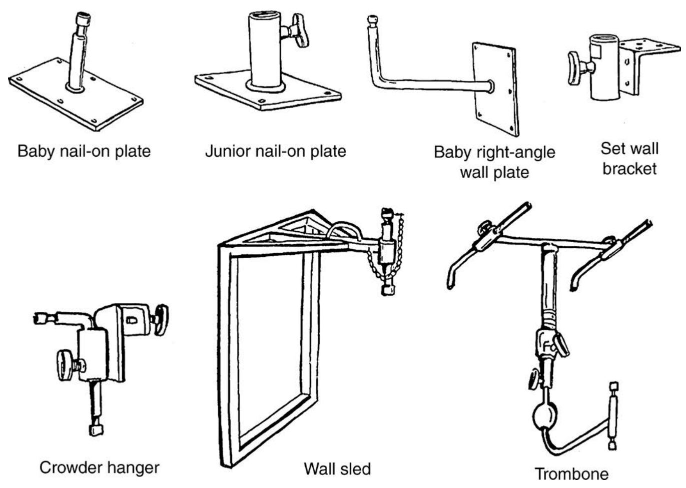


FIGURE 10.10

Plates and hangers for set walls.

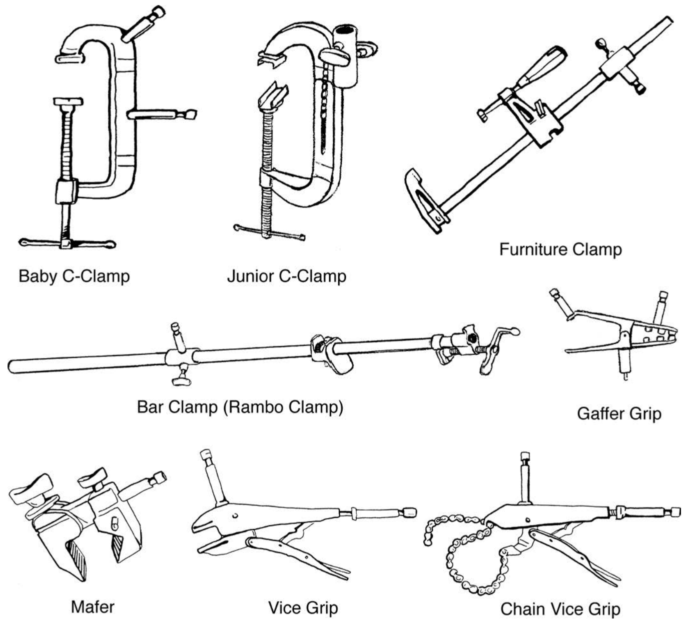


FIGURE 10.11

Clamps.

Set wall mounts

Figure 10.10 shows a variety of set wall mounts.

Set wall bracket. A set wall bracket is a right-angle plate that mounts to any right-angle corner, such as the top of a flat.

Crowder hanger. A crowder hanger fits over the top of a door or on 2″ × 4″ lumber. It can be used with a baby adapter that provides two mounting positions—one above and one below the hanger.

Edge plate bracket. An edge plate bracket is similar to a crowder hanger. It is used to mount lights to the side edge of a green bed (explained shortly).

Wall sled. A wall sled is suspended on rope from the top of a set wall. The weight of the light holds the sled in position against the wall without screws or tape. Wall sleds are available with either a junior or a baby mount.

Trombone. Like the crowder hanger, a trombone also fits over the top of the set, but it is adjustable to any width of wall. It provides an adjustable drop-down position for the light. Use a rubber ball on the telescoping arm to prevent it from scraping the wall. A trombone can have either a junior or a baby mount.

Clamps

C-clamp. C-clamps (Figure 10.11) come in various sizes: 4, 6, 8, and 12 in. Each one has two baby pins or a 1⅛-in. junior receiver welded to it. With any of the clamps shown, to prevent puncturing or marring the beam and to increase the surface area of the clamp, insert two pieces of 1″ × 3″ cribbing between the clamp and the surface. Wrap the cribbing in duvetyn cloth when it is important not to scratch the finish. A common problem when mounting lights to a C-clamp on top of the set wall is that the light cannot be tilted down far enough. Use the angled pin on a C-clamp to get around this problem.

Furniture clamp and bar clamp. Furniture clamps and bar clamps are normally used by woodworkers to clamp work pieces together during glue-up. Furniture clamps come in various sizes (6, 12, 18, 24, and 36 in.); standard bar clamps are 48 in. (but can be any length), all of which are adjustable. Furniture clamps are typically used to undersling lights from ceiling beams or square pillars that are too wide for a C-clamp. As with C-clamps, use cribbing to increase the surface area of the clamp and to protect the surface to which you attach the clamp.

Gaffer grip. A gaffer, or gator, grip is a spring clamp with rubber teeth. It is used to mount smaller lights to doors, pipes, and furniture.

Mafer. A mafer (pronounced *may-fer*) is a versatile mount, small but strong. A cammed screw mechanism closes and opens the rubber-lined jaws. It can attach to any round surface from ⅝ to 2 in. in diameter and any flat surface from ¼-1⁄16 to 1-in. thick. The baby pin snaps into place with a spring-loaded lock. The removable pin can be exchanged for accessories, such as a flex arm, a double-header offset arm, or a right-angle baby pin.

Vice grip. The adjustable width of a vice grip provides a strong grip. As with any vice grip, the clamp is released by pressing the unlocking handle.

Chain vice grips and "candlesticks." Figure 10.12 shows a correctly threaded chain vice grip. A chain vice grip provides a very solid mount to any pipe up to 6 in. in diameter. It is used to mount a light to a standing pipe or pillar. Using a chain vice grip is preferable to using a clamp in this application, because a clamp can crush a pipe; a chain vice grip, on the other hand, applies force evenly around the diameter of the pipe.

Chain vice grips are often used to secure a "candlestick" to a standing post. A candlestick is nothing more than a metal pipe with a junior receiver on one end. It is like a junior riser, but is stronger,

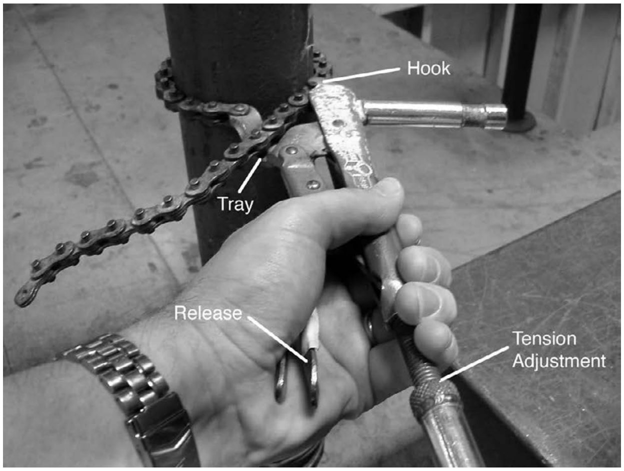


FIGURE 10.12

Using a chain vice grip: Face the tray up, toward you. Wrap the chain around the post and into the tray. Engage the chain's pins into hooks and squeeze the vice handles until they snap closed. To loosen or tighten the tension, turn the knurled knob before closing. Wrap tape around the handles to ensure that the vice does not open if it gets accidentally bumped. To release, remove the tape and pull the release lever.

because it does not have a cast aluminum receiver. When heavy lights are rigged to an aerial lift, for example, a great deal of sideways force may be exerted on the receiver when the aerial lift stops and starts. A normal junior receiver casting can crack open under such stresses. To make sure that the vice grip does not open, always wrap tape around the handle after the chain vice grip is in place. People are sometimes tempted to mount small lights to plumbing pipe on location. This is a bad idea. Although it may look sturdy, old cast iron pipes can be paper-thin, corroded on the inside after years of use. *Never* mount lights to fire sprinkler system pipes. It is against fire codes and a bad idea. If you rupture the pipe, it can flood the building.

Grids and greenbeds

Pipe clamp. Pipe clamps (Figure 10.13) are used when hanging lights from an overhead pipe. The threaded bolt that secures it can mar aluminum pipe and truss. It is best used on steel black pipe. Pipe clamps come with a safety pin attached to the clamp with a safety chain. The cotter pin prevents the receiver from slipping off the pin. Always use the safety pins when hanging lights.

Grid clamps, couplers, and claws. A grid clamp has a coupler like a Cheeseboro that hinges closed around the pipe. They are available with a junior receiver or baby pin for mounting lights, as well as many other forms. They make a very secure connection to pipe with less chance of marring or crushing the pipe than a clamp. There are various types of couplers and clamps of this type. Moving lights often employ two coupler clamps, because the torque of the moving fixture requires a very firm attachment. Figure 10.14 shows several examples of coupler clamps that are used to secure lights. When mounting to aluminum pipe and truss, this kind of clamp is less likely to damage the pipe. Grid clamps, couplers, and claws also take up less room than a pipe clamp.

Telescoping stirrup hanger. To get a light lower than the height of the grid, use a telescoping hanger to lower it to the desired height. Hangers have a stirrup to which you attach a pipe clamp. They are also made with a baby pin or junior receiver instead of a stirrup.

Greens and bazookas. Greenbeds are work platforms that are typically suspended a foot or so above the set walls to provide lighting positions. They are suspended on chain from the perms (the permanent

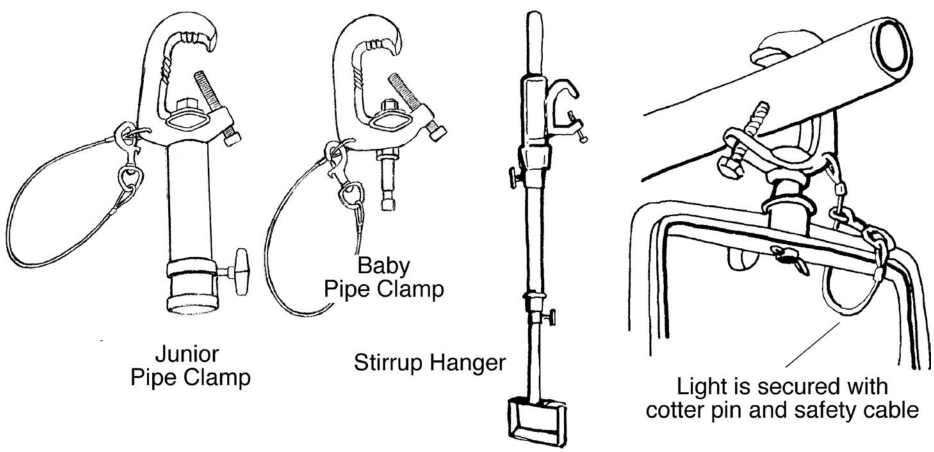


FIGURE 10.13

Pipe clamps.

overhead structure on a studio sound stage intended for rigging). Along the edges of the greens, at 18-in. intervals, are holes into which a junior pin fits. A light may be inserted directly into this receiver or a bazooka can be inserted into the hole. A bazooka is like a one-riser stand with no legs. An L-shaped bracket fits over the catwalk's handrail to support it.

Other rigging hardware

Wall spreader and tube stretcher. Wall spreaders (Figure 10.15) support lights by exerting pressure against two opposite walls or the floor and ceiling. A 2 × 4 or 2 × 6 of dimensional lumber creates the span. The hardware mounts to either end of the lumber and uses a threaded post to apply pressure against the walls. Lumber must be cut to fit the particular span needed. A wall spreader is handy as a means for mounting overhead lighting or grip equipment when shooting on location in a relatively small room or corridor.

A wall spreader can create a secure overhead beam of up to about 16 ft., from which lighting fixtures can be hung. With a long span, be sure that the hardware is aligned with wall studs and screw the wall spreaders to the wall. A *tube stretcher* essentially adapts a wall spreader for use with speed-rail pipe instead of lumber.

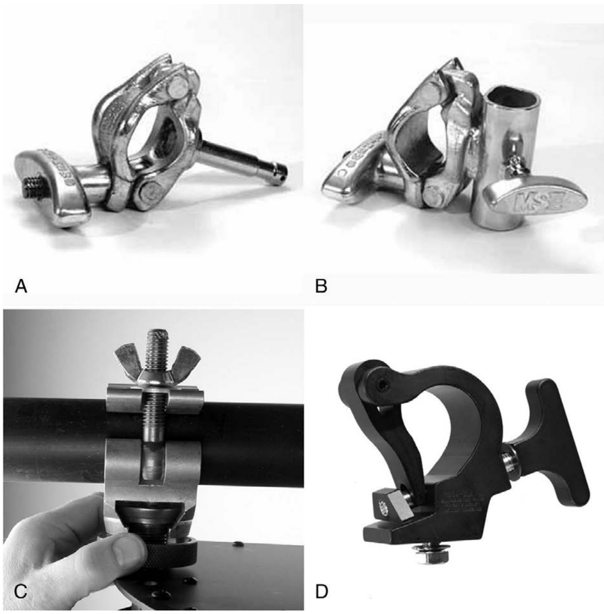


FIGURE 10.14

Grid clamps provide a very secure grip to the pipe for lights with either a baby receiver (A), or junior pin (B). (A) baby grid clamp; (B) junior grid clamp (courtesy Matthews Studio Equipment). Unlike a pipe clamp, a grid clamp does not allow you to rest the weight of the light on the pipe while tightening the clamp. You have to attach the clamp first, and then hang the fixture. With moving lights, the couplers are bolted to the light, so hanging these heavy lights with traditional couplers is a pain. Couplers such as (C) the T-slot coupler (courtesy City Theatrical, Inc.) or (D) the Mega Claw (courtesy The Light Source, Inc.) allow the weight of the fixture to rest on the pipe while the coupler is locked in place.

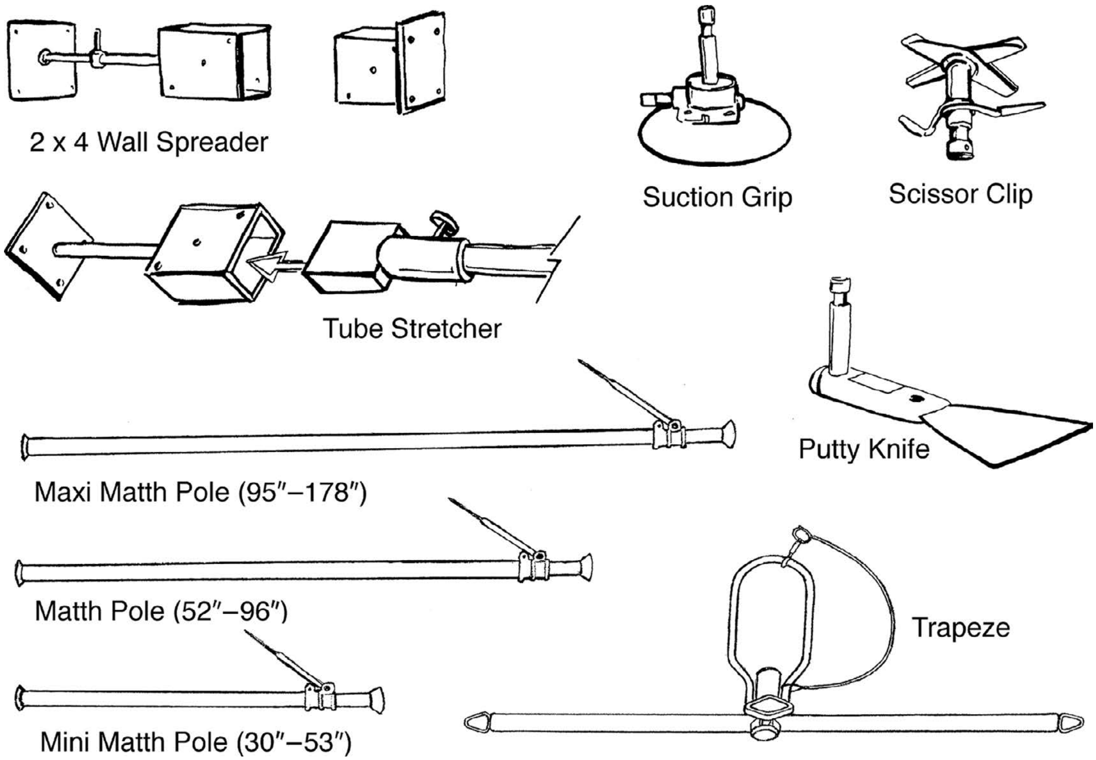


FIGURE 10.15

Rigging equipment.

Matth pole. A Matth pole, or pole cat, is a smaller, lighter-duty version of a wall spreader, especially useful in doorways or narrow halls or used vertically between floor and ceiling. A Matth pole can support lightweight fixtures or grip equipment.

Suction grip. Suction grips of 4 or 6 in. can be used to affix small lighting units to nonporous surfaces, such as a car hood. These grips generally use a cam to create the suction; they are not as strong as the larger, pump-type grips. Suction grips come with baby pins only and should be limited to use with smaller lights.

Scissor clip. A scissor clip is used to mount small lightweight lights to the metal frame of a dropped ceiling. The scissor closes over the metal strips that support the ceiling tile. It is tightened in place by turning the ⅝-in. pin. Cables can be dressed above the ceiling or clipped to the metal strips with small grip clips.

Putty knife. A putty knife can be wedged in a windowsill or door frame. It provides a baby pin for a small light fixture.

Trapeze. A trapeze is used to dead-hang a light of any size from a rope. It provides a junior receiver. Eyelets at each end of the trapeze are provided for guy wires, which aim the light and hold it in place once in position.

CHAPTER

Set protocol

11

SET PROTOCOL

Work on set is most rewarding when everything runs like a swiss watch, when everyone on the team knows the drill, they work together, they use tricks and techniques that make things easier and more efficient, and above all, work safely and watch out for one another.

Staging area

Upon arrival at each new shooting location, one of the first jobs is to establish a staging area where electrical equipment is kept, ready to go onto the set when needed. The best boy will have scoped out a spot that is convenient to the set but not so close as to block access. Stake out the good spot early before another department claims it. The entrance to the staging area must be clear of obstructions. You don't want a line of director's chairs in front of the area. You need to be able to carry equipment in and out easily.

The lighting technicians "head-up" a selection of lights, Noah's Arc-style (two of each) on stands in the staging area, ready to be brought into the set when called for. Line up the lights on stands. Organize them in rows so that each type of light is readily accessible. Skinny up the legs of the stands so they can be packed together closely. To be totally proper about it, the lights should be arranged with the stand fully lowered, T-handles lined up in a straight line down the back of the stand, power cord coiled, hanging on the hanger. For tungsten lights, the switch is OFF, gels and scrims should be hanging on the stand (not in the light), and doors closed.

The staging area should be arranged in an orderly fashion for easy access to all the equipment. The set carts typically provide a place for light accessories and modular parts, wireless equipment, batteries, gel and diffusion, boxes of practical bulbs, tape rolls, and similar electrical expendables. A crate each of 25- and 50-ft. stingers are set out ready for use. If lights are being controlled from a console, DMX cables and stingers should be staged near each distribution point.

When a light, stinger, or cable is no longer needed on the set, it goes back to the staging area, where it will not create clutter. The light should be "head wrapped": the stand fully lowered; the cord coiled.

Lighting the set

Lighting technicians have to be alert and always have one eye on the gaffer. You tune in to the sound of his voice and learn to pick it out from the general rumble of noise. An experienced lighting technician has a sense of the ebb and flow of activity on the set and knows when he or she needs to work fast and when there is time to spare. When lighting begins on each new setup, all the lighting technicians should automatically come to the set. There is a great deal of activity as the broad strokes of the lighting are put in. The director's monitor and the camera dolly should be provided power immediately if need be. A period of tweaking and adjusting follows the broad strokes; a few small lights may be added.

Each time the first AD announces a new shot, the lighting technicians working the set should quietly get close to the lights that they might need to move and watch the gaffer and DP for instructions. Even when lighting activity is at a minimum, one lighting technician should always be on or near the set. Before you leave the set to grab a soda, conduct business, or go to the restroom, be sure that another lighting technician is on the set and knows that you are stepping out. If the gaffer needs to step out, he will assign a set lighting technician to cover him, and that person must remain alert to the DP until the gaffer returns.

Setting lights

The gaffer gives instructions regarding which light to use, where to place it or hang it, what color it should have, and any diffusion accessory or material that should be put on it. Think of all the parts, accessories, and cables you may need so that you avoid making repeated trips to the staging area.

A complete set of appropriate-size scrims and a set of barn doors should be brought to the set with every light. Hang the scrim box on the stand. When the gaffer wants a little less from a light, you should be able to drop in the scrim in seconds. It is bad form to have to search for scrims. They should always be with the light.

Each *raised stand* should have a sandbag placed on the leg. The more time you spend on sets, the more you see just how easily stands are toppled. It becomes second nature to check that stands are properly bagged. Similarly, when working in a wind, around Ritter fans, or around helicopters, the grips may need to tie guy lines (no less than three) to the top of the light stand and secure them to stakes driven well into the ground. Prop-wash from a helicopter will blow over a Dino on a supercrank like a piece of paper, even with 130 lb. of sandbags on it. Don't ask me how I know that!

Focusing lights

Usually it will be apparent to the lighting technician what the light is to be used for, or if not, the gaffer explains briefly what he or she wants it to do. The lighting technician comes in with the light, sets it up, powers it, and aims it to light the prescribed area at approximately the desired angle.

If the light is to be controlled on a network, the technician plugs in the DMX cable or checks that the wireless receiver shows that it has a signal. The lighting technician then notifies the programmer what *fixture number* they have just connected and informs the gaffer he or she is ready. When the gaffer gives the go ahead, the programmer turns the light on and works with the gaffer to make any needed color and intensity adjustments.

Don't make the mistake of turning on a tungsten or HMI as soon as you arrive with it, especially if you're not clear on exactly what the gaffer has in mind. The gaffer and DP may be in the middle of focusing other lights or taking light readings. Usually background lights can be turned on and focused by the lighting technician without the gaffer. The gaffer is notified for final approval after the light is totally set, before the lighting technician walks away. This saves the gaffer time. But, if in doubt, check before you hit the ON switch.

While the lighting technician handles the light, the gaffer either stands on the set with the light meter or views the scene from the appropriate camera angle. To focus a Fresnel, very often the gaffer starts with the light at full spot to aim the beam. Some gaffers will hold out a fist where the beam should be spotted. The lighting technician spots the light onto the gaffer's hand, then returns the light to full flood. The gaffer may direct the lamp operator with hand signals (Figure 11.1) or verbal instructions.

FIGURE 11.1

Hand signals.

Pan lamp-left or lamp-right: Lamp-left is your left when you face the direction the light is facing. Lamp-right is your right.
Camera-left or camera-right: Camera-left is your left when you face the direction the camera is facing. Camera-right is your right.
Tilt up: Tilt the light up.
Tilt down: Tilt the light down.
Stem up: Raise the stand.
Stem down: Lower the stand.
Walk it back: Move the stand and light back.
Walk it in: Move the stand and light closer to the action.
Walk it upstage: A term that originates in the Shakespearian theater, where the stage is sloped toward the audience. Upstage is away from the audience. In film and television, it is taken to mean the direction away from the camera (e.g., the upstage lights are backlights)—see Figure 11.2.
Walk it downstage three feet: As if the camera is the audience. Move the light downstage.
Walk it offstage: As if the camera is the audience. Offstage is the direction away from the center of the shot laterally (for example, always place the C-stand on the offstage side of the light).
Walk it onstage: The direction toward the center of the shot laterally (for example, "You can move your light 2 ft. onstage before you get in the shot").

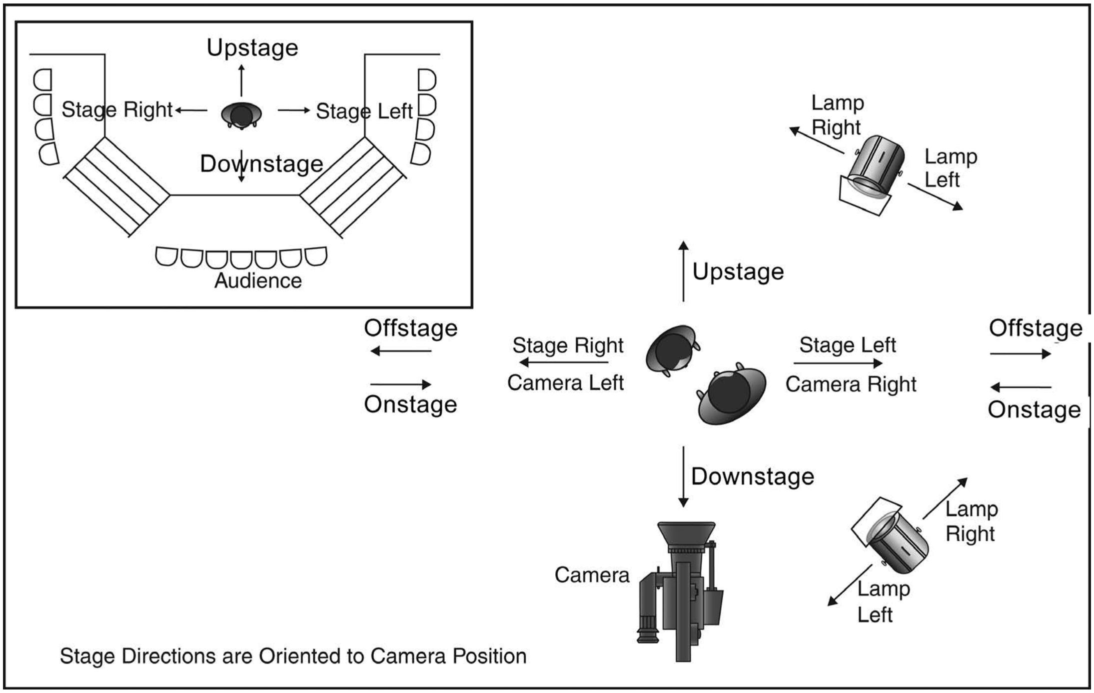


FIGURE 11.2

Stage directions are relative to the camera's position on a single camera show, or the proscenium on a multicamera show or stage performance. "Lamp" directions are just relative to that lamp, when the operator is facing the same direction as the light.

Lock it down: The light is aimed correctly; tighten the T-handles to lock that position.
Walk away: It's perfect. Make sure that everything is secure. You're done with that one.
A scosh: Technical term for an increment slightly less than a smidge or a tad, as in "Flood it out a scosh."
Door it off the back wall: Lower the top barn door.
Waste some of that: Pan or tilt the light so the hot spot isn't directly on the action.
Do off/on or A-B: Switch the light off and on so that the gaffer can observe what the light accomplishes. Announce "On" as you turn it on and "Off" as you turn it off.
Shake it up: With regard to a shiny board. As the sun moves, shiny boards have to be readjusted. The grips have to recheck that it is properly aimed. The phrase can refer to lights in the same way. Pan or tilt the light to make sure that it is aimed properly.
Flag the light: Pass your hand back and forth in front of the lens to show where the beam is hitting.
Rotate the beam: PAR lights have an elliptical beam, rather than a round one. You can turn the lamp housing to orient the beam horizontally, vertically, or at any angle.
Dress the cable: Neaten up the cable or run it out of sight or out of the way.
Dress the light: Something is hanging off the light (i.e., a safety chain or diffusion is hanging into the shot). Clean it up.
Count to 10: Hold off on what you are doing; things are changing and it may not be needed after all.
Cancel: Yup, sure enough, we don't need that light.
Save it or save ###: Turn it off or turn off fixture number ###.
Strike it: Usually means take it back to the staging area. When referring to an HMI, strike means to turn it on, as in "Strike it up."
Strike the set: Take down all the lights and return them to the staging area.

For a Fresnel, fixture instructions may include the following:

Flood it out: Turn the flood/spot knob slowly toward flood until told to stop. Reply "Flooding."
Full flood: Go directly to full flood.
Spot it in: Turn the flood/spot knob slowly toward spot until told to stop. Reply "Spotting."
Full spot: Go directly to full spot.
Drop a double: Put in a double scrim. Reply, "Double in" when finished. You also hear expressions like "Slow it down" or "Bring it down to a dull roar."
Drop a triple: A double and a single in a light.
Home run: Two doubles in a light.
Grand slam: Two doubles and a single in a light (someone picked the wrong light).
Pull the wire: Pull out all scrims. Reply "It's clean" when no scrims remain.
Bottom half-double: Put in a half-double scrim oriented to cut the bottom. Reply "Bottom half-double in."
Give me a slash here: Bring the barn doors together to create a line where indicated.

It is customary for the lighting technician to respond to the gaffer's directions by repeating each direction back as he performs it. This assures the gaffer that she has been heard and someone is following her instructions. When she says, "Flood it out," the lighting technician responds, "Flooding" as he does so. When a delay is involved, he lets the gaffer know he has heard her before proceeding; if she asks for a light, the lighting technician responds, "Flying in" as he goes to fetch it.

Sometimes a gaffer and DP will try to sneak in some final accent lights while the director and actors are already rehearsing on set. The gaffer needs this to be done without drawing attention to what is being done. The lighting technician should be especially careful to focus and contain the light before turning it on and to work quietly.

Labeling intensity settings
Usually, if lights are controlled from a console, the programmer sets levels and programs any cues. However, sometimes this is just done by a technician at the LED's onboard controls, or with a variac or hand dimmer. When setting an intensity level, unless the gaffer says otherwise, start at 100 percent. Say, "That's 100 percent." The gaffer may then specify a setting to try, by saying "Set it at 90 percent " or just say, "Lower . . . lower . . . lower, good." Keep replying with the level, "That's 80 . . . 70 . . . 60." Once it is set, mark the setting (such as with a sharpie marker on white tape). If several settings are used, number them. After the shot is completed, leave these markings on the dimmer until you're sure that they won't be needed again.

Moving on
When lights are controlled on a network, do not turn lights off to clear them from the set without first telling the programmer. The gaffer or lighting technician should tell the programmer which lights can be shut off by saying something like "save 245, 248, and 430." If you shut off lights at the switch without notifying the programmer, the console will continue to show that those lights are in use.

Walkie-talkies
Walkie-talkies with earpieces or radio headsets are an invaluable tool for the grip and electric crew. They cut down the noise and the need to yell on the set, and save a lot of unnecessary steps. If you need something from the staging area and someone has just gone over there, for example, you can quietly ask that person to bring you what you need on the way back.

When using headsets or walkie-talkies, be sure to use proper mic technique: press the button fully, allow a second for the transmitter to engage *before* you start speaking and don't let up on it until *after* you have finished your last word. Otherwise, your first and last words will be cut short. When speaking, keep the mic about an inch from your mouth for a clear, strong signal.

A walkie-talkie has several channels that are typically assigned to specific departments. Usually, the assistant directors are on channel 1; the electric, grip, and transportation departments claim their own channels.

The gaffer initiates a conversation by asking for someone by name, "Dave, come back," or simply a general call for aid, "free hands." Respond with your name: "Go for Dave." Always acknowledge a transmission by saying "copy" or some similar response. If the transmission is interrupted by another transmission, say "You were stepped on, say again." If the signal breaks up during transmission, say "You broke up, come again" or repeat what you think the other person said and ask for confirmation. A broken signal is often an indication that the battery on the transmitting walkie-talkie is low and should be exchanged for a fresh one. Common usage has evolved to include various CB radio codes, such as:

Q: "What's your 20?" (Where are you?)
A: "I'm ten one-hundred." (I'm in the john.)

Use concise phrases. Brevity is the soul of wit, as Shakespeare said; try not to clutter up the frequency with rambling. If a lengthy explanation is unavoidable, you may want to change to an unused channel so as not to monopolize the frequency. Say, "Go to 3" (or whatever channel is free). Then change to channel 3 and wait for a response. When the conversation is finished, say "Back to 5" or whatever the original channel was.

Last but not least, if you do not have an earpiece or headset and are operating with an open speaker, turn the volume on your walkie-talkie to 0 during takes, and remember to turn it back up again when the take is finished. Allowing your radio to blurt out, "Hey Dave, what's for lunch?" in the middle of a performance is what you might call a faux pas.

Safeties

When a light is hung above the set (suspended from the ceiling, set walls, or overhead pipes), a safety line should be tied around the yoke and around a permanent structural support capable of holding the weight of the light if it should come off its stud. The best type of safety line is aircraft cable with an eye on one end and a spring clip on the other. Be sure to leave enough slack in the safety line for the light to be panned and tilted.

Barn doors should also come with safety chain connecting them to the light to prevent them from falling. If a light does not have a barn door safety chain, attach some before hanging the light.

Protecting sets and locations

Protecting the floor becomes a concern when shooting in a set where the floors might be scratched by metal stands, especially on location. A number of precautions can be taken. One is to put crutch tips on the feet of each stand. Tape the rubber tips in place with electrical tape. A stock of crutch tips should be ordered in advance after the location is initially scouted.

Layout board (hard cardboard that comes in 4-ft. × 8-ft. sheets) can provide a protective covering over the floor. It is usually laid out over the entire area and taken up wherever it will be seen in the camera's frame. A more temporary substitute is a furniture pad placed under the stand.

Teamwork

It is important for each lighting technician to watch for a chance to back up others on the electric team. When a light is called for, one lighting technician sets the light, while another gets the power. When an HMI is called for, one person connects the head, the other connects the ballast. If a light is called for at the last minute, all the lighting technicians work in a team: one person carries the head, another grabs a stand, and two more carry the ballast together, throwing the head cables over their shoulders. By the time the head is on the stand, the ballast cable is attached to the ballast and someone has run power to the ballast. The whole drill takes only a minute. The key to teamwork is communication. If you're running someone's power, be sure to tell that person so. Working together, a sharp crew can make the work that much easier and faster.

Warnings

When carrying large, heavy, or hot equipment through the set, call out warnings such as, "Coming through—watch your back" or "Hot points—coming through." You don't want to poke anyone with a stand leg. Ideally, one should be polite but firm, but "Duck or bleed!" also works pretty well.

When turning on a bright light, call out "Watch your eyes" or "Light coming on" before you hit the switch. This is a courtesy to the actors, stand-ins, and crew who are in front of your light. It is meant to warn them not to look at the light. It is a good idea to tilt the light up, away from the set, or put a gloved hand in front of the light as you turn it on. That way the light doesn't come on suddenly, and you give the actors or stand-ins a second to adjust to it before you pull away your hand. By the same token, the dimmer board operator brings lights up slowly on a two-second count; this is a courtesy to those in front of the lights at that moment, but also causes less stress on the lamp filament. This kind of courtesy is not just a matter of politeness but also one of professionalism. Similarly, avoid blinding people in general. If a working light needs to be moved, don't let it swing around and blast into people's faces.

If you are about to plug in a light and you can't tell if the switch is on or off, you can give the warning, "Possible hot stab." This is especially important if the light is aimed at someone or if the light coming on is likely to be an annoyance to the DP or gaffer. It is important to make a habit of turning lights off at the switch before unplugging them to avoid hot stabs.

Whenever a flash camera is used on the set, the photographer should call out "Flashing" before snapping the shot. This is mainly a courtesy to people in front of the camera, but it also alerts the lighting technicians that a camera is about to flash. This way, the flash is not mistaken for a bulb burning out or an electrical arc.

STINGERS AND CABLING

A set can quickly become a rat's nest of tangled cables if care is not taken when running cables and stingers. Here are some guidelines.

Cables crossing the set

Keep cables out of the shot and out from underfoot. A lighting technician rarely runs a cable in a direct line from power to light. Before running the cable, consider the best way to run it. Avoid crossing doorways, especially if there is a chance that the door will work in the scene. Run stingers around the edge of the set. Gaffers often say that you can tell a good lighting technician by the cable you *can't* see. On a sound stage, it is sometimes possible to drop boxes into the set on a line from above, eliminating the need to run cables around the set.

Cables crossing work areas

When cable has to cross an area where there is foot traffic (a hallway or doorway), use cable crossovers (Figure 11.3) or put a rubber mat over the cable and tape it securely to the floor with wide gaffer's tape.

If there is a danger of people tripping on the bulge of the mat, put diagonal stripes of yellow tape across it so that it will be noticed. When cables cross an area where vehicles or carts will be moving, protect the cables with cable crossovers. HMI cables especially should never be left vulnerable. Another way to protect cable from damage from wheels and foot traffic is to lay two-by-four lumber on either side of the cable and tape it down to the floor.

Stingers

Use an appropriate length stinger to reach the light. A *clothesline cable*, one that is taut and off the floor, is an accident waiting to happen—someone is sure to trip on it. Stingers normally come in lengths of 25 and 50 ft. A rule of thumb for fast identification is: a 25-ft. stinger has about seven coils and a 50-ft. stinger has roughly 14. When a light is on a stand, the power cord should fall straight to the ground at

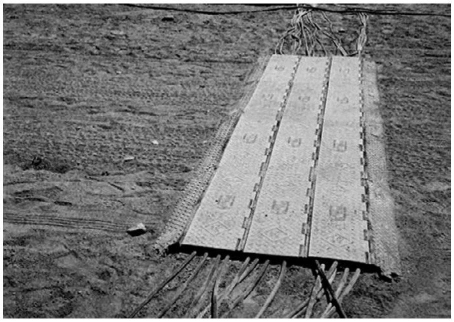


FIGURE 11.3

Cable crossovers protect cable from traffic, and protect pedestrians from tripping or rolling on cables.

(*Courtesy of Yellow Jacket, Inc.*)

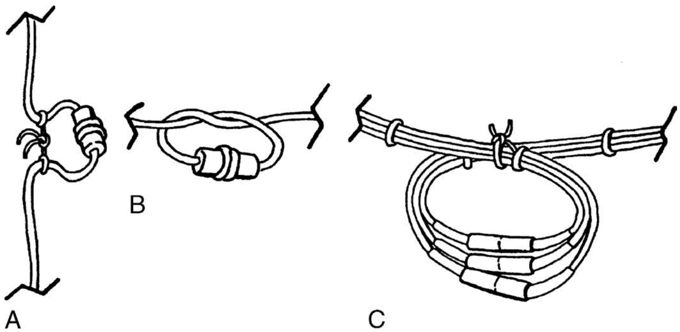


FIGURE 11.4

When there is danger of an accidental kick-out, use a strain relief. (A) A dangling connection held with the tie ropes, (B) a simple strain relief for a stinger running along the ground, (C) banded cable connection point.

the base and have some excess cable coiled neatly. Place the coil such that if the stand is moved, the cable will play out from the top of the coil, not from the bottom.

When lights are hung from pipe, be sure to leave two loops of slack cable hanging at the light. If the light later needs to slide down or pan around 180°, you need slack to play with. Run the power cable down the pipe to the service or to the end of the pipe. Tie it to the pipe at intervals with mason line or sash cord. Never wind a cable around a pipe; this makes it impossible to move later, and a hassle to remove at wrap. Remember: “Rig to wrap.”

Preventing kick-outs

When connecting two cables, tie a strain-relief knot to prevent the connection from being tugged apart (Figure 11.4). This helps prevent a “kick-out” (accidental unplugging). In the event of a kick-out, a lighting technician must quickly track down the gap in the line. For cables with more delicate connectors such as DMX512 control cables, tie the strain relief so that there is no bend or stress at the connector.

Repatching

You will sometimes need to unplug a light that is in use to replace a cable, run power from a different direction, or readjust the loads of various circuits. Before you unplug the light, inform the gaffer of the need for a repatch, and as you disconnect it, call out, "Repatch." This assures everyone that the light has not gone out accidentally. Frequent repatches can be irritating for the gaffer and DP. In many situations, it may be best to find another way to solve the problem.

2k plugging policy

To help other lighting technicians know which duplex outlets are maxed out and which still have amperage to spare, make it a policy within the department to always plug a 2k light into the top duplex outlet. If you are plugging a 1k or smaller, use the bottom outlet first. This way, any lighting technician knows at a glance which duplex outlets have capacity to spare and which are already maxed out. It is also helpful to label the plug of 2k lights so that you can identify them among the many cords at the outlet box, and keep them on separate 20 A circuits.

Labeling stingers and power cords

Labeling cables helps immensely in identifying problems and recabling lights when needed. When a cable runs out of the set through a rat hole, over the top of the set, or up into the pipes or greenbeds/catwalks above the set, both ends of the cable or stinger should be labeled with tape. Indicate the lights it is powering—for example, "2k window light" or "stair sconces." Similarly, when using a dimmer board, the gang box or female receptacle of the power cord should be marked with the circuit number. See Chapter 16 for notes on labeling and laying out distribution equipment.

It is essential to be able to identify each light by number, especially lights that are hung from a grid. Label each light so that the number is visible to the gaffer on the ground below. Write the numbers large and legible on 2-in. tape on the underside of each unit. Mark the tails (the plugs) with the same numbers. With the lamps numbered, it is easy for the gaffer to communicate what he or she wants.

Coiling stingers and cable

All cables and stingers are coiled clockwise. Each loop puts a twist in the cable. When uncoiled, it must be allowed to untwist, or it will start to twist onto itself and become knotted.

The stranded copper wire inside a cable has a natural twist; coiling counterclockwise works against the grain. When a cable is consistently coiled in the same manner each time it is used, the cable becomes "trained" to coil that way. A trained cable coils easily. If a cable is coiled different ways with each use, it becomes confused and unmanageable.

The over/under method shown in Figure 11.5 is used for coaxial cable, DMX, and Cat 5 cables. Every other loop counteracts the twist so that the cable can be unraveled without twists. Using the occasional underhand loop sometimes makes a cord more cooperative.

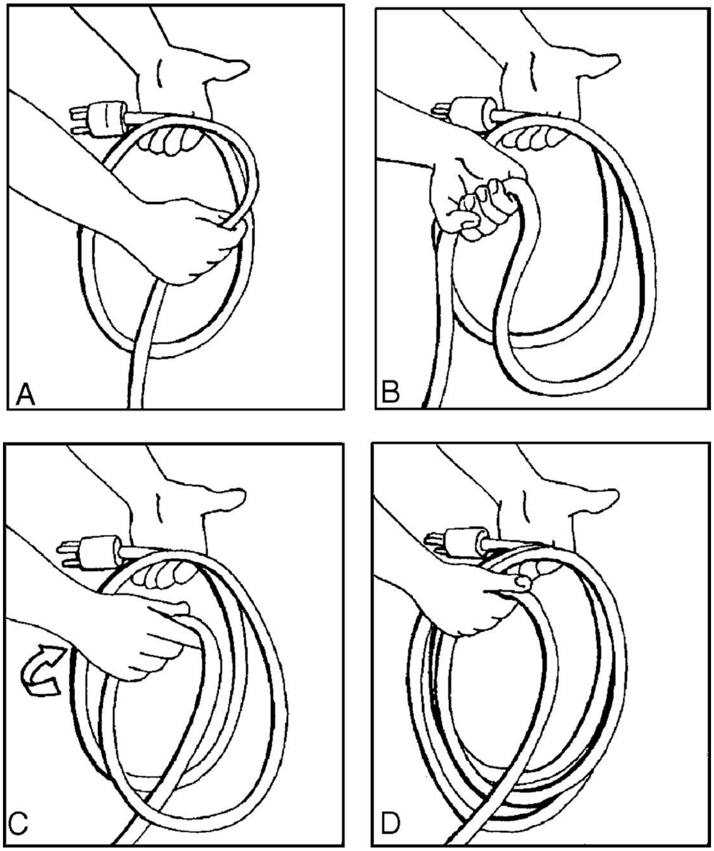


FIGURE 11.5

When you coil a stinger, use your wrist to put a slight twist on each loop; the stinger will coil easily. When a cable wants to twist too much, you can use the over/under method of coiling. Always use this method with control cables: (A) start with a normal loop; (B, C) give the second loop a twist to the inside; (D) make the next loop normal. Alternate back and forth between a normal loop and a twisted loop.

Circuit balance and capacity

The best boy electric, generator operator, or other designated technician may be responsible for monitoring the balance of loads on the cables. If possible, keep the three phases more or less balanced. If there is a big difference between the loads on the three phases, it can show up in surprising places. It can affect the operation of SCR dimmers and the generator. If the loads are out of balance, start adding any new loads to the low leg. Repatching one or two well-chosen lights can usually redistribute the current and balance the phases.

Overheating and short circuits

It is normal for cables to run warm, but if they become hot to the touch, replace cables as necessary and notify the best boy electric.

If a fuse blows repeatedly, something is wrong. The circuit could be overloaded, in which case the problem will be solved by redistributing the load onto other circuits. There could be a short in a light, a plug, or an outlet. The short can be found by isolating the items plugged to the circuit. If necessary, turn them all off, then reintroduce them one at a time until the breaker trips. Mark the bad part with an X, mark it "B.O." and take it out of service and hand it off to the best boy to repair or replace.

Smoke, fire, and other bad smells

Lights can get very hot and can easily start a fire. Common sense and proper care are essential to the prevention of accidents. If a curtain is blown by the wind it could blow onto a nearby light. If there is debris flying in a scene, precautions should be taken to prevent it blowing onto the fixtures. This is especially important when fixtures are unattended. Know where the fire extinguishers are and how to use them.

If you smell smoke, don't cause a panic, but let the other lighting technicians and grips know so they can help look for the source. The smell of burning wood may be caused by a toasting clothespin or a tungsten light placed too close to a wooden set piece. The smell of burning plastic or rubber may be traced to smoldering insulation on a cable connection or inline switch. An overheated stinger is a common offender. Check the lights for burning gel or diffusion and smoking flags or nets. Check the set walls and ceiling for bubbling or smoldering paint. Keep looking until you find the source of the smell.

A smoking light is usually the result of some foreign matter getting into the light and burning up. Dusty lights often smoke for a short time when they are first turned on. Moths are relentless kamikazes. Outside in a ventilated area, this does not pose a danger to anyone but the moths. Inside, though, it may be necessary to turn off a smoking light and clean it out.

Sprinkler systems

Placing a hot light too close to a sprinkler head can easily melt the soft alloy valve that normally holds back the flood. There is no way to stop an activated head from flowing once it has started, and the water in the pipes will continue to drain sometimes for hours, even if the sprinkler system is immediately turned off at the source. In the category of big blunders, few are more conspicuous than activating the emergency sprinkler system. Provide adequate clearance around hot lights for sprinkler heads as well as from walls, ceilings, and surfaces.

ELEVATED WORK

Ladders

When working with suspended lights, you must often work from a ladder. Have someone hold the ladder. Use the appropriate-size ladder. Don't use the top two steps. Don't overreach. Get a taller ladder, or climb down and move the ladder.

Parallels

Parallels are used as a lighting platform. They are quick and easy to assemble and, if used with proper caution, can be safe. However, “caution” is the watchword. Almost any veteran lighting technician can tell you a story about an accident involving parallels.

Parallels must be set on level ground or be leveled with leveling jacks. On uneven ground, it can be hard to tell what is level; a plumb line or bubble level should be used. Do not use a scaffold that is not plumb and level. When lifting equipment up to the platform, don’t place all the weight on one side. Get help from the grip department to stabilize the scaffold. Never mount lights outside the perimeter of the railing. Any scaffold, including parallels, must have a safe means of access such as a ladder. You should not have to climb the frame, unless the frame forms a ladder.

Large light stands should be strapped down to the platform. Ratchet straps are ideal. Remember to take into account the force of the wind blowing on 4-by frames. Tie guy lines to the bail or stand when needed. Tie the power cable to a vertical post on the platform, leaving plenty of slack to maneuver the light.

Working at height

Anytime you work at a height—on a ladder, greenbeds, catwalk, parallels, or truss—remove your tool belt. Tie any necessary tools to your belt. Dropping a tool from the catwalks could seriously injure or even kill a person below. Dropping objects from the catwalks is a serious safety violation, and doing so can get you kicked off a studio lot.

Remember to bring a tag line so that you can hoist equipment as you need it. The tag line should be tied off at the top end so that it cannot fall. Call “Line out” before you toss down the line.

Aerial lifts (Condors and scissor lifts)

There are a variety of types of aerial lifts commonly used as platforms for lights and lamp operators: a straight mast boom (Condor), articulated boom (knuckle boom), scissor lift, and man lift. Aerial lifts are invaluable tools, both on the sound stage and on location. With the right lift, riggers and lamp operators can move easily into hard-to-reach places to hang and adjust lights and cable.

The standard moonlight rig for nighttime street exteriors consists of one or two large lights mounted to the basket of a telescoping straight mast boom lift, raised over one end of the street. Condor, Snorkelift, JLG, Genie, and Simon are the dominant makes, but for some reason the name *Condor* has stuck for a straight mast boom. A lighting technician is designated to operate the platform and the lights mounted on it. Productions often need to bring on an extra hand for “Condor duty,” so knowing how to operate an aerial lift can get your foot in the door with different crews.

Lighting technicians must receive training and gain some experience operating aerial lifts before accepting such work. One has to learn how to inspect the aerial lift, what to check for, how to operate the controls, how to level the lift. Equally important, one needs to learn how to load, rig, and operate the lift so that it remains within the manufacturers’ specifications. (See Chapter 16.)

COLOR CORRECTION ON LOCATION

Correcting commercial/industrial fluorescents

The color rendering of fluorescent tubes in office buildings, warehouses, factories, and commercial buildings will depend on the installed lamps. Daylight fluorescent tubes are designed to light spaces that have supplementary daylight, such as offices with large windows. Warm lights, which have a color temperature closer to that of household bulbs (3000 K) are intended to be used in enclosed spaces where supplementary light comes from table lamps and wall sconces.

In Appendix B, Table B.2 lists specifications for various types of fluorescent tubes. A high CRI tells you that the tube has a nearly complete spectrum of light frequencies and is therefore capable of rendering colors adequately; however, they often have a strong green spike. A low CRI rating indicates the lamp emits a limited spectrum of light and is incapable of rendering all colors. If the tubes have low CRI ratings they should be replaced with better tubes for filming, or turn them off if possible.

Green and magenta color correction gels were developed primarily to allow color matching between fluorescent lights and other sources. Table G.9 lists green and magenta correction gels and Kodak filter numbers and corresponding color meter readings that may be useful in this process.

There are three general approaches to matching the color temperatures of fluorescent lights, tungsten lights, HMIs, and daylight: (1) Match all the sources to daylight (5600 K), (2) match all the sources to tungsten (3200 K), or (3) match all the sources to fluorescent daylight (5600 K plus green). What works best depends on the situation. A loft with huge windows along the walls would not be a good candidate for a window gelling solution: better to change out the fluorescent tubes or gel them. An office building with hundreds of fluorescent fixtures on the other hand might be a better candidate for correcting the color balance of the fluorescents. Table 11.1 details each approach.

When gelling fixtures that have frosted plastic panels, you can cut sheets to lay inside each fixture. If you have to gel tubes individually, place tabs of snot tape along the tube and roll the tube up in gel. Carefully cut away excess gel.

Rosco makes tubular sleeves of color correction gel that can make gelling tubes easier. You can also get clear plastic sleeves that are meant for protection in case of lamp breakage; cut and roll the gel inside them.

Heat protection and gels

Very often, DPs and gaffers like to warm up HMIs using some amount of CTO correction. As the sun sinks in the afternoon and turns more and more orange, the correction on the lights needs to increase as well in order to match. While large HMI pars have awesome power and fill a niche no other light can, gelling them is a challenge and sometimes impossible. Gels work by absorbing selected wavelengths of light, and that energy converts into heat. Excessive heat can burn a hole right through the gel or fade the gel color quickly. This makes color correction a problem.

There are a few techniques and products that can help mitigate heat buildup in the gel:

- Use a frame of heat-shield spaced at least 18″ from the gel.
- Perforate the gel with pinholes to reduce absorption and increase ventilation. This will help slow the fading of the gel color.
- Divide the work between two gel layers. For example, to accomplish a full CTO correction, use

Table 11.1 Strategies for matching mixed color sources

Strategy	Ceiling fluorescents	Fixtures	Windows	Camera
Match to tungsten				
Used when the daylight sources are small and manageable (e.g., a night scene, or a location with small windows).	Replace with high CRI, lamps with good tungsten balanced color rendering. Add ¼ or ⅛ minus green as necessary. Gel warm whites with full minus green. Gel cool whites with fluoro filter (not ideal).	Use tungsten-balanced lights to light the scene. If HMIs are used, apply full CTO gel. LEDs set to 3200 K.	Apply Sun 85 or full CTO gel.	3200 K setting or film stock.
Match to daylight				
Good approach in a room with many large windows.	Replace with high CRI, lamps with good daylight balanced color rendering. Add ¼ or ⅛ minus green as necessary. Gel cool whites with full minus green.	Use daylight-balanced light. Don't use tungsten. LEDs set to 5600 K.	Use it as is or with ND as needed.	5600 K setting of film stock.
Match to fluorescent daylight				
Resort to this if the ceiling lights must remain on and (1) there are too many fluorescent lights to gel or replace them all, (2) the lights are not accessible, or (3) there is no other alternative.	Use cool white fluorescent tubes.	Apply full plus green gel to HMIs. Don't use tungsten. Daylight-balanced LED or fluorescent and add plus green as necessary.	Gel with window green.	Daylight-balanced with FLB filter or take out in post.

two frames of ½ CTO, or a frame of ¼ CTO followed by a frame of ¾ CTO (the first frame takes a bigger portion of the intensity).

- If you have the space, seam gels together onto 8′ × 8′ frames and place them as far from the light as possible.

Gelling windows

When the outside of the window is accessible, gel can be stapled or taped over the outside window frame, which hides the gel more easily. When stapling gel, apply a square of gaffer's tape to the gel and staple through the tape to prevent the gel from ripping. The key to gelling windows is to keep the gel tight and free of wrinkles. CTO correction is also available in 4′ × 8′ acrylic sheets. Using acrylic sheets avoids the problems of wrinkles, movement, and noise that gel makes.

With a very light dusting of spray adhesive (Spray 77), you can stick gel directly onto a window or acrylic sheet. Press bubbles and wrinkles out to the edges with a duvetyn-covered block of wood. If gelling windows promises to become an everyday process on a particular location, an elegant system is to cut acrylic inserts to fit the windows, then add neutral-density (ND) and CTO gel (using the spray adhesive technique) as needed to suit the light conditions and time of day. Move the inserts around from shot to shot depending on the camera angle.

You can also use snot tape (3M transfer tape) or secure the gel by carefully taping around the edge of it with tape that matches the color of the window frame. Another fast method is to spray water on the windows and apply the gel with a squeegee. This method will not last all day, but it saves so much time that it doesn't matter if it must be redone.

PRACTICAL BULBS

On any interior set, the art department will provide *practical fixtures*: table lamps, wall sconces, floor lamps, desk lamps, china hats, fluorescents, chandeliers, and so forth. Each time you begin working on a new set, one of the first things to take care of is the wiring and testing the practicals and changing the bulbs as desired by the gaffer. Appendix B illustrates various common lamp types and lamp-base sizes.

PH bulbs and photoflood bulbs

Photoflood bulbs are color-balanced for use in photography (3200, 3400, and 4800 K) and come in various wattages, as shown in Appendix B. The 211 (75 W) and 212 (150 W) are often used in table lamps and suspended China-hat practicals. Higher-wattage photofloods are sometimes used in soft boxes, Chinese lanterns, and scoop lights. Most photoflood bulbs burn very hot and have a short life, in order to provide the high color temperature. It is a good idea to preserve them by turning them off between takes when possible.

The color temperature of regular incandescent household bulbs (15, 25, 40, 60 W) falls between 2600 and 2900 K, which may be acceptable, depending on the look that's desired and the color balance of the camera.

MR-16

An MR-16 looks like a small PAR lamp, two inches in diameter, and makes an excellent accent light. They are available in various color temperatures including 3200 K. The MR type reflector (multi-faceted reflector) creates a punchy little beam of light, ideal for art and display lighting. They come in a variety of beam widths including 8°, 24°, and 36° in 20, 50, 75, and 100 Watts.

Lee Filters makes a range of accessories to fit MR-16 lamps, including louvers, gel holders, clip-on baffles and barn doors, and a variety of different diffusion lenses that spread the beam and soften the edges (Figure 11.6). MR-16s are available with a standard medium screw base in 75 and 150 W. There are also a few other bi-pin base sizes for low voltage systems such as track lights.

Mushroom floods

Flood- and spotlights of the mushroom-shaped variety incorporate a silver reflector inside the bulb for better output and throw. Common wattages are 75, 150, 300, and 500 W (EAL). 3200 K R-40 bulbs are available in

FIGURE 11.6

MR-16 accessories: barn doors, gel holder, grids, louvers, diffusion glass (not shown).

(*Courtesy Lee Filters*)

200, 300, 375, and 500 W wattages (see Table B.1). The rest fall between 2800 and 2900 K. The R-40 size is the most commonly used. A Lowel K-5 kit includes sockets, mounting bracket, and barn doors that fit snug onto the front of an R-40 bulb. There are a wide variety of other reflector bulbs. The number indicates the size; for example, in R-40/FL, R stands for reflector and 40 is the size (in eighths of an inch: 40/8 = 5 in.). FL indicates flood. Smaller R-30 and R-20 bulbs are great for track lighting or lighting wall art at close range.

Dimming practical lamps

When practicals are controlled remotely, on a dimmer or network, label each practical with the dimmer circuit number or fixture number. A small, neat label, made with a p-touch printer and adhered right to the sconce or practical lamp base, will be invisible to camera, but easy to read on set.

It is standard practice to put all practical lamps on dimmers so that their intensity can be easily adjusted. If the bulb is not actually visible (the fixture has a lamp shade or frosted glass) a shot length of LED ribbon may actually offer better control of color and intensity than using a bulb. Technicians sometimes just wrap ribbon around the non-functioning bulb (see Chapter 7). Incandescent lamps should be put on a dimmer (see Chapter 15). Incandescent bulbs sometimes buzz when powered by an SCR dimmer at certain dimmer settings. If this becomes a problem, a quick solution is to repatch the light into a variac dimmer.

There are other ways to dim a bulb that do not alter the color temperature. Spraying the bulb with a light speckle of black streaks and tips is a fast way to reduce the bulb's intensity. (Don't spray a hot bulb; it will burst.) Sometimes you want to reduce brightness in only one direction. This can be done by spraying one side and not the other. Placing diffusion on the inside of the lamp shade and installing ND gel around the bulb are also ways to dim a practical. Of course, you can also just use a lower wattage bulb to avoid having to dim the light.

Wiring fixtures and outlet boxes

Practical lamps

Lamps and sconces often come from the prop house with bare wires and typically need to be fitted with a cord and plug. When adding a tail to a light fixture, extra-hard usage cable is required. Use wire nuts to insulate wire splices and house the splice inside the base of the fixture, or inside an approved electrical box. If a lamp or sconce is metal and not UL-listed, a grounding wire is required. UL-listed lamps may use 18/2 power cord up to 6 ft. long, provided that the cord is consistent with the lamp's original design.

In the past, 18/2 zip cord, add-a-taps, and quick-on plugs were often used for wiring small fixtures; however, the National Electrical Code and all the major studios require the use of "hard usage" or "extra hard usage" cord on sets and locations used for filming, so zip-cord, which is "junior service" cable, does not qualify.

Junior service cord is prohibited because it poses a potential safety hazard. A long run of zip cord imposes so much impedance in the cord that a dead short may not trip the circuit breaker. The cord can potentially overheat before it will trip the circuit protection, which is a serious fire hazard. Zip cord is rated for 10 A.

Wiring plugs, sockets, switches, and connectors

It is very convenient for sets to be wired with *practical wall outlets*, for both practical lights and movie lights. The outlet must be housed in a standard UL-approved outlet box. Fit the outlet with a short tail using 12/3 or 14/3 extra hard usage cord, and attach an Edison plug. Do not use smaller wire; the assembly should be capable of delivering the receptacle's full rated load (15 A). Ensure the assembly has a proper ground. On the outside wall, the Edison plug can then be connected to "hard power," at a distribution box or to a dimmer circuit. Again, label each receptacle on set with a small p-touch label and label the Edison plug outside the set with a sharpie and white tape.

When wiring or repairing electrical devices, be sure to make a good, solid connection, copper-to-copper, with each terminal tight and secure. Plugs, sockets, connectors, and switches are the weak spots in a circuit. Overheating poses a fire and shock hazard as well as causing a nuisance by eventually burning out.

Also, for safety reasons, any time you install or replace a switch or connector, *pay attention to the proper polarity*. On plugs and sockets, the gold terminal is for the hot (black) wire, and the silver terminal is for the neutral (white) wire. The green terminal is for the green grounding wire. If an electrical device is connected with reverse polarity, the neutral and hot wires are reversed, and a potential safety hazard exists. The switch controlling the fixture, which normally interrupts the hot wire, now interrupts the circuit on the *return* wire (neutral). Although the switch still functions, it has a hot lead running to the lamp when turned off—a hot lead looking for a place to ground. So, even though the fixture is off, it is still *hot*. For example, someone attempting to change the bulb, thinking that because the switch is off the light is safe, could be in for a jolting surprise. This is why one should always unplug a fixture before putting a hand inside it, even if the switch is off. When installing a switch, *a single-pole switch must be connected on the black wire*, not the white.

Double-pole switches and three- and four-way switches

For 208 or 240 V circuits and lights 2k or more, it is necessary to have a switch that interrupts both wires at once. This is known as a *double-pole* switch.

It is sometimes handy to have two or more switches in different locations to control a circuit. To do this, wire two three-way switches. When more than two switches are needed, a three-way switch is connected at the beginning and end of the chain of switches, and any number of four-way switches can be connected between them. In either case, any of the switches will close and open the circuit, regardless of the position of the other switches.

THE WRAP

When filming is completed at a given location, all the equipment has to be packed back into the truck. This may take an hour or two when a lot of equipment is in use. Especially after a long day, it is everyone's dearest wish to get the truck packed as quickly as possible and get home. One of the best boy's responsibilities is to begin the wrap early and have as much of it done as possible before the actual wrap is called. Prior to wrap, the best boy organizes the removal of superfluous equipment from the set and the coiling of cable no longer needed. Once the last setup is lit, on the gaffer's word, any equipment not in use can be stowed and ready to drive away.

When wrap is called, the lights are packed onto the carts, and equipment starts coming back to the truck. I find that it works best if the best boy remains at the truck and packs the equipment as it is brought to the lift gate by the lighting technicians. This avoids equipment piled up at the gate. Lights that have cases should be packed safely, making sure that all the power cords and accessories are accounted for. Tungsten lights should look like the one shown in Figure 11.7. The bail is swiveled up over the top of the light. The power cord is coiled, tied, and hung over the bail or tucked under the bail. The barn doors are shut. Scrims, diffusion, and gel have been removed and returned to the scrim and gel boxes. Spreader lenses are removed from PAR lights. The lamps should be removed from larger HMIs before travel.

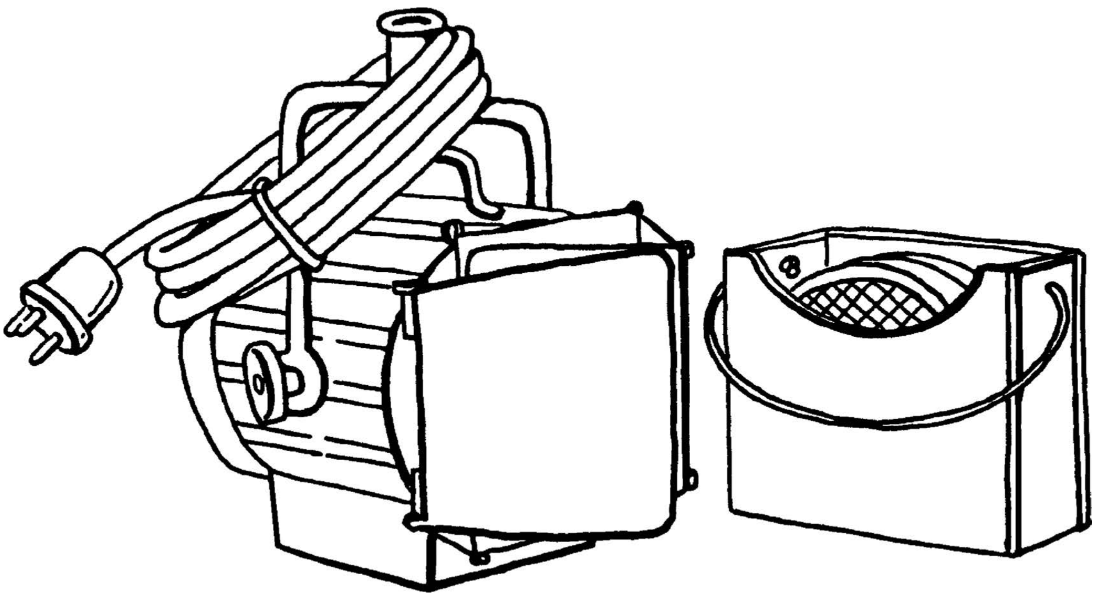


FIGURE 11.7

A properly wrapped light. Some lighting technicians prefer to tuck the cable inside the bail to prevent it from getting caught on other equipment.

Coiling feeder cable

The fastest way to coil feeder cable (banded, 2/0, or 4/0) is to stand with your legs apart and coil in a clockwise circle on the ground. With a little practice you can get into a rhythm, pulling the cable toward you with one hand, then the other, guiding it into a coil. The ideal size for a coil is tight enough that the finished roll is not floppy and unmanageable, but not so tight and tall that it becomes impossible to stack. Use the tie strings to secure both ends firmly. Loose ends tend to swing around, hit people, and get snagged. Lift with your legs, not with your back. To protect your back, try to avoid lifting from awkward, twisted body positions, like when you are reaching into the belly of the truck, and avoid yanking. Back injury from repetitive heavy or awkward lifting is one of the more common causes of lost work days and disability, so be careful.

Inventory

The best boy conducts an equipment inventory during loading. If each cart and truck shelf has been labeled with the type and quantity of lights it holds, this process is quite straightforward. Strap off each shelf as soon as it is complete; this helps keep track of what is still missing; and once all the shelves are filled, the truck is ready to go without further delay. Putting each light in its proper place is not just a matter of organization, it can be crucial to fitting everything on the truck. Before leaving any location, one of the lighting technicians should run an idiot check on the set, looking in each area where lights were placed during filming.

REPLACING LAMPS

When a lamp fails, be sure to label the light so that it isn't brought back onto the set by mistake. Put an X across the lens with 1-in. tape, and write *NG* (no good) or *BO* (burnt out) on it. If you know what is wrong with the light, write that on it also (e.g., blown bulb, bad switch, bad plug). When a lamp fails, the light is very hot, so the quickest course of action is immediately replace the entire head with a new one, rather than attempting to change the lamp. The lamp can be changed after the light cools.

Matching the lamp to the fixture

Lamps are identified by a three-letter code assigned by the American National Standards Institute (ANSI). For example, a 1k Fresnel typically uses an EGT bulb. ANSI codes are listed in Appendix B.

There are often alternatives to the standard type: a bulb with a different wattage or color temperature, or one that uses frosted instead of clear glass. It is quite common to install alternative lamps, depending on the intended use. For example, a lamp with a color temperature of 3000 K often has a far longer lamp life than the same size lamp with a 3200 or 3400 K color temperature. To be compatible with a light fixture, two things must match: the lamp base must match the socket of the light fixture and the *lamp center length*, LCL, must match. LCL defines the position of the center of the filament of the lamp, and centers it with respect to the reflector, the lens, and the rest of the optical elements (see illustrations in Appendix B). Lamp information available from GE, Sylvania, Osram, Phillips, Koto, Ushio, and others list specifications for every bulb and socket manufactured.

Most tungsten lights use a *tungsten halogen lamp*. It is a type of incandescent lamp that contains special regenerative elements to prevent deposits of tungsten from blackening the sides of the lamp. The regenerative elements carry the evaporated tungsten back to the filament, where it is reused, thereby increasing the life of the lamp. For the regenerative process, called the *halogen cycle*, to occur, a high temperature (at least 250 °C) must be maintained inside the lamp; for this reason, tungsten halogen lamps tend to be compact and made of quartz, which can withstand such a high temperature.

The two kinds of HMI lamps, single-ended and double-ended, are shown in Figure 11.8.

Mercury

HMI and fluorescent lamps contain very small amounts of mercury, which is poisonous. If a lamp breaks, take sensible precautions to prevent ingestion. Keep chemicals off your hands and wash your hands after cleanup. Dispose of broken and burnt-out bulbs in an appropriate place. Burnt-out lamps usually must be returned to the rental house for inventory.

Replacing tungsten and HMI lamps

Before opening a light to change the lamp, first always be sure that the power cord of head feeder cable is unplugged from power and keep that cord where it is under your sole control. For HMIs, be sure the head feeder cable is unplugged *from the fixture*; do not rely on circuit breakers that may be 25 feet away and not under your sole control.

Be sure the lamp is cooled to avoid burning your fingers. HMI bulbs build up internal pressure when in use. It is dangerous to handle them when hot; if broken, they can explode. For more on relamping HMIs, see Chapter 9.

The golden rule when relamping any fixture is never to touch the quartz envelope with your fingers and never to allow moisture or grease to come into contact with the bulb. Even a light smudge of finger grease causes a hot spot on the quartz envelope, which weakens the quartz and causes the

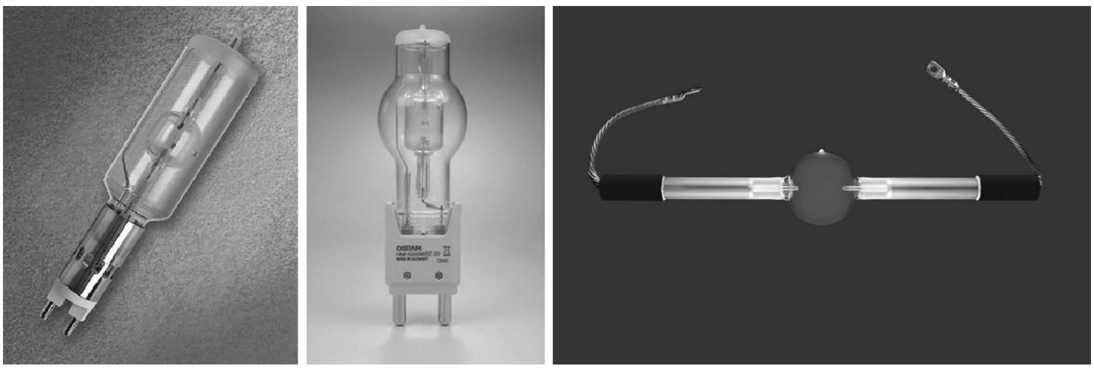


FIGURE 11.8

From left to right: a 12 kW single-ended lamp, a 4 kW single-ended lamp, and a 24 kW double-ended lamp.

(*Courtesy Osram Corp.*)

envelope to bubble. When the lamp loses its shape, its photometric and structural properties are compromised, and the lamp could fail. Lamps are too expensive to handle carelessly. When a large HMI lamp suffers catastrophic failure (explodes), it can shatter the lens and destroy the lamp holder and reflector, bringing the total loss to a staggering sum. Always handle lamps with a clean and dry rag, with clean cotton gloves (editor's gloves), or with the padding in which the lamp is packed. Follow the lamp manufacturer's recommendations for cleaning the lamp once it is mounted in the fixture. They often recommend wiping the lamp with a presaturated alcohol wipe or isopropyl alcohol and a clean lint-free tissue.

Figure 11.9 shows how to open up various models of tungsten lights to get at the lamp. Figure 11.10 shows a diagram for relamping a Source Four tungsten ellipsoidal spotlight. Most larger Fresnels used in motion picture work have a bipostal (two-pin) lamp base. On lights 2000 W and larger, the fixture has a thumbscrew that tightens the base around the pins of the lamp. The lamp comes out freely when the thumbscrew is loosened. On small units, the pins on the base of the bulb simply plug straight into the lamp base and are held in place by friction. When removing the bulb from this type of base, be careful not to break the glass off its porcelain base. Firmly grasp the porcelain base and wiggle the lamp out. Do not handle the glass.

Smaller lamps, such as the 200 W FEV, have a bayonet base. Bulbs are listed by base type in Table B.3.

If the bulb is not seated properly or the reflector is bent, the lamp's performance is drastically reduced.

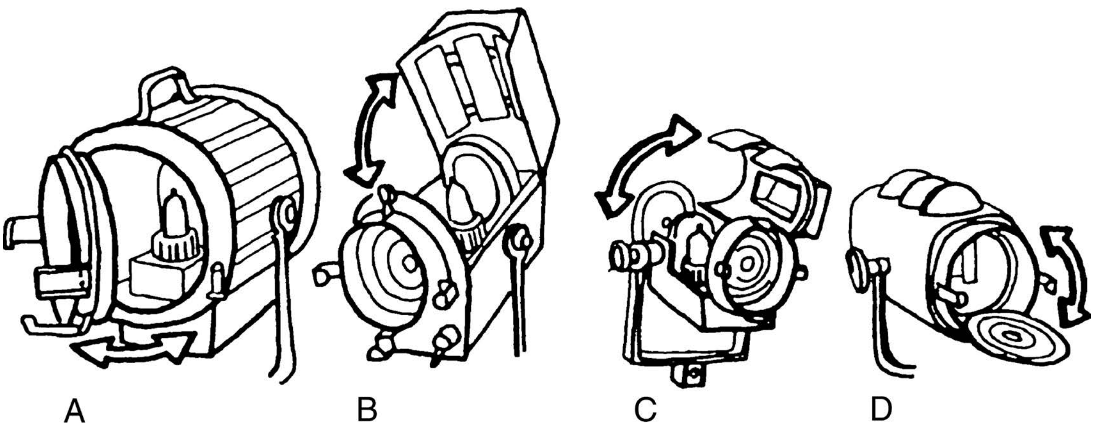


FIGURE 11.9

Four common ways to access the inside of a Fresnel fixture. (A) With most lights 1000 W and larger, the lens door swings open on a hinge. (B) On a baby-baby, the top of the housing swings back on a hinge at the back of the fixture. (C) The top of a Pepper's housing swings open to one side. (D) The lens of a midget is held in place by a metal tab. Push down the tab to take out the lens.

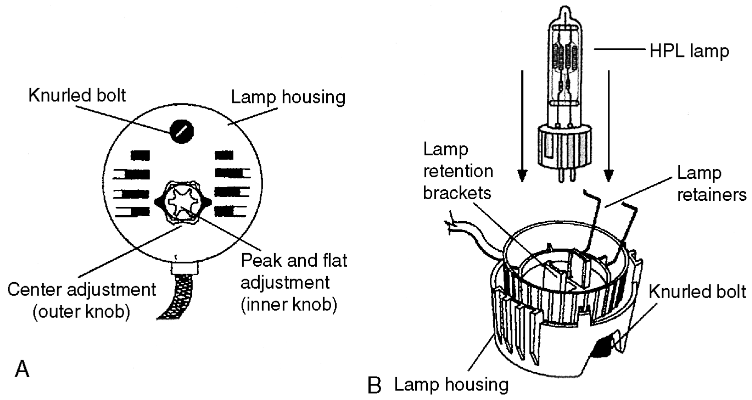


FIGURE 11.10

Relamping a Source Four (tungsten). (A) The outer knob centers the lamp; the inner knob adjusts the flatness of the field. (B) The lamp base, lamp, and retention bracket.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

CHAPTER

Lighting control networks

12

There are many clear advantages of controlling lights remotely. You don't have to carry a ladder into a busy set to manually adjust a light, adjustments are immediate, and the console makes complex tasks like color selection and lighting effects intuitive, repeatable, and archivable. The on-set workflow is streamlined; once a light is positioned, powered, and connected to the network, it can be handed off to the programmer who works with the gaffer to finesse the color and intensity, freeing the lighting technician to move on to another task.

It has become increasingly important for lighting technicians to understand how various types of control networks operate down to the granular details. There are two categories of networked lighting control. The first is DMX (officially DMX512-A). DMX is a digital multiplex communication protocol for entertainment lighting, recognizable by the 5-pin XLR connector on equipment. When it was first conceived, DMX was designed to replace the analog control of large numbers of dimmers. However, once DMX became a standard, it made one manufacturer's products interoperable with other's. Even though it was not perhaps the ideal protocol for every one of the thousands of applications it was eventually used for, the need to have one, simple, universal system that works with all consoles and lighting devices made DMX ubiquitous. As you have seen throughout this book, many devices can be controlled by DMX: LED fixtures, HMI ballasts, fluorescent fixtures, shutters, pan/tilt yokes, distribution switching equipment, foggers, lightning effects, moving lights, media servers. Doug Fleenor (Fleenor Design) even famously made a DMX coffee pot just to make this very point.

The second category of networked control is Ethernet, which is familiar to most people because it is how the Internet is delivered. As lighting controllers became increasingly computerized it made a lot more sense to use this computer-based protocol (Ethernet, IEEE 802.3) to network lighting devices because it is extremely fast, reliable, has widely available network hardware, is scalable, has error correction, and integrates directly with servers, storage devices, and existing Ethernet infrastructure at studios and sound stages. While DMX is fast enough for most lighting needs, it is slow compared to Ethernet. DMX communicates at 250 Kbits/s, while Ethernet (100BASE-TX) over CAT5 cable has a data rate of 100 Mbits/s, and Gigabit Ethernet (CAT5e or 6 cable) delivers data at 1,000 Mbits/s. In addition, an Ethernet cable can carry a lot more data. Art-Net, a non-proprietary protocol for transporting DMX and RDM over Ethernet, can carry more than 4000 DMX universes on a Gigabit Ethernet system. If DMX is like a postal Jeep making its daily rounds along a single-lane dirt road, Ethernet is like, well, email.

Once the system is controlled via Ethernet, it is only one short additional step for it to communicate with portable devices like tablets, iPads, and smartphones, communicating wirelessly. We'll get to all this later in the chapter.

In the larger entertainment industry Ethernet is the de facto standard for lighting control. Large productions routinely use Ethernet as the primary control infrastructure to network console(s) with

FIGURE 12.1

DMX and Ethernet (RJ45) data port on a moving light fixture.

servers, switches, central backup storage, and lighting devices. Lighting devices that use a lot of channels usually have an RJ45 connector to connect a CAT5 or CAT6 Ethernet cable directly (Figure 12.1). DMX devices can be connected to an Ethernet network using DMX nodes.

But Ethernet and DMX are not necessarily competing technologies. The two technologies are complementary, operating in two different portions of the communication highway, with DMX being the last mile to the device. There are many advantages to using Ethernet as the primary network, especially for big shows with multiple universes. We'll get into the details of these networks later in this chapter.

DMX512

The current DMX512 standard is known as DMX512-A.[1] DMX512 is a fairly simple and reliable system if it is set up correctly; however, there are a number of ways things can go wrong that can lead to

[1] The Engineering Commission of the United States Institute for Theatre Technology (USITT), made up of representatives from various manufacturers, first created a DMX standard in 1986. It was revised in 1990, resulting in the USITT DMX512/1990 standard. Through efforts by the Entertainment Services and Technology Association (ESTA) beginning in 1998, it was further revised and eventually approved as an ANSI standard in 2004. The resulting standard, known as DMX512-A, is officially titled "Entertainment Technology—USITT DMX512-A—Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories."

mayhem. Later in this chapter, we'll discuss the best practices for building reliable wired and wireless DMX512 networks as well as ways to test and troubleshoot problems. Before we get to that, however, let's cover the practical aspects of how a network is configured.

The signal of a DMX512 network is generated by a *controller* such as a control console. The output from the controller, called a *data link*, provides data for up to 512 channels. The 512-channel link is known as a *DMX universe*. Each device controlled by the signal is assigned to one or more channels.

The data link typically uses a female 5-pin XLR connector. DMX512 uses *serial* data transmission—a bus-type topology meaning that DMX lighting devices can be daisy-chained together so that each DMX512 device gets the control signal fed to it through the previous DMX512 device. Each DMX512 device has a male DMX IN and female DMX OUT (or THRU). This works well for lights rigged to batten or truss, but in motion picture applications, for lights on the ground, we often prefer to connect each light back to an optical splitter co-located with the power distribution. This is known as making a *home run* with each data cable. In fact, our industry can be credited with creating a data/power stinger for this purpose called a *super-stinger* (Figure 12.2). Using home runs for each light makes it easier to move them around independently.

FIGURE 12.2

A super-stinger combines DMX data (5-pin XLR) with 120 V power (Edison).

DMX512 does not have error detection or correction. Because of this, it should not be considered for controlling pyrotechnics or laser lighting or any device from which there would be risk of harm to crew, performers, or audience. Other control protocols are better suited for such situations. DMX512 should also not be used to control chain motors for moving truss or sets if this will cause the loss of manual control, as this poses a safety hazard.

DMX512 addressing

The lighting technician assigns each DMX512-controlled device a three-digit *start address* in the range from 001 to 512; this is the first channel number that the device will respond to. You will sometimes hear addresses referred to as *slots*.[2] The data stream starts with a start code. Each receiving device starts counting slots after the start code, and when it reaches its assigned address, it responds to the data in that slot.

Each DMX512 device has an addressing interface, like one of those shown in Figure 12.3, where the start address is set. A single, stand-alone dimmer occupies a single slot, and the start address is the only address the dimmer pays attention to. For devices that utilize multiple slots, the start address is the first of several slots to which the device will respond. A dimmer pack with six dimmers responds to six slots of data, starting with the start address. If the start address is 001, then dimmers 1 through 6 will respond to slots 001 through 006. A DMX512 HMI ballast uses two channels: one for the dimmer level, and a second one to turn the light on and off. If the start address assignment for this ballast is 010, then the ballast will respond to slots 010 and 011.

BINARY ADDRESSING

Lights that use dip-switches are addressed using the binary system. Switches one through nine have values as follows:

Value	1	2	4	8	16	32	64	128	256
Switch #	1	2	3	4	5	6	7	8	9

Some lights have a tenth dip-switch that sets the light into DMX mode. The DMX address is the sum of the values of the switches that are in the ON position. For example, to set DMX address 67, you would turn on switches one, two, and seven. Switch one has a value of 1, switch two has a value of 2, and switch seven has a value of 64. 1 + 2 + 64 = 67. A simple way to set a given address is to turn on the switch with the closest value that is not more than the address. Then calculate the difference and turn on the switch that is closest to the difference, and so on. For example, to set address 12, turn on switch 4 (value of 8). The difference is now 4 (12 – 8 = 4), so turn on switch 3 (value of 4): 8 + 4 = 12.

[2] The term "slot" derives from the way the DMX512 communications protocol is structured. Each packet of data for the 512 channels begins with a "break" followed by a "mark after break" (MAB). This is followed by the "start code" and then data is transmitted in a fixed format: a start bit, followed by eight data bits and two end bits for each of the 512 channels. These framed data bytes are known as slots.

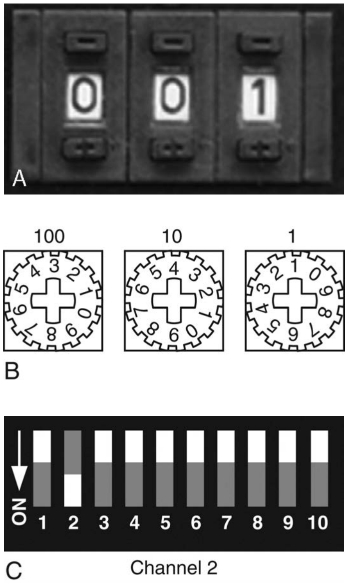


FIGURE 12.3

Three different DMX512 addressing interfaces: (A) wheel addressing is the most common and simplest; (B) a small Philips head screwdriver is used to set the address for an interface like this one; (C) dip-switches are used for binary addressing. See sidebar for a quick explanation of binary addressing. The easy way to translate binary code is to use an iPhone app or online software. Menu-based addressing (not shown here) is also common on many lights and HMI ballasts.

Most lights that have complex color and effects can be operated in a variety of different *modes*. Setting an LED's DMX mode is covered in Chapter 7. The decision of what mode to use is a tradeoff between the size of the DMX footprint vs. functionality and resolution. When a high degree of control is required, the user must select a mode that uses more DMX channels, and takes up a larger chunk of the DMX universe. If there are constraints on the number of channels available, the user may opt to use a mode with a smaller footprint and forfeit some advanced functionality that is unlikely to be needed.

As an example, at this writing an ARRI SkyPanel has 31 possible modes. In mode 2 it has 8-bit resolution and uses seven channels (dimmer, CCT, green/magenta, fan, preset, light strobe, and one channel reserved). In mode 6 the SkyPanel has smoother 16-bit resolution and uses 20 channels (doubling the number of channels for intensity, CCT, green/magenta point, and adding crossfade between white and RGBW as well as separate intensity control over red, green, blue, and white channels).

The number of DMX channels required for a single light escalates very quickly when lights have multiple light engines or pixels. For example, the SkyPanel 360 can be controlled as 12 separate light engines. These advanced modes can create some very cool effects, but one SkyPanel can eat up as many as 193 channels.

If you have two identical devices that you always want to respond in exactly the same way, you *could* assign them the same start address. Multiple devices can be assigned the same start address, and all devices will respond to the values for that address. Typically, however, you will want to maintain as much individual control in the addressing as you can. Lights can be easily grouped and ungrouped using the console software, but changing an address on a light fixture that is way up in the rig can be a lot more trouble.

The flip side of this is that you do not want to accidentally address devices so that their channel numbers overlap. For example, if you assigned one HMI ballast start address 010 and the next HMI ballast start address 011, unexpected things would start happening because 011 is the first channel for one ballast and the second channel for the other. Reducing the value of fader 11 would cause the second light to dim, but the first light would shut down.

The patch

Management of the control system is the responsibility of the lighting control programmer (with the help of the rigging programmer if there is one). Before the show begins, the programmer takes the equipment inventory and generates a patch list. Having decided what mode to use for each light, the programmer knows the number of channels to allocate, and can assign start-addresses for each light, dimmer, and device that is to be controlled on the network. Because there are limited channels in a DMX universe, the programmer will normally want lights addressed with no empty channels between fixtures. Since devices can only use channels that are consecutive, any gaps just waste available channels which you might need. If the patch is generated on a console or using console emulation software on a computer, it is saved within the show file, ready to use. If that's not possible, the programmer could work out the patch on a spreadsheet program. Working out addressing on some sort of computer is a good idea because it reduces the chance of error, and it allows the programmer to be further ahead of the game. Programmers can typically patch the first-unit package to one or two universes (typically universes 1 and 2).

It is natural for gaffers and console programmers to feel that they have to be ready for anything, and not want to choose a mode that limits them. That may be fine if they don't have too many lights. However, a good practice to manage the "what if" scenario is to choose a channel-efficient mode that provides the functionality needed every day, knowing that if a light may occasionally need to change modes (to perform an effect, for example), that light can be temporarily reassigned to a different universe where channels are plentiful.

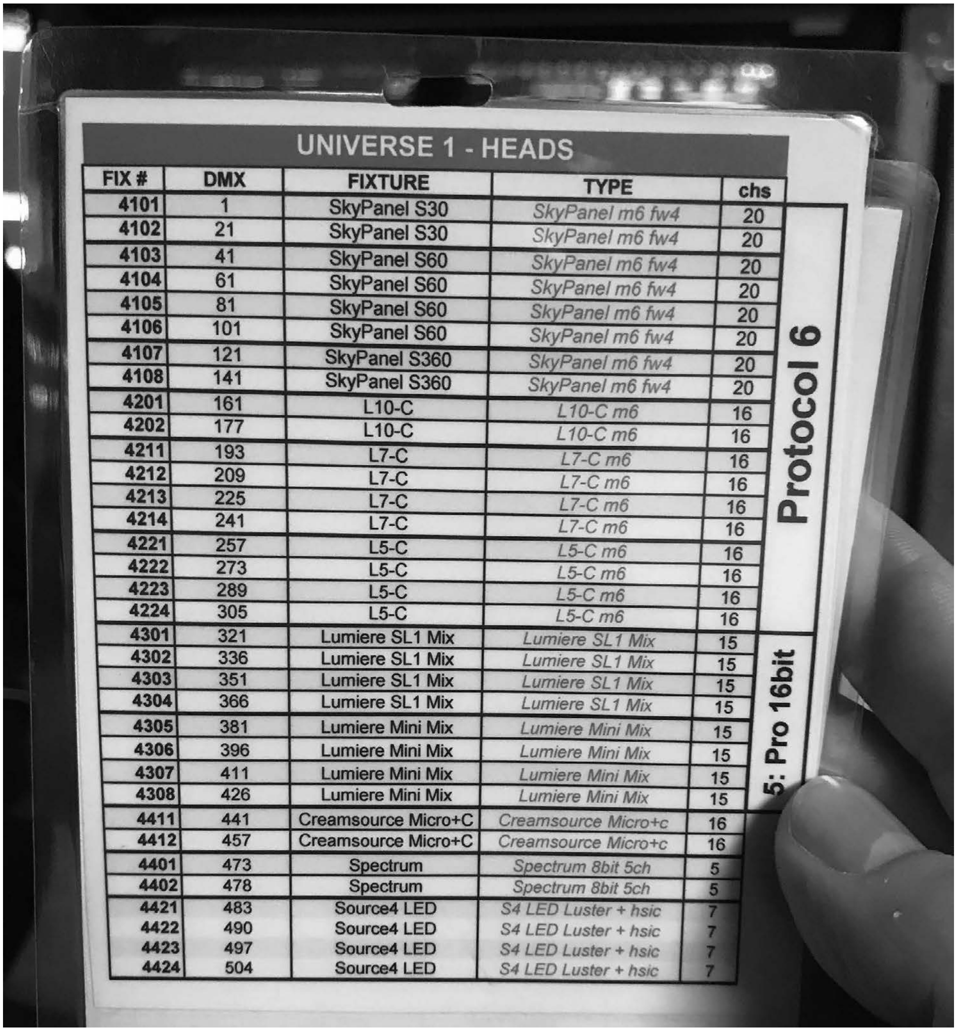
Fixture numbers

Importantly, the patch also establishes *fixture numbers*. In the console software, the programmer identifies the type of light associated with each block of DMX channels, which the console then controls as a fixture. Each fixture is assigned a number. The fixture number is then written in big letters on the light. This is the number that the technicians and gaffer will use throughout the show to identify that light when speaking to the programmer.

No matter how many slots the light uses, the console represents it as one unit, and the lights can therefore be numbered sequentially regardless of their slot footprint. Having a block of channels controlled as one unit simplifies things for the programmer. Say you have a bunch of space lights, and you wish to turn on three of the six circuits on all of them. This can be accomplished with a single command sequence: for fixtures 5–12, set the 1st, 3rd, and 5th channels to full. By having each device identified as a fixture, the programmer does not have to look up the channel numbers for each of those circuits.

The cheat sheet, fixtures, and universes

Once the programmer works out the patch, he or she may want to create a cheat sheet for the gaffer and technicians. The cheat sheet is something they keep in their pocket for reference and is a huge help for managing a large inventory of lights. In the example shown in Figure 12.4, the programmer



UNIVERSE 1 - HEADS

FIX #	DMX	FIXTURE	TYPE	chs
4101	1	SkyPanel S30	SkyPanel m6 fw4	20
4102	21	SkyPanel S30	SkyPanel m6 fw4	20
4103	41	SkyPanel S60	SkyPanel m6 fw4	20
4104	61	SkyPanel S60	SkyPanel m6 fw4	20
4105	81	SkyPanel S60	SkyPanel m6 fw4	20
4106	101	SkyPanel S60	SkyPanel m6 fw4	20
4107	121	SkyPanel S360	SkyPanel m6 fw4	20
4108	141	SkyPanel S360	SkyPanel m6 fw4	20
4201	161	L10-C	L10-C m6	16
4202	177	L10-C	L10-C m6	16
4211	193	L7-C	L7-C m6	16
4212	209	L7-C	L7-C m6	16
4213	225	L7-C	L7-C m6	16
4214	241	L7-C	L7-C m6	16
4221	257	L5-C	L5-C m6	16
4222	273	L5-C	L5-C m6	16
4223	289	L5-C	L5-C m6	16
4224	305	L5-C	L5-C m6	16
4301	321	Lumiere SL1 Mix	Lumiere SL1 Mix	15
4302	336	Lumiere SL1 Mix	Lumiere SL1 Mix	15
4303	351	Lumiere SL1 Mix	Lumiere SL1 Mix	15
4304	366	Lumiere SL1 Mix	Lumiere SL1 Mix	15
4305	381	Lumiere Mini Mix	Lumiere Mini Mix	15
4306	396	Lumiere Mini Mix	Lumiere Mini Mix	15
4307	411	Lumiere Mini Mix	Lumiere Mini Mix	15
4308	426	Lumiere Mini Mix	Lumiere Mini Mix	15
4411	441	Creamsource Micro+C	Creamsource Micro+c	16
4412	457	Creamsource Micro+C	Creamsource Micro+c	16
4401	473	Spectrum	Spectrum 8bit 5ch	5
4402	478	Spectrum	Spectrum 8bit 5ch	5
4421	483	Source4 LED	S4 LED Luster + hsic	7
4422	490	Source4 LED	S4 LED Luster + hsic	7
4423	497	Source4 LED	S4 LED Luster + hsic	7
4424	504	Source4 LED	S4 LED Luster + hsic	7

Protocol 6

5: Pro 16bit

FIGURE 12.4

The fixture cheat sheet, laminated for durability over the course of the show, shows fixture number, DMX start address, type of fixture, mode, and number of channels. Note that each of the S60s in this rig is assigned to mode 6 and occupies 20 channels each. So, the start addresses are 1, 21, 41, 61, and so on.

starts the fixture numbers for the first unit (traveling package) at 4000. This sets the starting number high enough to ensure that they never overlap with the fixture numbers of lighting rigged separately by the rigging crew. Note, in this example, the hundreds digit is used to designate the type of light: SkyPanels are 100s, L-series Fresnels are 200s, Lumières are 300s, and so on. It does not take long before the crew learns to associate numbers with the type of light, which is useful. The cheat sheet also provides the number of channels required by a light in a particular mode. Having a quick reference for this information is helpful if the light needs to be re-addressed and for troubleshooting addressing errors.

DMX VALUES AND DEVICE PERSONALITY

When the control console communicates with the DMX512 devices, it sends an 8-bit *value*—a number from 0 to 255—to each address. The DMX512 device responds according to this value. For a dimmer, for example, the values 1–255 correspond to dimmer intensity from 0 percent to 100 percent (Table 12.1). For ease of use, control consoles typically display the values for dimmer channels as a percentage (0–100 percent), rather than the actual 8-bit DMX value (0–255). But for other DMX devices, the console needs to display the 8-bit value, because each value may call for a specific response. It is theoretically possible to have a light fixture perform up to 256 different tasks depending on the DMX value sent from the console.

The mapping of DMX channels to the functions of the fixture is known as the device's *DMX personality* or *protocol*. A programmer must study the DMX personality of each device to be familiar with all its attributes. The personalities of light fixtures are listed in the unit's user manual. Many device personalities are also available from the console manufacturer's Web sites. Let's look at some examples.

The HMI ballast (Table 12.2) dims to 50 percent output using the first channel, but notice that the protocol is set up so that below 128 (50 percent), the fader no longer changes the response, because HMIs don't dim below 50 percent. The ON/OFF function is on a separate channel, which operates like a two-position switch:

0–127 (0–50%) = OFF
128–255 (50–100%) = ON

Table 12.1 Dimmer pack with six dimmers (six channels)

Channel	DMX value	Function
1st	0–255	Dimmer 1 intensity 0–100%
2nd	0–255	Dimmer 2 intensity 0–100%
3rd	0–255	Dimmer 3 intensity 0–100%
4th	0–255	Dimmer 4 intensity 0–100%
5th	0–255	Dimmer 5 intensity 0–100%
6th	0–255	Dimmer 6 intensity 0–100%

Table 12.2 DMX512 HMI ballast—ARRI (two channels)

Channel	DMX value	Response
1st	1–127	Remains dimmed at 50%
	128–255	Dim level from 50% to 100%
2nd	0–127	Fixture shut OFF
	128–255	Fixture turned ON

Table 12.3 Kino Flo True Match® firmware 3.0, gel/hue color mode, 16-bit dimming (7 channels)

Channel	DMX value	Response
1 & 2	1–65535	Dims light from 0 to 100% intensity. By using two channels to control a single parameter, resolution is increased from 255 steps to 65535 steps. (User may select a *linear* or *square* DIM curve.) Square mode allocates more values to the lower end of the dim scale, enabling finer control at the low end.
3	1–255	Kelvin color from 2500 to 9900 (for example: 0 = 2500 K, 35 = 3200 K, 125 = 5000 K, 200 = 6500 K, 255 = 9900 K).
4	0–11	0 Green/magenta.
	12–22	100% full minus green.
	23–121	Adjusts from 99% minus green to 1% minus green.
	122–133	0 Green/magenta.
	134–232	Adjusts from 1% plus green to 99% plus green.
	233–243	100% full plus green.
	244–255	0 Green/magenta.
5	1–255	Gel list (even numbered DMX values produce 116 different gel colors). Note: G/M must be less than 3 for this function to be active.
6	1–255	Sets hue angle (for example: 0 = 0°, 64 = 90°, 128 = 181°, 255 = 360°).
7	1–255	Adjusts saturation from 0 to 100%.

Kino Flo's True Match® firmware applies to all of its LED controllers, including the FreeStyle, Celeb, Diva, and Image L-series lights. In its current version (3.0) the firmware supports three modes: white mode, gel/hue color mode, and RGB color mode. All modes use 6 channels with 8-bit dimming or 7 channels with 16-bit dimming (Table 12.3).

The ARRI MaxMover remote head can be controlled by either a simple three channel DMX converter, or by an eight-channel fully programmable (FP) DMX converter (protocol shown in Table 12.4). In FP mode the pan and tilt parameters are each controlled by two channels: coarse and fine. Fixtures use two channels for a single attribute to increase *resolution*. By going from 8-bit (one channel) to 16-bit (two channels), the resolution of pan and tilt increases from 256 possible positions to 65,536 possible positions. This smooths out slow pan/tilt movements and increases the accuracy with which

Table 12.4 MaxMover remote head—ARRI (employing ARRI FP DMX interface)

Channel	DMX value	Response
1st	0–255	Pan coarse (50% = center "home" position)
2nd	0–255	Pan fine
3rd	0–255	Pan speed
4th	0–255	Tilt coarse (50% = center "home" position)
5th	0–255	Tilt fine
6th	0–255	Tilt speed
7th	0–255	Focus flood to spot
8th	0–101	Lock
	102–153	Release
	231–255	Home position

the light can be focused. Note that the eighth channel of the MaxMover operates like a three-position switch between LOCK, RELEASE (for normal operation), and HOME.

The protocol for moving light fixtures is even more complex. Table 12.5 gives an example of a light that has three different modes and over thirty attributes. Many of these attributes are controlled in a linear fashion (colors, dimmer, iris, for example); others are not. For example, channel 6 operates the stop/strobe functions. A range of DMX values is assigned to activate each effect or macro such as shutter open, shutter closed, random strobe (different assignments for different speeds), pulsation (different assignments for different speeds), and strobe at different speeds. To access the features of each light, the programmer must be familiar with these features and must know how to harness the power of a control console.

General Device Type Format (GDTF)

With hundreds of fixtures, scores of parameters, multiple modes, and constant firmware updates, the industry needed a central database and file format to designate and communicate fixture parameters. The consoles' profiles have to match the actual profile of the lighting fixtures and visualizer software otherwise unexpected and potentially disastrous things happen.

General Device Type Format (GDTF) is a file format developed by Vectorworks, Robe, and MA Lighting. Other manufacturers are joining the party. GDTF includes DMX mapping, modes, photometrics, and 3D geometry that can be used by consoles, visualizers, and CAD systems to keep information consistent. GDTF is an open standard. All manufacturers are welcome to upload GDTF files for each firmware release of their lights to gdtf-share.com. Users can create their own profiles for lights that are not in the system using the GDTF Builder software and upload them as well.

Multiple DMX512 universes

An innate limitation of DMX is that each universe of DMX contains only 512 channels. When DMX512 was conceived, a universe was to control up to 512 dimmers, one channel each, which

Table 12.5 Clay Paky Alpha 1200 control protocol

Channel	Mode setting		
	Standard	**16-bit**	**Extended**
1	Cyan	Cyan	Cyan
2	Magenta	Magenta	Magenta
3	Yellow	Yellow	Yellow
4	Linear CTO	Linear CTO	Linear CTO
5	Color wheel	Color wheel	Color wheel
6	Stop/strobe	Stop/strobe	Stop/strobe
7	Dimmer	Dimmer	Dimmer
8	Iris	Iris	Iris
9	Fixed gobo	Fixed gobo	Fixed gobo
10	Rotating gobo change	Rotating gobo change	Rotating gobo change
11	Gobo rotation	Gobo rotation	Gobo rotation
12	Blade 1A	Blade 1A	Gobo fine
13	Blade 2A	Blade 2A	Blade 1A
14	Blade 1B	Blade 1B	Blade 2A
15	Blade 2B	Blade 2B	Blade 1B
16	Blade 1C	Blade 1C	Blade 2B
17	Blade 2C	Blade 2C	Blade 1C
18	Blade 1D	Blade 1D	Blade 2C
19	Blade 2D	Blade 2D	Blade 1D
20	Framing rotation	Framing rotation	Blade 2D
21	Prism/animation effect/frost	Prism/animation effect/frost	Framing rotation
22	Prism/animation effect rotation	Prism/animation effect rotation	Prism/animation effect/frost
23	Focus	Focus	Prism/animation effect rotation
24	Zoom	Zoom	Focus
25	Pan	Pan	Zoom
26	Tilt	Tilt	Pan
27	Reset	Reset	Pan fine
28	Lamp on/off	Lamp on/off	Tilt
29		Pan fine	Tilt fine
30		Tilt fine	Reset
31		Gobo fine	Lamp on/off

seemed like plenty. As you can see from the device personalities described above, today's lights generally require between 3 and 20 channels and sometimes many more, eating up 512 channels very quickly. Accordingly, most modern consoles support multiple universes, typically between four and eight (Figure 12.5), but can provide as many as sixteen DMX512 data links. In addition, many modern consoles use Ethernet networks to expand the system and add even more universes. Networks with 16 or 20 universes are not uncommon on feature productions. The big national awards shows, like the Emmy Awards, will use more than a hundred universes. Figure 12.6 offers three increasingly complex examples of DMX topology.

Each universe has its own separate data link. The slots of each universe are numbered from 1 to 512, so the device occupying the 513th slot would be assigned to slot 001 of the second universe. The syntax on consoles for universes and slots is commonly written like this:

1/512 or 1:512 (where 1 is the universe and 512 is the slot)

FIGURE 12.5

The back of this Road Hog board provides four DMX512 data links for a total of 2048 DMX channels.

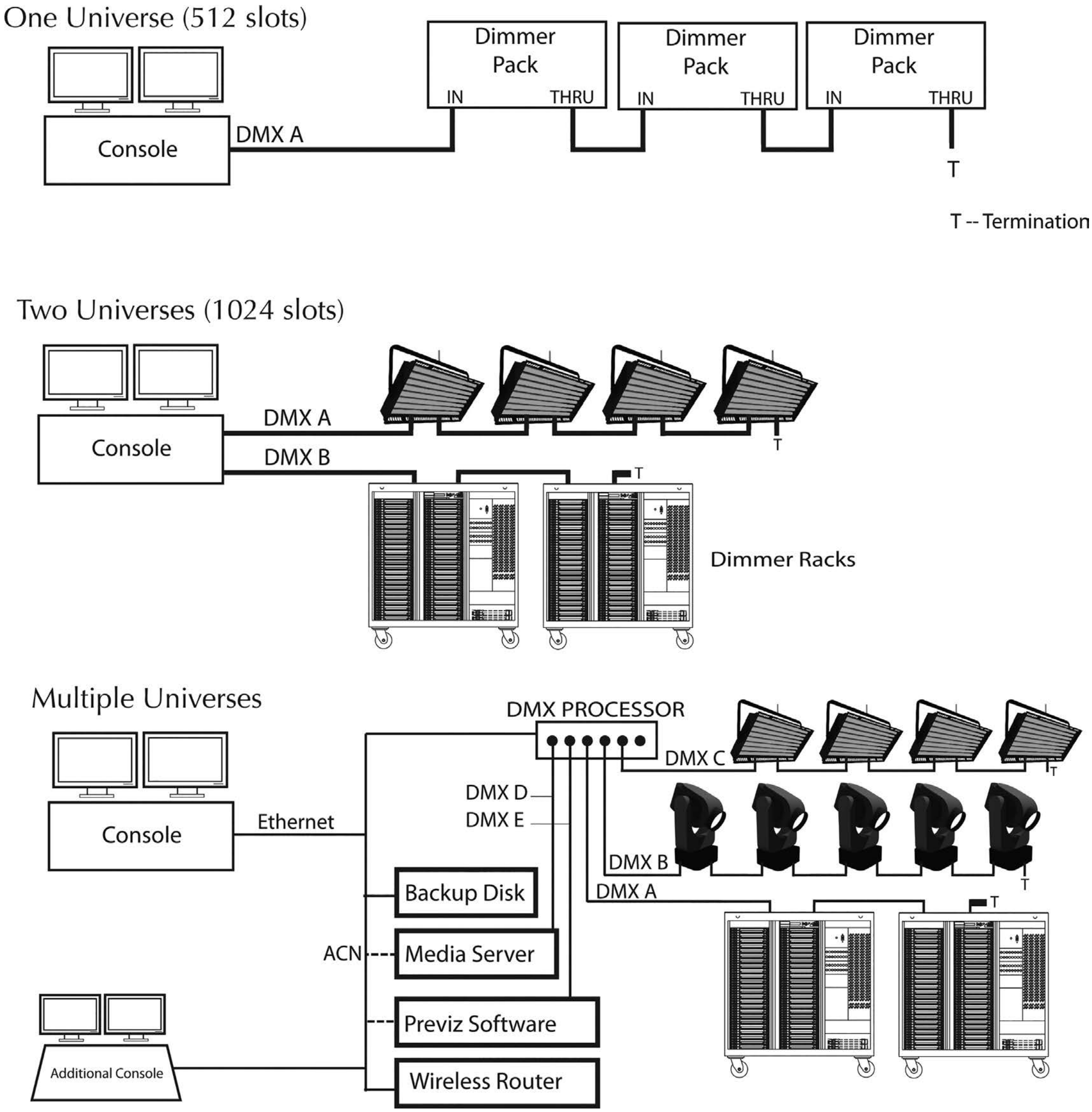


FIGURE 12.6

A network may be as simple as a single DMX universe (top), or expanded to include two, three, or more additional universes with a console with multiple DMX512 data links (center). The network can be expanded almost infinitely using Ethernet as the backbone (bottom).

When rigging, circuits will often be labeled with the universes lettered:

A 512 (where A is the universe and 512 is the slot number).

In big systems, there may also be separate nodes, for which the syntax is:

1:2:512 (node: universe: slot)

Inside the console, it references each fixture by an *absolute address* (Table 12.6). Fixtures in different universes may use the same DMX512 address assignments, but have different absolute addresses.

You can see how critical it becomes to identify the universe on every piece of DMX512 equipment—dimmer racks, optical splitters, dimmer circuit cables. Plugging lights into the wrong universe is a common mistake. Console programmers will sometimes set aside channel 512 as the universe identifier. For example, for universe 8, the programmer sets the level on channel 512 to 8 percent. This enables anyone armed with a Swisson DMX tester (or similar DMX reader) to plug into any data link and check the universe number by reading the setting of channel 512.

To help technicians keep track of which universe they should be plugging into, it is helpful to organize universes by function. A programmer might organize and color code the infrastructure something like Tables 12.7 or 12.8. Nodes, optical splitters, PDB boxes, and DMX cables should be marked with colored tape for quick visual identification of the universe.

In Tables 12.7 and 12.8, note that universe 1 is reserved for the first unit's traveling package. These DMX assignments stay the same throughout the show no matter where the filming is taking place. Depending on the show, the main package may spill over into universe 2, or universe 2 might be for the standing rigging on stage. Universe 3 might be reserved for lights that may change day-by-day such as loose LED ribbon or for a potential drop package on location. The general philosophy is to start with assignments that are least likely to change and use later universes, which tend to have more available channels, for situations that are more liquid.

In Table 12.8, universes 4 and 5 are reserved for lights with a big footprint such as Astera tubes or SkyPanels in pixel mode and automated fixtures. Universe 6 has been set aside as an open universe, so

Table 12.6 DMX vs. absolute addresses

	DMX address	Absolute address
Universe 1	1/001–1/512	001–512
Universe 2	2/001–2/512	513–1024
Universe 3	3/001–3/512	1025–1536
Universe 4	4/001–4/512	1537–2048

Table 12.7 Universe breakdown (small or medium-sized TV series)

Universe	Color code	Function
Universe 1	White	1st Unit truck package
Universe 2	Yellow	Stage package (dimmers, backings, and permanent lights rigged on stage)
Universe 3	Orange	Loose RGBW ribbon and open channels for special occasions

Universe	Color code	Function
Universe 1	White	1st Unit
Universe 2	Yellow	1st Unit
Universe 3	Orange	Location drop package
Universe 4	Green	Pixel LEDs
Universe 5	Pink	Pixel LEDs
Universe 6	Red	Open
Universe 7	Blue	Fixtures (built-in and on-camera lighting)
Universe 8	Purple	Fixtures (built-in and on-camera lighting)

Table 12.8 Universe breakdown (feature film)

space is always available for expansion if needed. Universes 7 and 8 are reserved for lights that have been built into the set by the fixtures crew (LED ribbon built into the architecture, practical fixtures, lights that are part of the set dressing, etc.).

Expanding the scheme in Table 12.8, universes 9–16 might be reserved for the rigging crew. The programmer (or rigging programmer if the show has one) will designate universes such as: overhead softlights, translight backlight, floor lights, dimmers, moving lights, or whatever other groupings of lights make sense for the lighting plan on that particular set.

REMOTE DEVICE MANAGEMENT (RDM)

The original DMX512 standard allowed data to move in only one direction, from the console to the devices. Remote Device Management (RDM) is a protocol that makes DMX capable of two-way communication. It enables devices to talk back to the console, which is a huge convenience during setup and troubleshooting. Many times, a bleary-eyed programmer working into the wee hours of the morning has thought to him- or herself: "If only these lights could talk back to me! Then I would know why nothing I do is fixing the problem. Curse you, DMX!" Thanks to the good people at ESTA's Control Protocols Working Group, RDM enables two-way dialog between a DMX/RDM control console and RDM-enabled DMX devices and totally changes the way the programmer interacts with the devices.

RDM enables DMX addresses to be set from the console, without having to go to the actual device. In fact, many fixture setup parameters can be set this way. No longer does the programmer have to manually add and patch the fixtures into the console. With RDM, the controller goes through a process called "discovery" to seek out intelligent life—RDM-capable devices. In this process, the controller learns the unique identification number (UID) for each RDM-capable device connected to it. A UID is a unique number given to each device at the factory that cannot be changed. Once a device is discovered, the controller can send and receive messages to and from that device using its UID. Upon discovery, the console requests device information and each device then tells the controller a great deal of information about itself, including the product model ID, software version, slot footprint (number of consecutive DMX512 slots it uses), DMX512 personality, start address, number of sensors, and so on. This way, the console knows everything it needs to automate the patching process, and the chance of accidentally overlapping addresses is eliminated.

Every device has its own list of messages that it can send to the console to alert the programmer of its status (address and settings), of its condition (sensor readings, component failures), of the integrity of the data (data transfer failures), and other necessary information. Sensor readings include important health diagnostics like temperature, current, and voltage. The commands supported by a particular light are determined by its manufacturer, but the list of potential response messages that can be created is long, and will get longer as more and more devices adopt this technology.

RDM was cleverly designed to share the same two wires used by DMX512-A, so the wiring remains unchanged, and RDM and non-RDM devices may work simultaneously on the same DMX512 network. The network speed is also unchanged. However, any device that generates a signal, such as an opto-splitter, must be RDM-capable in order to carry signals in both directions. And of course, the console has to be RDM-capable.

Although DMX512 is a totally one-way conversation, DMX512 with RDM is not exactly a free two-way conversation, either. DMX/RDM is like a single-lane street, where traffic may flow in only one direction at a time. RDM provides the traffic lights needed to accommodate two-way traffic. An RDM enabled console controls the flow of data; it queries the RDM fixtures and then switches from transmitting to receiving during the exact millisecond in which the RDM device responds. The console processes and displays the message for the programmer. In order to prevent packets of data coming to and from the DMX512 devices from colliding, the system is set up so that RDM devices speak only when spoken to. The console has to ask the device if it has anything to report, and then the device is given a very specific time window to say what's on its mind. If a device has an issue to report, it stores the error message in a queue, waiting to be prompted.

BUILDING WIRED DMX512 SYSTEMS

There are specific standards and procedures for running DMX512 cable that help ensure a reliable signal. The basic rules are summarized in the sidebar ("Rules for running DMX512 cable"). This section will flush out more of the details.

As you probably know, data communication is in binary code—a series of zeros and ones organized into meaningful blocks by conforming to a prescribed protocol (in this case DMX512-A). Ones and zeros are transmitted as voltage and no voltage.

A DMX data link is driven by a differential line driver (op-amp) that amplifies the data signal, generating a binary (0 V or 10 V) differential between the two wires. The receiver interprets 0 V as a binary 0 and 10 V as a binary 1. In this way, the driver is able to transmit binary code to the receivers in the DMX512 devices. The pin configuration for DMX512 cable is shown in Figure 12.7. Pin 1 is common. It is a 0 V reference for pins 2 and 3, which are minus and plus voltages, respectively. People sometimes confuse common with ground; they are not the same. Pin 1 should not be connected to the shell. Pins 2 and 3 are the active data conductors. Pins 4 and 5 were originally designated for future expansion of DMX512 capability or to include a second universe on a single cable, but because some manufacturers started using these free pins for other purposes, future expansion now creates conflicts, and pins 4 and 5 are commonly unused.

RULES FOR RUNNING DMX512 CABLE

- When you initially run the DMX cable, run two lines so that you always have a spare cable already in place. The cost of renting extra cables is nothing compared to the cost of delay during production.
- Provide termination after the last fixture at the end of each run of DMX512 cable, using a terminator plug or termination switch on the last DMX512 lighting device. (Be sure that any device equipped with a termination switch does not terminate unless it is the last DMX512 device on that link.)
- Never directly connect DMX512 cable between two devices that are powered from two separately derived power sources that are not bonded, such as building power and a generator. An optical isolator must be used between any two such devices.
- Never use a hard-wired Y-splitter on a data cable.
- A DMX512 signal is typically strong enough to feed a total cable length of 1000 ft.; however, here again, many programmers feel far more comfortable inserting an opto-splitter or amplifier every 500 ft. Performance depends to a large extent on the number of devices connected in the cable run. Each connection point sinks current.
- The cable used must meet the design criteria for high-speed data cable: 100–120 Ω, low capacitance, no smaller than 24 AWG wire in twisted pairs.
- DMX512 cable and XLR connectors should be treated with the utmost care. One crushed connector can bring a whole production to a grinding halt, and no one will even know where to start looking for the problem. Test control cable using a DMX tester (not a DC continuity checker like a microphone cable tester).
- DMX512 cable should be rigged high near the ceiling, away from power cables, out from under foot, and out of harm's way.
- The XLR connectors are a point of potential failure and must be protected from strain. Tie a strain relief at connection points so that the cable takes any pull, not the connector. Do not tie the cable in a knot to do this (this bends and strains the cable where it exits the connector). Make a big loop and use the cable tie-strings to make the strain relief.

Deviations from the standard

The DMX512-A standard specifies the use of 5-pin XLR connectors. However, you will find equipment that deviates from this standard. For example, some moving lights use a 3-pin XLR (arranged as shown in Figure 12.7B). A 3-to-5-pin adapter cable allows 3-pin devices to be plugged into a 5-wire system. Another deviation from the 5-pin standard is a 4-pin XLR system commonly known as *Power/DMX*, used for devices like color scrollers and gobo rotators.

The fourth pin provides 24 VDC power to the device (Figure 12.7C). A Power/DMX power supply connects to the DMX512 signal via the standard 5-pin XLR input. It then combines the control signal with the 24 VDC power into one 4-wire cable, which can commonly feed several of these small devices. Because this creates the potential for power to be inadvertently applied to the communication wires

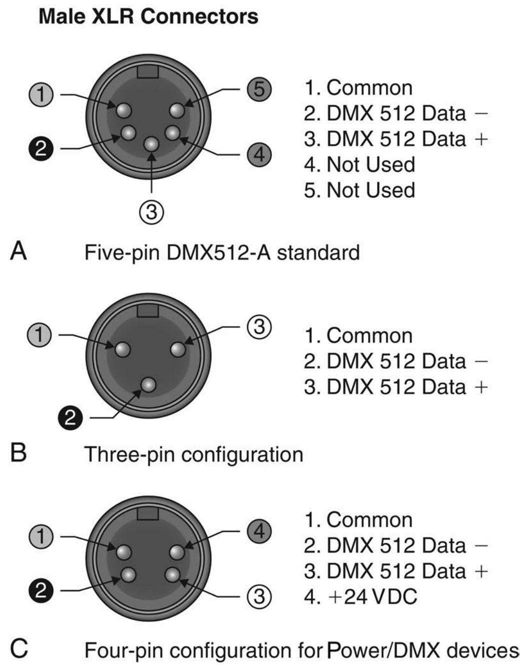


FIGURE 12.7

DMX512 pin-out diagrams of a male XLR connector: (A) 5-pin DMX512-A standard, (B) 3-pin DMX, (C) 4-pin Power/DMX.

by a shorted wire or improperly wired connector, Power/DMX supplies should be optically isolated to protect all the DMX512 devices upstream from potential damage.

Data termination

When DMX devices are daisy-chained together (and even when they are not) the last device on the chain must be terminated. This can be done by placing a *terminator* on the DMX OUT. The terminator is just an XLR plug that has a 120 Ω, 0.25 W resister connected between pins 2 and 3. Many modern devices provide a termination switch that can be used to terminate the signal at the last device (however, some practitioners believe that a terminator plug is more reliable). Some DMX devices provide auto-termination, meaning they automatically terminate the signal if they sense no additional DMX devices are connected.

Termination absorbs the signal at the end of the data line by matching the impedance of the cable (as if the cable just keeps going infinitely). Without a terminator, the signal runs up against infinite impedance at the end of the line, which is like a rubber ball hitting a concrete wall. It reflects the signal back up the line toward the source. Reflections corrupt the data because of phase cancelation. Improper termination often goes undetected on smaller installations, because devices will sometimes still function. However, without proper termination, the signal along the entire line is compromised. When there are many devices on the network or longer lengths of cable, some devices will start acting erratically or not responding. Things can appear just fine and then suddenly stop working. Moving lights sometimes develop a twitch.

Capacity

A DMX512 signal is strong enough to feed 32 "units of load"—which means 32 DMX512 devices. In practice, technicians commonly limit the load to 16 devices. Each device, and the cable between them, sinks current from the transmitter, especially when the cable lengths are very long. At some point, the signal becomes too weak to be reliable. It is good practice not to use cables that are much longer than needed and to not string together multiple cables that are shorter than needed. Each connection point increases resistance and risk of failure; the fewer, the better.

There is also a limit to the total length of the DMX512 cable from the console. The maximum specified in the RS-485 standard is up to 1 km (3281 ft.). However, in practice, the limit is much shorter. Some manufacturers say to use no more than 1000 ft. Some recommend keeping it below 500 m (1640 ft.). Many programmers prefer to be even more cautious, and do not exceed 500 ft. without regenerating the signal. To regenerate the signal, an optical splitter (covered shortly) or data repeater is installed inline.

DMX cable

The cable used for wiring DMX512 must be appropriate for high-speed data transmission. It must meet certain standards: 24 AWG wires in twisted pairs, 100–120 Ω impedance, low capacitance, and a foil shield and overall braided shield. Be sure DMX cable is shielded and in good condition from the rental house. Every cable should have a tie string.

The data line uses twisted-pair cable to help cancel out electromagnetic noise if it is picked up on the line. Because it is picked up equally by both the wires, it cancels at the differential amplifier. RS-485 cable is 120 Ω cable; RS-422 cable is 100 Ω cable. Both kinds are used in the field, but it is best to use either one or the other for the entire rig, because in long runs, a change of impedance between cables can cause reflection issues. These precautions help reduce noise and interference, line loss, and signal degradation.

Just because a cable has an XLR connector does not mean that it is a good cable for DMX512. In fact, audio cables—which use 3-pin XLR connectors—are completely wrong for digital signals. Microphone cable has high capacitance and relatively low impedance. On long cable runs, a high capacitance cable has a tendency to alter the shape of the waveform to a sawtooth shape, which DMX512 devices will have trouble reading.

CAT5 cable, which is used for computer networking and for telecommunications, has also been tested and approved by ESTA for use with DMX512-A in permanent installations. CAT5 cable is far less rugged than DMX512 cable. For a long-running show, a television series or large feature film, wiring long runs with CAT5 cable could be more cost effective. The RJ-45 connector on CAT5 cable is wired as shown in Table 12.9.

Table 12.9 Wiring a CAT5 cable for DMX

Pin 1	Data 1+
Pin 2	Data 1–
Pin 3	Data 2+
Pin 4	N/A
Pin 5	N/A
Pin 6	Data 2–
Pin 7	Common (0 V) for Data 1
Pin 8	Common (0 V) for Data 2

Optical isolators and splitters

Opto-splitters and opto-isolators are devices that read the incoming DMX512 signal, transfer it optically within the device, and then regenerate the signal for output. An optical *isolator* is a device that has one DMX512 input and one output. An optical *splitter* is an opto-isolator that regenerates multiple identical data signals for output.

There are several benefits to using optically isolated devices. First, because there is no electrical connection between the input and the output, an electrical fault downstream of the opto-isolator cannot affect the signal upstream and potentially harm other devices and the control console. Programmers often protect their console by installing an optical isolator or splitter at the console. Using a splitter here has the added benefit of making available a DMX512 link for any DMX512 device that may be added during filming.

The second benefit is that the isolator or splitter regenerates a totally clean signal so that each output signal is strong enough, theoretically, to feed another 32 devices and run another 1000 ft. The signal can thereby be split onto multiple lines and branch out in different directions, which has some obvious practical advantages when cabling multiple lighting positions. Each new DMX512 line from the splitter must be terminated at the last device connected to it, but need not be terminated if unused.

In addition to the amplified outputs, an opto-splitter provides a THRU output (which is not amplified or optically isolated). If the THRU output is not used, *it must be terminated*. The THRU output is important, because unlike the other outputs, it is not affected by a loss of power to the opto-splitter. (Any opto-isolator or -splitter requires AC power, and must be properly grounded.) For example, if DMX512 cable feeds data to a line of fixtures and then continues on to the dimmer room, where it feeds a room full of dimmers, you would want to use the THRU output to feed the dimmer room. You would not want to risk losing signal to the dimmer room due to a power kick-out of an opto-splitter. To make life even more fool-proof, the programmer may arrange that the signal cable to the dimmer room makes a *home run* to the console, and not be routed through other lighting devices. If an opto-splitter were used in this scenario, then the splitter should be located at the control console, so the programmer has it in sight.

Optical splitters are a great help when they isolate signal problems geographically. This makes it much easier to find the faulty cable or device, and allows the rest of the rig to continue to operate. Without this kind of isolator, when a fault occurs in a cable somewhere in a rig, it might literally take days of testing, disconnecting sections one at a time, and replacing parts before the faulty cable is found. This is why installing opto-splitters is a very good investment of time and money. It is insurance against a potentially catastrophic delay caused by the failure of a small connector. Therefore, the strategy for installing optical splitters is isolate each segment of the DMX512 universe, as illustrated in Figure 12.8. The THRU output on the opto-splitter should be used to daisy-chain the optical splitters together. When you are using multiple dimmer racks, it is a good idea to put each rack on an isolated

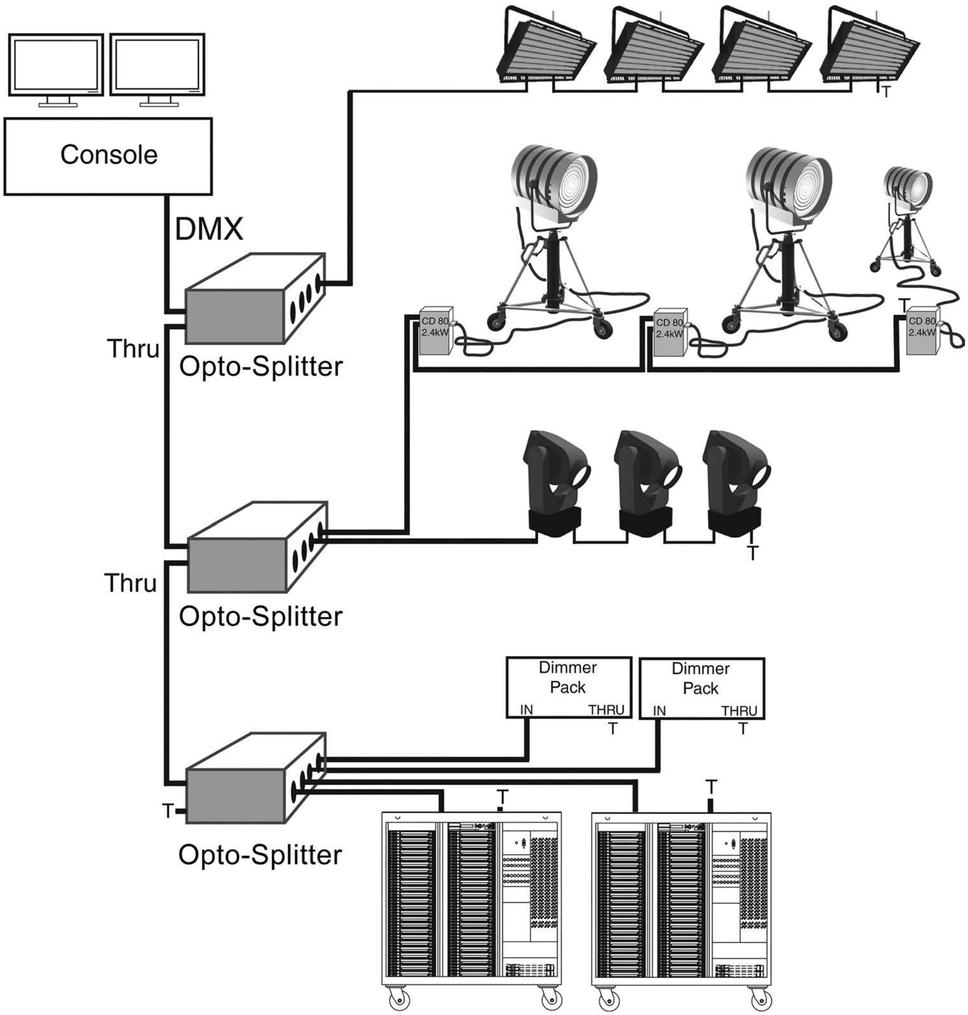


FIGURE 12.8

To provide a clean signal, and isolate potential problems, the network may be divided up so that each section of the network is supplied by a separate optically isolated data signal. Note that each dimmer pack and rack are individually isolated.

line. This way, any problem with the signal will be isolated to one rack. Practitioners form opinions about the ill effects of certain equipment on the control signal, and isolate certain equipment accordingly. Some people always isolate Image 80s and 20k CD80 dimmers, for example.

It is also very important to plan the layout of optical isolators and splitters carefully when lights and devices are powered from separately derived power sources. The DMX512 cable between any two devices powered from separate sources must be optically isolated as a matter of safety, as well as for system reliability. Figure 12.9 illustrates how dimmer racks powered from separate sources can be kept electrically isolated using an opto-splitter.

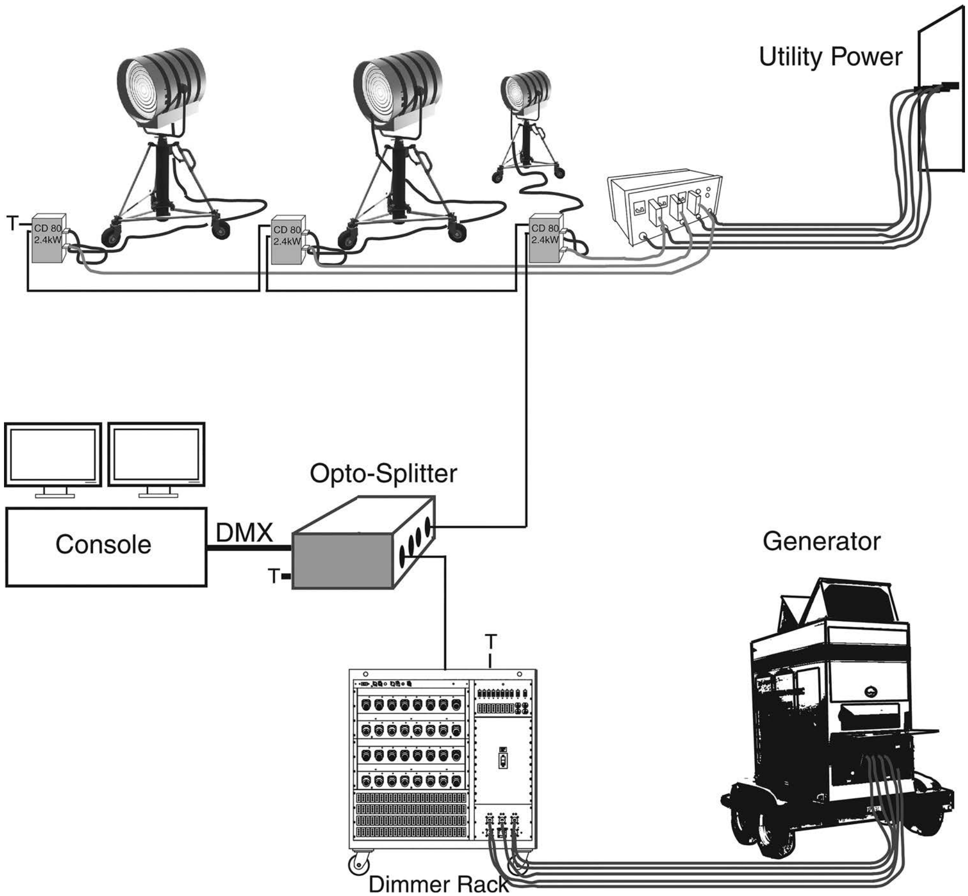


FIGURE 12.9

When DMX512-controlled lighting devices are powered from different sources, such as house power and a generator, an optically isolated repeater or splitter should be installed between them.

DMX512 testing

When troubleshooting a large network, it is extremely helpful to have test equipment. A DMX line tester plugs into the control cable and tells you whether you are receiving a signal (Figure 12.10A). More sophisticated testers (Figures 12.10B and C) perform a whole host of helpful diagnostic functions:

- Generate a DMX512 signal for one entire universe.
- Read and store looks and sequences.
- Control individual or groups of channels.
- Receive and read out the channel levels.
- Analyze the DMX512 signal.
- Test cables for continuity, shorts, and proper wiring.
- Run diagnostic tests on each channel.
- Run moving light tests.

DMXcat® (Figure 12.10D) is a small Bluetooth device with a female 5-pin XLR connector. It communicates with a suite of diagnostic apps on a mobile device. Apps include DMX controller, RDM

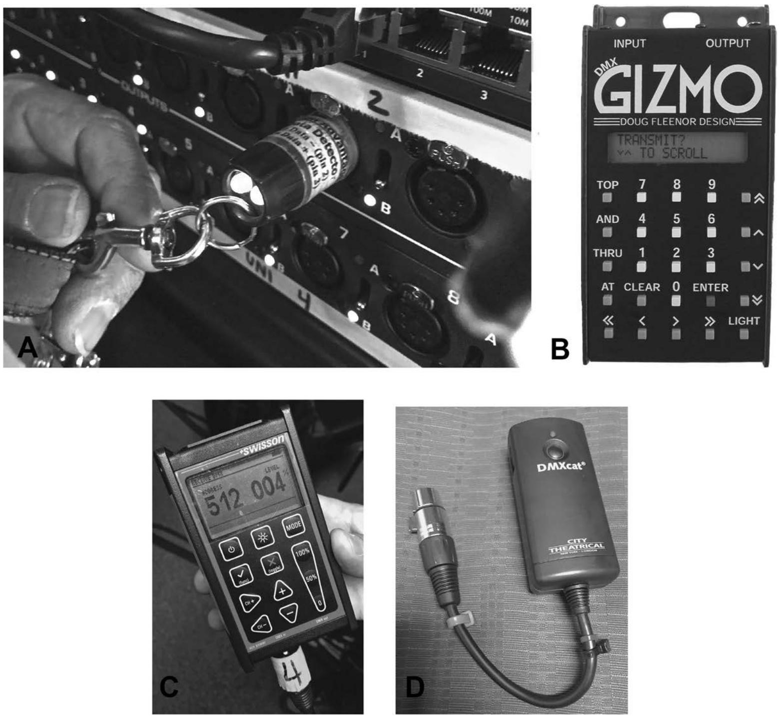


FIGURE 12.10

DMX512 testers: (A) DMXTSTR by Doug Fleenor Design, Inc. LED lights up if a signal is present; (B) GIZMO by Doug Fleenor Design, Inc.; (C) X-MT-120 Swisson DMX tester; (D) DMXcat® by City Theatrical.

controller, DMX tester, and others. The RDM controller provides a fast way to load settings into fixtures when rigging large numbers of RDM-capable lights, like ARRI SkyPanels.

Loss of signal

If the control console is shut off or gets disconnected from power, an opto-splitter loses power, or the DMX512 cable is disconnected, the signal will cease from that point. Failure to plan for this eventuality when the system is set up can potentially have very serious consequences when you have large numbers of dimmers under load at one time. If the dimmers lose the DMX512 signal and black out immediately, there would be a huge sudden change in load that can damage a generator, and also a big portion of the stage might be thrown into darkness. It is understandable to occasionally have temporary loss of control of the lights, but a blackout is a disaster. Potentially, someone could get hurt. It is also easily avoidable with proper forethought and precautions.

When a device loses its DMX512 signal, it will not necessarily just black out; most do not. Devices respond according to how they are designed and sometimes according to the settings made in their setup menu. Moving lights are typically set up to remain on and continue at the last settings sent from the console. Typically, DMX512 HMI ballasts and LED fixtures will maintain their last settings, and will shut off only with a command from the controller. Digital dimmers can be set to respond in various ways in the event of signal loss, for example:

- default to a selected preset,
- hold status quo indefinitely, or
- fade to black after a delay of a selected number of minutes.

Electricians often leave the status quo feature turned off, using the logic that if there is a problem, it is better to know about it right away, not 30 minutes after the fact. You have a better chance of someone realizing the source of the problem if there is an immediate cause and effect (for example, “Well, we were moving the set wall and all of a sudden those lights went out. Oh, look, the cable got snagged”). However, when signal loss could pose a hazard, it is essential to set up dimmers so that they maintain status quo levels with critical lights. The key is to also consider how the programmer can be alerted immediately upon signal loss. Of course, the programmer will notice the problem as soon as he or she goes to change a level, or sooner if there is a chase effect or moving light working. The programmer can choose dimmer packs with noncritical lights and set them up to black out immediately. If nothing else, the programmer can set up a light at his or her station that will shut off if it loses signal. (Ideally, this test light would be connected as the last DMX512 device on the network, so that it will alert the programmer to a break anywhere in the line.) Most modern dimmer racks *can* provide alerts back to the control console via Ethernet network or RDM; however, these networks work only with a compatible console, so this option cannot always be implemented.

Another part of the strategy is to use opto-splitters (as mentioned earlier), so that if one dimmer pack has to be disconnected or swapped, the DMX512 signal is not taken offline for the remaining dimmer racks (or packs). This also isolates any problems to one trunk line of the DMX512, and makes it easy to troubleshoot. Opto-splitters typically have LED indicator lights that show if they are receiving a DMX512 signal, as do dimmer racks and other DMX512 devices. These indicators are valuable for identifying a failure and tracking down the point of failure. If you suspect a control signal failure, the first things to check are the DMX status indicator lights (1) at the control console and (2) in the dimmer room.

The control console and the critical opto-splitters should be powered through uninterruptible power supply (UPS) devices to eliminate any chance of losing signal that way. In the event of power loss, the UPS supplies power for a limited time via battery and sounds an alarm to alert everyone to the problem. If no UPS is in place, no one has any way of knowing where or why a loss of DMX control has occurred. Although a tripped alarm will disrupt production, it allows the electric crew to go right to the problem and fix it.

Another contingency to plan for is the occasional need to reboot the control console. You want to be able to do this without causing any disruption to production, and, in fact, it can usually be accomplished without anyone knowing at all. Provided that the dimmers and lights are set up to preserve status quo for at least 5 minutes, you can safely unplug the DMX512 cable from the data link, reboot the console, return to the look that is currently on set, and reconnect the DMX512 cable without affecting any dimmer levels. However, keep in mind that if the DMX512 cable is connected when the console reboots, it will immediately clear the last command, and black out the set. If you are using a PC as a console, you can unplug the computer; the PC DMX interface will continue to generate the last signal it received as long as it has power. You can reboot the computer if necessary, without ever losing DMX512 signal. You'll want to check the manuals for the equipment you are using to be sure that you have a plan in place to handle these contingencies.

ETHERNET, ART-NET, sACN, AND RDMNET

As mentioned in the introduction to this chapter, using a closed Ethernet network enables far greater network capacity. With DMX overflowing into multiple universes, in many cases it makes more sense to build the network infrastructure with an Ethernet backbone, and convert to DMX right before the signal goes to the lighting device (compare Figure 12.11A and B). A *network switch* enables multiple devices access to the network. A *DMX gateway* or *node* converts a selected DMX universe from the Ethernet protocol into a standard DMX, or DMX/RDM signal.

DMX over Ethernet

Console manufacturers have their own proprietary Ethernet protocols for use within their own ecosystem. We will touch on these later in this chapter. However, there are two DMX over Ethernet protocols that we need to introduce now, Art-Net and Streaming ACN (sACN). These are standardized, free-to-use protocols, that gives the industry universal interoperability.

Art-Net was designed as a simple way of transporting DMX and RDM data over a closed Ethernet network. It can transport 400 universes over 100BASE-T Ethernet. sACN is the little brother to full ACN, which was a superior system designed to replace DMX that never took off because it took a radically different approach from what the industry was used to. sACN (ANSI E1.31–2016) uses familiar concepts like universes and slots, but it transmits over an IP network and can carry up to 63,999 universes of DMX data. Unlike Art-Net, it does not incorporate device discovery and remote configuration. However, starting with Art-Net 4, Art-Net was designed to work in tandem with sACN, with Art-Net handling the RDM aspects, while sACN is responsible for DMX transport.

There are various Ethernet/DMX gateways or nodes on the market to convert a single universe from an Ethernet network to DMX. Enttec was one of the first companies making an Ethernet-to-DMX

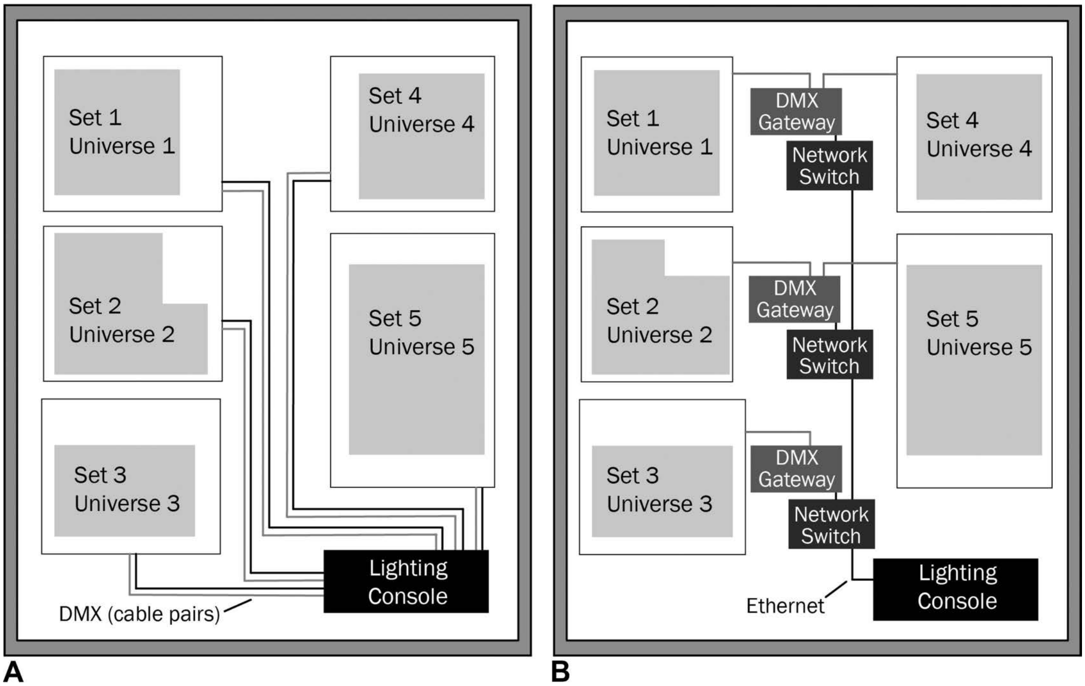


FIGURE 12.11

(A) A typical DMX topology, with each DMX universe making a home run to the console. This requires ten DMX runs, one for each universe plus a spare for each. (B) An Ethernet network uses a single CAT5 run to deliver DMX over Ethernet to the five universes.

(*Courtesy James Dornemann*)

device called Enttec ODE, which converts Art-Net and sACN to DMX (RJ-45 in, single 5-pin XLR out). To unify the infrastructure, manufacturers now build gateway devices into distribution boxes in various ways. Three examples are shown in Figures 12.12, 12.13, and 12.14.

On a bigger scale, Figure 12.13 shows a rack-mounted data distribution center. FixtureNet is the Ethernet port that the Hog operating system uses to send Art-Net and/or sACN data to compatible fixtures, media servers, and DMX gateway devices. In Figure 12.13, an Ethernet switch marked Fixture Net (bottom right) receives sACN (in this case) from the console or HogServer. One of the cables connected to that switch feeds into the Pathport OCTO Ethernet/DMX gateway (rack-mounted above the switches). The gateway converts sACN into DMX and feeds it out to eight assignable DMX ports on the back of the gateway (not shown). sACN carries many universes of DMX, so each port on the gateway has to be assigned to the desired DMX universe. Those ports feed the four optical splitters (sitting on top of the box). Note that the opto-splitters are labeled with their assigned universe, in this case, universes 1, 2, 3, and 8. The Furman M-8DX at the top of the rack is a power conditioner/surge protector which supplies AC power outlets to all the devices in the rack.

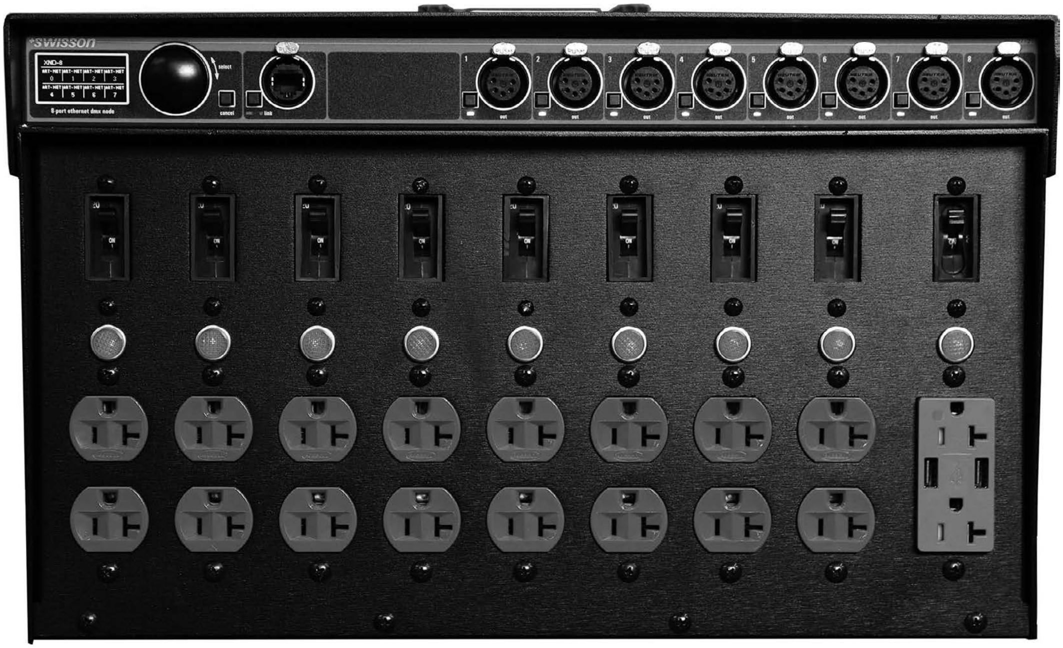


FIGURE 12.12

The Dadco OctoCat is a 100 A lunch box combined with an 8-port Ethernet/DMX node or gateway. Ethernet link in, 8 optically isolated DMX ports out. Each DMX port can be assigned to a different universe as needed. The AC outlet on the far right provides 5 V USB for charging phones or powering wireless devices.

The RatPac Unity box (Figure 12.14) performs many of the same functions as the rack-mounted system but is unified as an all-in-one package that also includes two wireless DMX transceivers. On the Unity box, the eight optically isolated DMX data links can be assigned to any universe and have color-coded LED indicators so you can identify the universe visually. The colored LED is also a button. Pushing the button brings up a selection screen in the interface for choosing the source of data for that output. The control signal can be assigned to come from DMX in, either one of the CRMX transceivers, or Ethernet in. There are colored lights for source assignment of all eight DMX outs, as well as one for each of the two wireless transceivers, and one for the configuration of the dimmer unit.

There is a master rotary switch on the right, which selects the default function of the Edison or Socapex outlets: DMX-controlled incandescent dim, DMX-controlled LED dim, DMX switchable ON/OFF, or all hot. However, each of the outlets is also individually configurable so you could assign some as incandescent dimmers, some as LED dimmers, and some as hard power, for example. The user can also assign a low or high ghost load to each dimmer. If the load is less than 75 W generally it requires a ghost load.

Unity has an internal battery. Pressing the battery button allows the user to configure the unit without having AC power applied, which is helpful when the rig may not yet be energized.

FIGURE 12.13

Rack-mounted Ethernet/DMX data distribution station.

FIGURE 12.14

RatPac's Unity box is a combination Ethernet switch, Ethernet/DMX gateway, optical splitter, CRMX wireless transceiver (two), dimmer pack, and gang box.

Other Ethernet protocols

Manufacturers of lighting control equipment developed their own proprietary protocols for Ethernet-based communications. Different network protocols are implemented on the device level (sending data to and from media servers, moving lights, dimmer racks) and on the computer level (networking multiple consoles, DMX processors, servers, computers, backup storage devices, wireless routers). For example, in Figure 12.13, there is a second Ethernet switch labeled HogNet (lower left). HogNet is the Hog operating system's proprietary protocol for networks of consoles, DMX512 processors, computers, etc. A DMX processor, like Hog's DP8000, operates on HogNet. In contrast to a gateway device like the Pathport Octo, a processor expands the capacity of the console by providing additional processing power. The DP8000 provides data links for 8 additional universes. It also has outputs for sACN and Art-Net, and can process 16 universes. Multiple DMX processor units can be networked together with an Ethernet switch or DHCP (dynamic host configuration protocol) router.

RDMnet

One reason that individual manufacturers created their own proprietary protocols for communicating with their DMX nodes is that there was no standardized way for passing RDM messages back through third-party Ethernet/DMX gateway devices. RDMnet is the final piece in the puzzle (see sidebar), designed to make it easier to access all the benefits of RDM when the system has an Ethernet backbone. RDMnet enables an RDMnet-capable controller to access RDM messages from devices though any gateway device and to set up any gateway device remotely, such as assigning universes to ports. RDMnet can coordinate between multiple controllers, so if one controller sets a new DMX address for a device, other controllers on the network immediately see the change as well. RDMnet supports mobile controller devices.

THE FOUR CENTRAL ANSI STANDARDS FOR LIGHTING CONTROL

E1.11	DMX-512 (2008): unidirectional slot information via RS485 link
E1.20	RDM (2010): bi-directional request/response messages for configuring systems via RS485 link
E1.31	Streaming ACN (sACN) (2009): unidirectional slot information via Ethernet (IPv4/IPv6)
E1.33	RDMnet (2019): bi-directional request/response messages for configuring systems via Ethernet (IPv4/IPv6)

The Standard specifies software that acts as a necessary "broker" between parts of the system. The broker, which is transparent to the user, takes responsibility for maintaining external connections to devices and controllers. The broker software would typically live within the controller, but in a more complex implementation it could also be parked on a server or external device.

RDMnet messaging elements include the following:

- Bonjour, one of the most common discovery protocols currently in use.
- Normal RDM messages (RPT, RDM Packet Transport).

- Manufacturer-specific messages (EPT, Extensible Packet Transport).
- Low Level Recovery Protocol (LLRP), which is a component protocol within RDMnet. It allows a device to discover and communicate with other devices even if they do not have valid IP settings. This allows the programmer to remotely discover all connected devices, even those that may be mis-addressed or on the wrong subnet. This function in intentionally limited in what it can do. It uses a limited number of multicast messages to get orphaned devices properly reconnected to full RDM communication.
- Configuration messages.

Advantages of Ethernet

Ethernet-based systems can provide many benefits, especially for productions rigging and working on multiple sound stages:

- A single Ethernet cable can carry data for hundreds of DMX512 universes at once.
- A backup hard drive can be networked as a client in case the main console crashes.
- A PC can be networked as a client running the PC version of the console software. Programmers can set up a wireless router and use a tablet PC (a portable laptop with a touch screen) to have a totally wireless mobile additional control console that is able to access all console functions remotely. The programmer can bring the tablet right on set to work with the DP or gaffer.
- A networked PC acts as a second console—handy anytime you have to work on two sets at once, such as when one set is being prelit while the other is being shot. Because the PC is just a client, all work is saved on the server—the main console—so if the PC loses the signal, everything still continues to work. There are even iPhone/iPod Touch applications available to run supported consoles from the handheld device using the network.
- The programmer will often connect a computer on the network for running system configuration software. This allows networked devices, like ARRI's SkyPanels and RatPac's Unity power/data box, to be configured remotely via a Web browser interface.
- Additional control consoles working on the same show can be added as clients onto the network. For example, on a show which has moving lights and conventional lights, it is ideal to have a console and dedicated programmer for each, and to save to one show file. When two production units are filming simultaneously, the show files can be saved to the same show file, so everyone is always working from the same information.
- This idea can be expanded to support client DMX512 processors in other sets—even in other soundstages—without moving the control console. Because the main control console will move with the first unit filming crew, the network allows the programmer to support lighting activities (such as rig testing and prelighting) in other sets without necessarily adding an additional console and programmer for those minor tasks.
- A media server can be added as a client. Ethernet is ideal for computer-to-computer communications. The control console becomes a tool to manipulate layers of video in the media server, and control video playback to monitors or projectors.
- Normally the console acts as the server and the other devices are clients; however, there are benefits to installing server stations on each sound stage and assigning the console as a client. This is helpful for company moves, for example. Say the first unit is moving from stage one to stage two, but a

splinter crew will remain on stage one to shoot an insert. Normally, lights are not operable without the console present. However, using the studio's network (and in coordination with the studio IT department) prior to the company move, the programmer can log onto the server on stage two and turn the lights on. When it is time to move, the programmer can leave the stage one server running the lights for the splinter crew, log off, and move the console to stage two. When the splinter crew is finished, the programmer can log back onto the server on stage one and shut everything off.

BASIC ETHERNET TERMS

Host. A device.

IP address. An IP address looks something like this: 192.168.10.1. The network uses this address the same way that FedEx uses postal addresses, to send packets of data to specific destinations. Each device in a network (server, console, DMX processor, DMX gateway, Wi-Fi router, Art-Net- or sACN-capable lights connected directly, etc.) must be assigned a unique IP address (IP stands for Internet Protocol). An IP address is a unique 32-bit number. IP addresses are expressed as dotted decimal numbers where each decimal group represents 8 bits (0–255). The decimal group between dots is called an *octet*. So, the range of possible IP addresses goes from 0.0.0.0 to 255.255.255.255. In show networks, it is best practice to use non-routable, Class C addresses for hosts. These are in the range: 192.168.0.0 to 192.168.255.255. Non-routable means, if by accident the closed network is connected to the Internet, the router should not forward these IP addresses outside the network (where they would run into conflicts).

Subnet mask. When you enter the IP address, you are also required to enter a subnet mask. Even though we rarely use subnets in our networks, an incorrect subnet mask can prevent devices from communicating. If all hosts have the same IP address except for the final octet (the digits after the last dot) then the subnet mask should be 255.255.255.0.

DHCP. Dynamic host configuration protocol (DHCP) is a process by which IP addresses are assigned to devices (hosts) automatically, usually upon startup. If the address is assigned this way, the address will be dropped when the equipment is shut down and a new one assigned when it is started back up again.

Static IP/fixed IP. An IP address that is configured manually by the programmer or system administrator (not using DHCP).

Switch. A device for connecting multiple Ethernet devices on a network. An unmanaged switch has no interface options; it is plug and play. A switch does not have an assigned IP address.

Router. A device that connects separate networks to one another. For example, a Wi-Fi router connects a wireless network to an Ethernet network.

Server. A computer program that serves the requests of other programs called "clients."

Client. A program that accesses the services of a "server."

Gateway or node. A connection point to a network. Example: A DMX/RDM gateway is an Ethernet device (with an IP address), which is the connection point for DMX/RDM (via 5-pin XLR).

Let's review the various ways that Ethernet and DMX networks can combine, and add a couple of additional possibilities.

- **DMX**. From a console's DMX data link, using DMX cable (XLR 5-pin), connected to the DMX port on the light. The signal may be daisy-chained or distributed via optical splitters to multiple lights.
- **Ethernet to DMX via gateway**. From a console's Art-Net or sACN data link, via CAT5 cable, then converted to DMX or DMX/RDM by a gateway device or Enttec ODE, and then DMX to the lights.

- **Ethernet to DMX via device**. Some lights, like the SkyPanel, can accept Art-Net and sACN directly via an Ethernet cable. They can also act as a gateway, outputting DMX/RDM via a DMX data link for wired connection to other lights.
- **Console's proprietary Ethernet protocol to DMX processor node**.

Those are some options if you want to go wired. Next, let's explore options if you want to or need to go wireless.

Lighting control apps

Lighting control apps for iOS mobile devices (preferably an iPad) include *Luminair*, ARRI's *Stellar*, and *Blackout*. Luminair is an easy-to-use app that allows the user to set fader levels, colors, and moving-light positions. Over 500 fixture profiles are accessible via the app's fixture library, so adding lights is usually as simple as loading the profile.

Stellar is designed to automate many of the tedious tasks of setting up the network, and its graphics interface is especially intuitive to operate (Figure 12.15A). The app automatically discovers RDM-compatible lights and sets their start addresses using the RDM discovery process. Stellar also allows the user to view the lights as a light plot. Light Plot view gives the user a visual reference for where the lights are in real space making selecting and controlling lights very simple.

Blackout is a highly capable iPad app, designed by a lighting control programmer with the familiar console interface. It is intended to provide functionality that more closely resembles what can be achieved on a full console for controlling lights on location, or wherever using a wireless, portable controller may be preferable to carting around a console (Figure 12.15B).

Apps for Android users include Art-Net Controller and LightFactory. For Windows there is D-Pro, Freestyler (a free app), LightFactory, and others. For Mac there is Chameleon, LXConsole, Lightkey and MadMapper (which is for mapping video onto lights or LED arrays).

Wi-Fi

An iPad, phone, tablet, or computer, using one of the apps above, controls devices on the network using Art-Net or sACN control protocols. The signal from a portable device could be via a wired connection. An iPad, for example, could be connected via its Lightning port using a Lightning-to-USB 3 adaptor, and then a USB to Ethernet adaptor, and then CAT5 or 6 cable to the Ethernet/DMX gateway device.

However, if you are using an iPad or tablet as a controller, chances are you'll want to operate via Wi-Fi. Like any Wi-Fi network, you need a Wi-Fi router as the network access point. (A *router* is a device that joins two networks, in this case a Wi-Fi network and an Ethernet network.) RatPac's AKS and ARRI's SkyLink are examples of router-equipped devices. To join the network, as you do any Wi-Fi network, you select the router ID from the list of networks in the iPad's Wi-Fi network settings.

RatPac's AKS and ARRI's SkyLink are more than just routers, however (Figure 12.16). They perform numerous interconnections including the following:

- Like any router, they connect the Wi-Fi network to other network devices, such as an Ethernet/DMX gateway or a control console via CAT5 cable.
- They are also DMX gateway devices themselves, meaning they can output DMX.
- They are also wireless transmitters that can send a wireless DMX signal to the lights and equipment. The transmitted DMX signal is encoded using the CRMX protocol. The DMX signal may originate

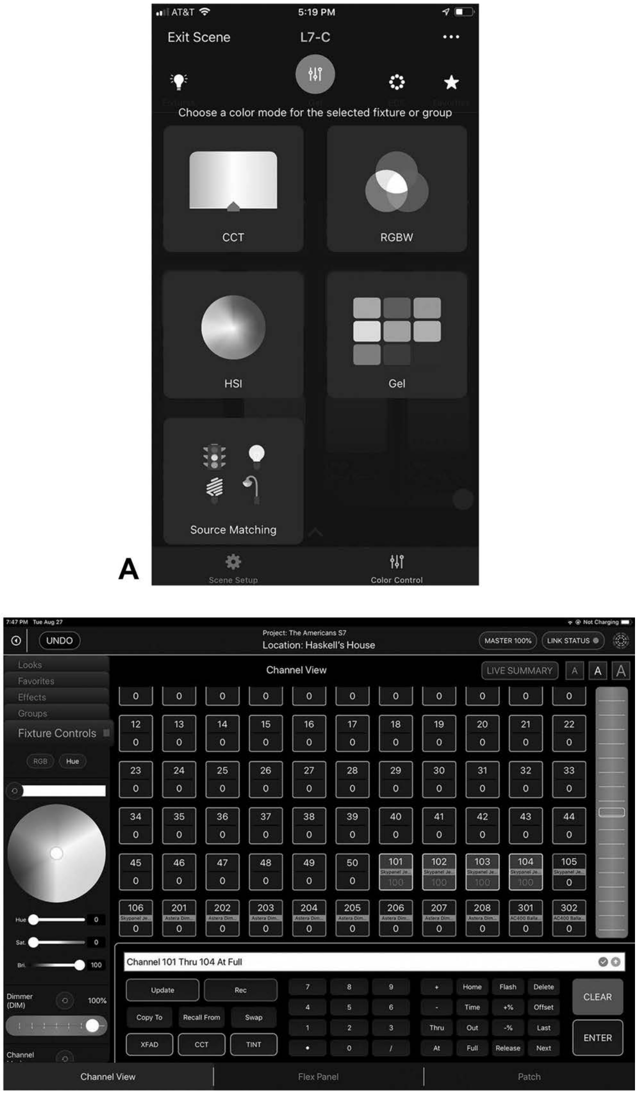


FIGURE 12.15

(A) ARRI's Stellar app. (B) Blackout app channel view.

from a Wi-Fi-connected device, from a console connected via Ethernet cable, or from a DMX controller via XLR input.

Before we had all these functions built into one box, each of these functions required a separate piece of gear, each one having a separate power supply. It was a mess.

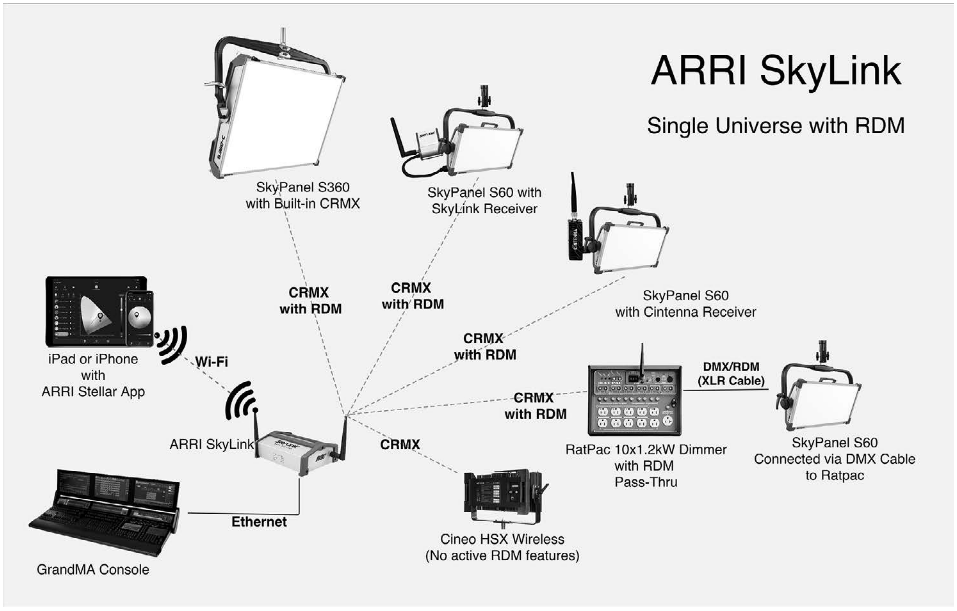


FIGURE 12.16

The diagram shows an ARRI SkyLink base station connected via Wi-Fi to an iPad or iPhone running the Stellar app. The network is also being controlled by a GrandMA console connected to the base station with a CAT5 Ethernet cable. The base station is transmitting and receiving DMX/RDM to all the RDM-enabled devices. The transmission is encoded as CRMX. Devices that are not RDM-compatible just receive DMX. Note that RatPac's PDB boxes also output the DMX/RDM signal for wired connection to other devices.

(*Courtesy RatPac*)

WIRELESS DMX

Wireless DMX512 transmitters and receivers use the 2.4–2.45 GHz bandwidth to deliver DMX512 signals without the need for DMX cable. The *transmitter* (identified as Tx) converts one DMX512 signal to a high-speed broadcast data format. The paired *receivers* (identified as Rx) receive the broadcast and decode it back into a clean DMX512 signal.

The promise of complete wireless control is compelling: it would eliminate having a DMX cable to every light and all of the data infrastructure that goes with it. Many, if not most, professional LEDs have built-in radio receivers, as do an increasing number of other devices. Figure 12.17 shows how convenient and portable a wireless control system can be.

Wireless DMX can be used in a couple of different ways. *Broadcasting* means transmitting a signal to many receivers, which may be located all around the set. Wireless may also be used *point-to-point*. This would be used, for example, to send a signal from the console to a receiver that is located closer to the lights. From there, the signal could be distributed via DMX cables, or rebroadcast wirelessly. A unit that receives and then rebroadcasts a signal is called a *repeater*.

FIGURE 12.17

DMXit controller connected directly to a Cintenna transmitter. Both are battery powered. The transmitter sends one universe of data to paired wireless receivers.

A *transceiver* is a unit that can act as either receiver or transmitter; it is user selectable. For example, a power/data distribution box may need to be able to receive or transmit, depending how it is used. It could receive a wired DMX signal from the console and then transmit to wireless receivers on nearby lights, or it could receive a wireless signal from a transmitter at the console and distribute the data using a wired system.

To be or not to be wireless

In practice, the decision to go wireless will depend on the radio environment, because above all else, the system has to be reliable. When the director calls "action," everything has to work. A set can be a very crowded and noisy radio environment with hundreds of wireless devices having to share a small piece of radio spectrum. The worst offenders are the high-powered, high-bandwidth transmitters used by the camera department for wireless video. In response to this issue, newer video transmitters in the US use the 5 GHz range and they have started incorporating spectrum analyzers to find uncrowded portions of the spectrum to operate in, which is an improvement. However, plenty of devices, from lens control units to regular Wi-Fi, Zigbee, and Bluetooth devices use 2.4 GHz. Microwave ovens also operate in this frequency range and can interfere with reception, so even the craft service guy making popcorn is part of the conspiracy against the wireless lighting network. Until we can solve this issue, either with a technological solution or by implementing effective universal spectrum management, gaffers who need 100 percent reliability will prefer to be hard-wired if possible.

That said, there are plenty of occasions where some or all of the lights can be reliably controlled wirelessly and situations where a wired connection is not possible.

TIPS FOR IMPROVED WIRELESS RELIABILITY

- Before the start of production, hold a dedicated meeting on spectrum sharing and management, as discussed in Chapter 2.
- A wireless system with normal antennas has a typical range of 600 meters line-of-sight, and farther with carefully selected antennas and repeaters; however, anything in between the transmitter and the receiver reduces the signal strength, including windows, walls, trees, and people.
- Transmission must be line-of-sight. Raise the transmitter antenna above obstacles and people, and move it away from walls that cut down its effective angle of transmission.
- Most Rx and Tx devices come with a small 2 dbi (low gain), omni-directional antenna. The linear shape of the antenna gives it an apple-shaped signal. The signal is strongest coming out the sides of the antennas, and weakest coming out the ends of the antenna. So, pointing antennas at one another creates a very weak signal. Careful attention to alignment of the antenna will do a lot to improve reception.
- It is recommended to use higher gain antennas on the receiver units when signal strength may be an issue. 5 dbi antennas and 8 dbi are commonly used indoors and 12 dbi antennas outdoors. Placing a high-gain antenna on a transmitter unit limits the spread of the radio signal and can help with point-to-point transmission.
- For point-to-point communications, use directional antennas for transmitter and receiver.
- Use a spectrum analyzer to pinpoint existing devices and what channel they are using. You can also survey Wi-Fi access points using a laptop and free software available from the Internet. This shows frequency and signal strength of Wi-Fi traffic; however, your laptop will not identify non-Wi-Fi devices that are using the spectrum.
- The 2.4 GHz band has only 11 channels, and each channel overlaps with adjacent channels. So, transmission on channel 6 may conflict with channels 5 and 7, but will not interfere with channels 4 and 8, for example.
- Adaptive Frequency Hopping Spread Spectrum (AFHSS) technology improves reliability for your system, but it also creates level of background noise across the 2.4 GHz band that can interfere with other networks. LumenRadio's cognitive coexistence technology has been popular because it actively looks for open spaces on the spectrum, rather than trying to broadcast over the top of other radio traffic.
- Watch for large Wi-Fi antennas that might be part of the facility you are working in and avoid placing wireless DMX antennas near them.
- If possible, adjust power just high enough to assure a consistent signal, not more.

- If possible, define the range of DMX addresses broadcast in order to shorten the broadcast burst.
- Walk the set with a signal-strength tester (e.g., the Ugly Box) to find the best locations for point-to-point receivers.
- A *booster* is an option in large spaces where radio range is a challenge.
- Use a *repeater* unit, to send the signal around corners when the ultimate receiver is not in the line of sight of the transmitter. A repeater receives the signal, cleans it up with some signal processing, and then transmits it afresh.

Wireless DMX transmitters and receivers

Three wireless-DMX technologies are dominant in entertainment: LumenRadio, W-DMX and SHoW DMX by City Theatrical. LumenRadio developed CRMX, a *cognitive coexistence* technology, which earned it a reputation for performance in a cluttered environment. It also features strong 128-bit encryption and error correction. The LumenRadio receiver chip is built into many LEDs, giving LumenRadio a firm foothold in the motion picture and television market.

For lights that don't have a built-in receiver, a small receiver unit can be attached. Popular transmitter/receiver kits like RatPac's Cintenna (Figure 12.18) and ARRI's SkyLink use LumenRadio's CRMX technology. The small receiver is held in place on the light by the 5-pin connector. The Cintenna is just 4 inches tall. It is available in a battery-powered version and can also be powered from a USB port on the light. The receiver is RDM capable when used with a Nova FX or TX2 transmitter, like the ARRI SkyLink base station.

Linking devices on a wireless network is as simple as powering them on, attaching and aligning the antennas, and pushing the RF link button on the transmitter. The status indicator lights on both devices will blink and then turn to solid color when connected. The transmitter automatically links to all receivers within range and starts sending DMX data. If a receiver is already linked to another transmitter, it has to be unlinked before attempting to link to the new transmitter. Pressing the RF link button for three to five seconds will unlink ARRI and RatPac receivers.

Satellite™ and Constellation

To build out the capacity and robustness of wireless networking, RatPac introduced the concept of satellite Wi-Fi transmitters. Their Satellite units receive Art-Net via Wi-Fi or wired Ethernet connection to the console. They transmit wireless DMX (CRMX). This is a specific subset of the functions of a standard AKS, and it serves a couple of specific purposes. Each Satellite unit can rebroadcast a different universe of wireless DMX. The number of universes is limited only by the bandwidth in the 2.4 GHz radio spectrum (Figure 12.19). The universe is color coded with an LED indicator light, just as it is on the RatPac's Cintenna 2 units and Unity box, for easy identification.

In this way several Satellites can create a constellation of wireless DMX transmission from an AKS "host" base station. RatPac has designed the units for remote management, using a tool they call Constellation. The Satellite units are placed in Wi-Fi Station mode and assigned to a universe. Wi-Fi Station mode requires assignment of a subnet mask. See RatPac's AKS instruction manual. The Satellite

FIGURE 12.18

(A) RatPac's original Cintenna™ kit. (B) Cintenna transmitter. (C) Cintenna receiver. (D) Cintenna 2 with built-in antenna and Bluetooth (front and back).

functions as an Ethernet client to the host AKS. Constellation enables the programmer to identify, link and unlink receivers, view battery level on individual Satellite and Cintenna 2™ units, and configure the Art-Net network. A Satellite unit can be placed in a different mode and can function to simply broadcast wireless DMX from Ethernet (Wi-Fi client mode). The transmitter is not as powerful as an AKS unit, but for many applications a Satellite may be all that is needed.

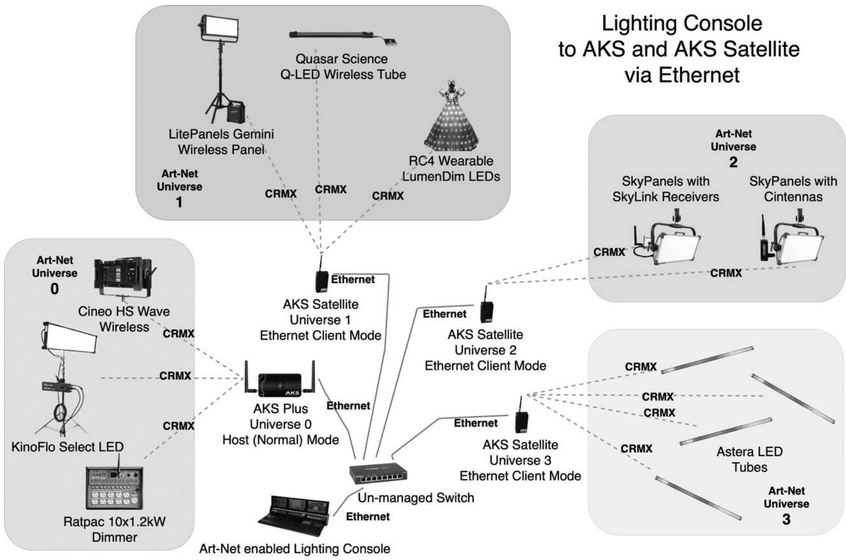


FIGURE 12.19

This diagram shows an implementation that uses Wi-Fi to distribute data from a host AKS (in normal mode) to satellite AKS Lite units in Wi-Fi station mode. The alternative to this is to wire the AKS units using CAT5 cable, and connect each to the network using an unmanaged Ethernet switch. The units work as Ethernet clients.

(*Courtesy RatPac Dimmers, Inc.*)

The system also features the ability for two users to operate in the same DMX universe, so that the gaffer can use an on-set iPad, for example, without affecting what the programmer is doing at the console. They call this the Gaffer's Window, shown in Figure 12.20.

Bluetooth

Some CRMX receivers, like RatPac's Cintenna 2, can also communicate directly with a mobile device via Bluetooth. This skips the middleman; it does not require a Wi-Fi network via AKS. Instead the mobile device can communicate directly with Cintenna 2 receivers on lights that are close by, within Bluetooth's limited radio range.

Similarly, MoonLite™ is a small, battery-powered CRMX and Bluetooth transceiver from LumenRadio (Figure 12.21). It enables tablets and lighting apps to connect directly to a CRMX wireless network using Bluetooth rather than having to use a Wi-Fi router (Wi-Fi network access point). Using an app called CRMX Toolbox, the user can toggle between Tx and Rx modes, change output power, check battery status, and update the firmware. It has a male XLR for connecting to a DMX controller as well as a female XLR pass through. It can also be used as a DMX tester. It has an open API so lighting apps like Luminaire have built their software to connect directly to MoonLite via Bluetooth. The battery is rechargeable with a 10- to 12-hour battery life. The CRMX transmitter has a reported range of about 300 meters.

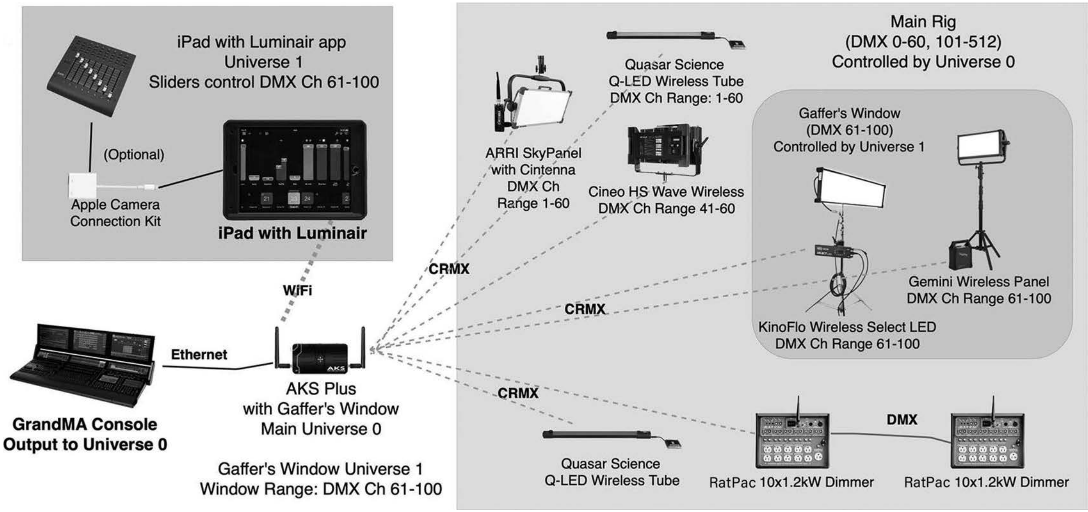


FIGURE 12.20

Satellite system with Gaffer's Window.

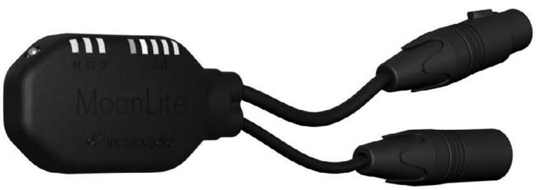


FIGURE 12.21

MoonLite™ from LumenRadio.

Mesh

LumenRadio's DMXmesh™ takes a potentially game-changing approach to wireless connectivity. With DMXmesh™, the radios in every light fixture (and any device with a compatible LumenRadio chip) help forward the lighting control data in a collaborative manner. The lights form a mesh of radio signals, so that the system no longer relies on a star topology (which requires one transmitter to reach each receiver), but instead, all devices can become repeaters. This greatly simplifies the process of planning a wireless network and promises to increase its reliability and simplicity.

As LumenRadio and other wireless manufacturers continue to develop their radio platforms (transmitter/receiver electronics and wireless protocols), lighting products integrate an expanding range of features including DMXmesh™, Bluetooth integration, improved cognitive coexistence, and support for third-party lighting control. Products that incorporate LumenRadio's TimoTwo™ radio module are the first to have this feature set.

Wireless system management

SuperNova is free computer software developed by LumenRadio. It is a system management tool that uses RDM to monitor network status and presents it on a color visualization, including all connected CRMX products, Ethernet devices, and Art-Net nodes. A computer running SuperNova can be connected to the show network to monitor the whole system. It provides frequency management tools such as displaying frequency traffic, your own and traffic from surrounding systems. It can be used to shut off certain channels on CRMX transmitters when those channels are reserved for other mission critical devices. It can check sensor outputs, change device settings, and can perform firmware updates to lights wirelessly. It enables monitoring and configuring of RDM devices throughout the network.

DMX CONTROLLERS AND LIGHTING CONSOLES

In its most basic form, a DMX controller is a device that generates a DMX512 data signal based on inputs from the user. DMX controllers come in many levels of sophistication.

- A *dimmer board* is a simple controller that may use slider faders or keypad inputs to set levels. Old style dimmer boards are designed for controlling dimmers. They may have memory capability and can save presets and serve up cues. Newer boards and consoles designed for small venues incorporate basic features for controlling full-color and RGB LEDs. A traditional dimmer board generates one universe of DMX and has one DMX data link.
- A *control console* or *desk* is a computer-based controller with a sophisticated interface designed to give a proficient programmer fast, intuitive access to a wide spectrum of control features including handling lights with complex personalities.
- *Control apps*, created by various lighting manufacturers, are often intended to provide intuitive access to features (like color pickers, gel swatches, and effects) that would otherwise require a console. For a small production or a commercial this could provide all the control that is necessary.

Small controllers

A small handheld controller like the DMXit shown earlier, Pocket Console or Apathy (both by Doug Fleenor Design, Inc.) are commonly used to control DMX512 devices directly on set as well as for testing equipment during rigging, when there is no console or programmer present. These little controllers are also handy for system troubleshooting. Although these devices possess only a few buttons, they generate an entire universe of 512 channels and can even be programmed to display presets.

FIGURE 12.22

Programmer John Crimins controls an immense set for the movie *Iron Man 2*. The rig includes: C-Splash fixtures in pools (Color Kinetics submersible color LEDs), LiteRibbon RGB LEDs around the lip of the pools, PRG Bad Boy moving lights on towers, conventional lights on dimmer circuits, and fluorescents lighting an immense green screen. Versa TUBE LED tubes are mounted to the columns in the distance. When active they displayed a waving American flag via a Catalyst media server. The console is a Hog III console by High End Systems.

(*Courtesy Mike Bauman*)

Consoles

Consoles are capable of controlling thousands of devices, multiple universes, and complex device personalities such as moving lights and media servers (Figures 12.22 and 12.23). The three predominant console operating systems are High End Systems's Hog-series, ETC's Eos-family, and MA's GrandMA-series.

A key philosophy of any advanced console's operating system is that the programmer should not have to be concerned with the specific operational characteristics of each of the different lights when he or she is programming looks and movement. This philosophy was born side-by-side with the advent of automated lights, but it now applies to full-color LEDs as well, or any device that requires managing dozens of attributes. The programmer thinks in terms of aesthetic parameters common to all the lights, such as color, position, beam, and intensity, and these are what the programmer controls with the console. This is known as the *abstract layer* because the software acts as an interpreter between the user and the next layer of software. (Modern communication systems are constructed of multiple discrete layers between the bottom physical layer of hardware and the top layer of the user interface.[3]) The console can do this because it maintains a working library containing fixture profiles for all of the different lights. It can therefore interpret the programmer's aesthetic inputs into DMX values appropriate to the individual make, model, and software version of each fixture. With just a few keystrokes, a programmer can instruct the console to take moving light fixtures 1 through 6, focus them down stage center, make them all Congo blue, and spin a particular gobo in a prescribed way. The programmer can do all this without ever having to consider DMX addressing or values, fixture profiles, color mixing, or any of the multitude of parameters required to execute that instruction.

[3] For more about the architecture of networks read John Huntington's book, *Show Networks and Control Systems,* 2nd ed., Campbell, CA: Zircon Designs Press, 2017.

FIGURE 12.23

Road Hog console, from High End Systems.

Most companies that make control consoles also offer PC console-emulation software or an off-line editor, which can be used offsite to work on the programming for a show (and also to learn and explore the features of the software); however, emulation software typically prohibits the use of the PC as a console itself. To this end, a number of companies have developed their own control software to use a PC as a lighting console (Figure 12.24); connected with the DMX512 network using a USB PC DMX interface. When control is relatively simple, such as on a television series, a laptop and PC DMX interface may be all that is needed to run the show. Although the PC software can typically do almost everything the console can do, it lacks the multiple screens and specialized keyboard functions for complex programming tasks. Users can add wings and additional monitors to their computer for programming and playback functions, providing a faster and easier interface.

Console operations

The full operation of control consoles is beyond the scope of this book, but it is helpful for the gaffer and lighting crew to be generally familiar with what functions can be performed on a lighting console. They include the following:

FIGURE 12.24

This laptop computer runs LSC Clarity. It is connected to the DMX512 network via a wireless DMX PC interface (not shown). The right-hand monitor shows the program and the left-hand monitor shows the real-time rendering. The faders on the left are the playback wing, which is an optional add-on. There's also a programming wing available.

(*Courtesy Richard Cadena*)

- **Levels**. Sets levels for lights and DMX512 devices.
- **Presets**. Stores a predefined set of intensities or values for a set of channels, stored in memory for later replay.
- **Cues**. Executes cues (recalling a preset from memory and putting the result on stage) using timed fades and crossfades to transition between presets. The console can also link cues to create a series of timed, connected lighting events. It can make presets dim or crossfade at different speeds or insert a delay before beginning a fade.
- **Cue list**. Keeps cues in a list for sequential playback. This is how light cues are executed for a theatrical performance or for individual songs in a concert.
- **Group**. Allows the programmer to group lights in multiple ways for ease of control.
- **Fixture numbers/patch**. The patch is a software assignment of unique numbers to the lights and DMX devices. Fixture numbers can follow whatever logic the programmer thinks best; it might be based on the type of light, for example. Using fixture numbers to identify the lights frees the lighting crew from having to deal with the actual DMX addresses after the fixture is addressed.
- **Submasters**. Assigns groups of fixtures or a sequence of cues to a fader.
- **Palettes**. Stores a set of values for color, position, beam, or intensity in a lookup table that can be applied to a compatible light or group of lights and recorded in a cue with a single button-push. This is very handy for moving lights, but is also useful for any device with more than one attribute. A palette is created and customized by the programmer. Changing a palette changes every occurrence

of that palette in every cue in the show, making it easy to make global changes to a show without having to do it one cue at a time.

- **Effects**. Consoles provide tools for creating effects sequences—a series of complex light cues that can be played back. The simplest example would be flash or chase effects, but effects can be manipulated in many ways to create patterned and random effects such as lightning, flame, and so forth.
- **Playbacks**. A moving light console utilizes multiple playbacks—cue lists assigned to a fader used for running a particular routine on selected lights.
- **Pixel mapping**. Pixel mapping plays a major role in programming lighting effects (discussed shortly).
- **Show files**. All work is saved as a show file, which can be copied, backed up, archived, edited on emulation software away from the job site, emailed, and shared with others.
- **Remote cueing**. Another way to trigger a light cue is to connect a remote switch to the control console, which executes the lighting cue. This momentary switch could be installed in a handheld switch-box activated by a lighting technician on the set, or it could be installed into the set as a wall switch and activated by the actor.

PIXEL MAPPING

Pixel mapping is increasingly being used as a way to achieve lighting effects in motion pictures. Pixel mapping means using graphics, images, or video files to drive DMX commands which overlays the color and intensity of a moving image onto an array of lights. This enables the programmer to make organic-looking reactive lighting effects for things like fire, moving clouds, or water by playing *content*, like a video of fire, over an array of lights. These are far more believable effects than can be generated by the console's effects engine or chases. Hundreds, even thousands of fixtures, can be controlled this way. It can also be used to achieve onscreen lighting effects like the familiar Star Trek elevator light that streaks past vertically.

Traditionally pixel mapping had to be achieved through a media server, like Mbox, but today's advanced consoles have built-in pixel mapping and media servers. Some LED fixture apps, like Digital Sputnik's DS Voyager Controller, incorporate pixel mapping, vastly increasing the effects capabilities of a simple app.

The rig in Figure 12.25 was used to emulate the sweeping beam of a lighthouse. The light strips are Color Force 72s. Each one has 24 pixels, separately controllable light engines. The programmer pixel-mapped a graphic of a white square which moved across the fixtures. The left and right edges of the white square were gradients to help achieve a smooth dimming up and down of the lights as the square moved across. This allowed him to narrow the control of 384 pixels down to one media layer.

RasterMAPPER is used to map out the LED array. The map and the media files are output as CFF files, loaded into a Compact Flash (CF) card, and loaded into a simpler drive device for playback. The drive device is controlled via DMX512 (or optional hand controller), so the playback, sequencing, and other manipulation of images can be written as lighting cues on a control console. This simpler system reduces the number of DMX512 channels from 40 or more for a media server to 6 for the CF Versa drive device. As many as 253 user-defined patterns (plus two factory defaults) can be played backward or forward, looped in various ways, and frozen at any point. The brightness, color balance, and resolution are also controlled via DMX512.

FIGURE 12.25

Using pixel mapping, each one of the 384 light engines in this rig is separately controlled in a complex chase pattern, but the programmer controls all the lights, simply by manipulating a geometric shape on the console screen over the mapped lights.

(*Courtesy Mike Bauman. Programmer Scott Barnes*)

CHAPTER

Electricity

13

A clear understanding of electricity enables the technician to troubleshoot intelligently and is an essential part of set safety for you and for all those you work with. In this chapter, we start with the principles of how electricity works. We want to build a mental picture of how electrical forces behave; how current, voltage, power, and resistance are related; and how these relationships translate to our daily work. We'll discuss single-phase and three-phase alternating current (AC) power systems, and their associated voltage configurations. We need to understand the role of switches, overcurrent protection, and grounding to help keep a system safe.

Woven throughout this conversation are references to the National Electrical Code (NEC) and other rules and guidelines. Later chapters focus on the equipment and techniques that we use for electrical distribution and rigging, electrical problems, and power sources. Before we get to that, let's take a look at the fundamentals of electricity and electrical power circuits.

THE FUNDAMENTALS OF ELECTRICITY AND ELECTRICAL FORMULAS

Electricity is the flow of electrons through a conductor. Electrons are forced into motion through a conductor when a power source is applied. As you know, a direct current (DC) battery provides two terminals to power an electrical device, such as a light; one terminal has a positive charge (+), the other has a negative charge (−). The amount of difference between their states represents the potential to do work. It is therefore referred to as the *potential* or *potential difference*. The greater the potential difference, the greater the force with which electrons are made to flow. When a light fixture is connected to the battery terminals, the wires and the lamp provide a path for electrons to flow from the negative terminal to the positive terminal of the battery. The chemical reaction taking place within the battery maintains the potential difference, which forces electrons to flow *continuously* through the circuit.

The flow of electricity and the electrical properties of components in a circuit are quantified by four basic units of electrical measure:

Unit	Description	Variable (used in formulas)	Abbreviation (units)
Volts	Electromotive force, potential difference	*E*	V (volts)
Amperes	Current	*I*	A (amps)
Watts	Power output	*P* or *W*	W (watts)
Ohms	Resistance	*R*	Ω (ohms)

Volts (electromotive force)

The potential difference is the *electromotive force* or *voltage*. It is measured in volts (V). A flashlight operates on 1.5 V, a car battery at 12 V, and a wall socket at 120 V. Voltage is the force with which current is pushed through a resistance. When we measure voltage with a voltmeter, we read the difference in voltage potential between two points in a circuit (between the phase wire and the neutral wire, for example).

By convention, E is the variable used to represent voltage in electrical equations (for example, $E = 120$ V). E for *E*lectromotive force.

Amperes (current)

The flow of electrons is called *current*. In an electrical circuit, the volume of electricity per second (rate of flow) is measured in *amperes*, or *amps* for short.[1] Ampere is abbreviated A (as in a 1000-watt light draws 8.3 A of current).

In practical terms, amps represent the amount of current being pushed through the load (lights) by the voltage of the power source. The amperage of a circuit is important to electricians because cable, connectors, and other distribution equipment must have enough capacity to carry the amperage. If cables are too small, they heat up, which causes a number of problems including the potential to start a fire. Every element in an electrical distribution system, from the generator to the lamps, has to be sized to handle the amperage.

By convention, the letter I is used to represent current in electrical equations (for example, for a 10,000-watt light, $I = 83.3$ A).

Watts (power)

Wattage can be thought of as total power *output*; in the case of lighting fixtures, wattage is the amount of total output (light and heat). A high-wattage bulb is brighter than a lower wattage one. The total amount of electrical power being delivered at any one moment is measured in watts (W). The wattage is the product of the amperage (volume of current) and the voltage (electro-motive force). Wattage is the measure of the amount of work being done in any one instant. It is the same idea as horsepower; in fact, 746 W = 1 hp.

By convention, the letter P is used as a variable to represent wattage (power) in equations. (However, W is also sometimes used.)

We refer to many tungsten and HMI lights by wattage. A baby is a 1000 W light or 1 kilowatt (kW). Thus, the common terminology: 1k, 2k, 5k, and so on.

For the purpose of billing, the power company's meter counts the electricity consumed in kilowatt-hours (kWh). The rate of consumption at any given time is reflected in the speed at which the disk in the meter turns. Kilowatt-hours measure the total amount of electrical power consumed over a given amount of time: the rate at which power is consumed in a given moment, measured in kilowatts, multiplied by the hours that power is consumed at that rate.

---

[1] One coulomb per second equals one ampere.

The power formula

Watts are mathematically related to volts by the power formula:

$$P = IE \quad \text{or} \quad \text{watts} = \text{volts} \times \text{amps}$$

An easy way to remember the power formula is to think of West Virginia ($W = VA$) or *easy as PIE*.

From this, we can see that both voltage and amperage contribute to the total output (wattage). Consider two 60 W bulbs, a household bulb and a car headlight. The household bulb runs on 120 V and draws a current of 0.5 A. The car headlight uses a 12 V battery, but draws current at a rate of 5 A. The total power consumed, and the total amount of light emitted are the same for the 60 W household bulb and the 60 W car headlight:

$$\text{Household bulb:}\ \ 120\text{ V} \times 0.5\text{ A} = 60\text{ W}$$

$$\text{Car headlight:}\ \ 12\text{ V} \times 5\text{ A} = 60\text{ W}$$

To make the same point another way, the standard voltage in the United Kingdom used to be 240 V.[2] Consider what this means for a 10k lamp.

$$120\,\text{V} \times 83.3\,\text{A} = 10,000\,\text{W}$$

$$240\,\text{V} \times 41.67\,\text{A} = 10,000\text{ W}$$

Note, the amperage of the 240 V lamp is half that of the 120 V lamp. The two lamps are the same brightness regardless of voltage. So, a 10k is a 10k the whole world over, but in the UK and Europe a 10k has half the amperage and can use a much smaller cable.

Take a look at Table 13.1. The table lists the amperage of lights of various wattages using various voltage systems. Note the various permutations of the relationships between voltage, amperage, and wattage. Note that a 100 W lamp operating at 12 V pulls the same amperage as a 1000 W lamp at 120 V or a 2000 W lamp operating on a 240 V system.

The power formula can be stated three different ways:

$$P = IE \quad \text{or} \quad \text{watts} = \text{volts} \times \text{amps}$$

$$E = \frac{P}{I} \quad \text{or} \quad \text{volts} = \frac{\text{watts}}{\text{amps}}$$

$$I = \frac{P}{E} \quad \text{or} \quad \text{amps} = \frac{\text{watts}}{\text{volts}}$$

Calculating the amperage of lights

To calculate the amperage of a given light fixture, divide the lamp's rated wattage by its rated voltage. For example, for a 1000 W light operating at 120 V, we make the following calculation:

[2] The declared UK standard is now 230 (+10%, −6%). This conforms to the 400/230 V standard used in the rest of Europe while preserving 415/240 V, which is still the actual supply voltage to most residences in the UK.

$$I = \frac{P}{E}$$

$$\frac{1000\,\text{W}}{120\,\text{V}} = 8.3\ \text{A}$$

Table 13.1 Amperage of lights with various voltage systems

	System voltage					
Lamp wattage	**240 V**	**230 V**	**208 V**	**120 V**	**30 V**	**12 V**
100 W	0.4 A	0.4 A	0.5 A	0.8 A	3.3 A	8.3 A
200 W	0.8 A	0.9 A	1.0 A	1.7 A	6.7 A	16.7 A
300 W	1.3 A	1.3 A	1.4 A	2.5 A	10.0 A	25.0 A
400 W	1.7 A	1.7 A	1.9 A	3.3 A	13.3 A	33.3 A
500 W	2.1 A	2.2 A	2.4 A	4.2 A	16.7 A	41.7 A
650 W	2.7 A	2.8 A	3.1 A	5.4 A	21.7 A	54.2 A
750 W	3.1 A	3.3 A	3.6 A	6.3 A	25.0 A	62.5 A
1000 W	4.2 A	4.3 A	4.8 A	8.3 A	33.3 A	83.3 A
1500 W	6.3 A	6.5 A	7.2 A	12.5 A		
2000 W	8.3 A	8.7 A	9.6 A	16.7 A		
3000 W	12.5 A	13.0 A	14.4 A	25.0 A		
4000 W	16.7 A	17.4 A	19.2 A	33.3 A		
5000 W	20.8 A	21.7 A	24.0 A	41.7 A		
6000 W	25.0 A	26.1 A	28.8 A	50.0 A		
8000 W	33.3 A	34.8 A	38.5 A	66.7 A		
9000 W	37.5 A	39.1 A	43.3 A	75.0 A		
10,000 W	41.7 A	43.5 A	48.1 A	83.3 A		
12,000 W	50.0 A	52.2 A	57.7 A	100.0 A		
20,000 W	83.3 A	87.0 A	96.2 A			
24,000 W	100 A	104.3 A	115.4 A			

Paper amps

A quick method for calculating amperage is to divide the wattage by 100, an easy calculation to do in your head. Dividing by 100 overestimates the amperage, which builds a valuable safety margin into the load calculation. This is known as the *paper method* of calculating the total load.

To calculate the total current flowing through a cable, simply add up the amperages of the lights it is powering. In Table 13.2, note how much easier it is to add the paper column.

Table 13.2 Paper method example

Wattage	Paper amps	Real amps
300	3	2.5
500	5	4.2
1000	10	8.3
2000	20	16.7
4000	40	33.3
5000	50	41.7
10,000	100	83.3
Total	**228**	**190** (rounded)

The real current is 83 percent of the paper value. There are several reasons it is valuable to maintain this safety margin. Inrush current, start-up loads, power factors, non-linear loads, and other phenomena can cause greater current to flow than may be expected. These are covered later in the book. Using paper loads is not an exact way of making load calculations, but it is quick, easy, and safe.

Resistance

So far, we have a mental picture of a lamp operating at the standard 120 V, drawing a certain amperage to generate a particular wattage output. However, this is an incomplete picture of the forces acting on a circuit. What prevents an ambitious 60 W lightbulb from drawing more current and becoming a 600 W lightbulb? The force we are missing is *resistance*. Understanding how resistance relates to power and current gives us a much clearer picture of the forces at work in a circuit.

Resistance is the opposition to the flow of current created by the load (the fixtures plugged into the circuit) and by the resistance of the wires themselves. Resistance is measured in ohms, abbreviated as the Greek letter omega (Ω). For example, a 120 V, 2 kW light has a resistance of 7.20 Ω. R is the variable used to denote resistance in electrical equations (for example, $R = 7.20\ \Omega$).

The resistance of a particular lamp filament, once it is running, can be considered a constant, determined by the conductive properties of the metal filament. The resistance of the filament limits the current that can be pushed through it by a particular voltage and, therefore, determines its ultimate output in watts.

Ohm's law

Ohm's law states the relationship between resistance, voltage, and amperage. It can be stated three ways:

$$I = \frac{E}{R} \quad \text{or} \quad \text{amps} = \frac{\text{volts}}{\text{resistance}}$$

$$R = \frac{E}{I} \quad \text{or} \quad \text{resistance} = \frac{\text{volts}}{\text{amps}}$$

$$E = I \times R \quad \text{or} \quad \text{volts} = \text{amps} \times \text{resistance}$$

Figure 13.1 shows the formulas wheel that gives all the possible relationships between voltage, wattage, amperage, and resistance. Figure 13.2 shows an easy way to remember these relationships.

Resistance of a load

Ohm's law, stated as $R = E/I$, can be used to calculate the resistance of an electrical device, like a light fixture: resistance is the light's rated voltage divided by its rated amperage. For example, a 5000 W bulb, rated for 120 V, uses 41.67 A. The resistance of the lamp can be calculated as follows:

$$\frac{120\,\text{V}}{41.67\,\text{A}} = 2.88\,\Omega$$

Resistance of cable

Cables also have resistance. The resistance of a particular length of cable is equal to the voltage drop in the cable divided by the amperage running through it. The *load* is the total amperage in a conductor

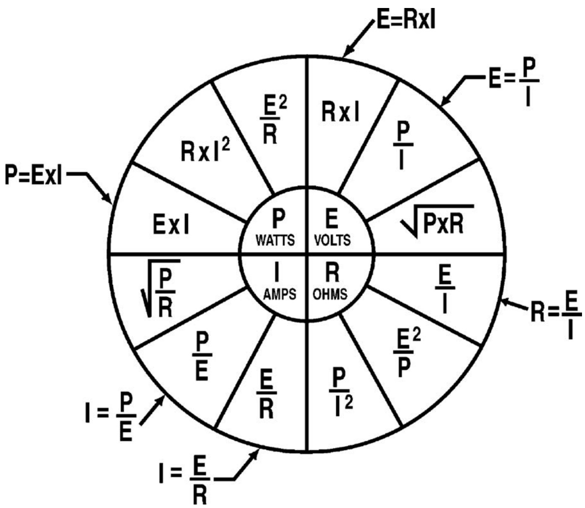


FIGURE 13.1

The formulas wheel gives every permutation of the relationships between voltage, amperage, wattage, and resistance.

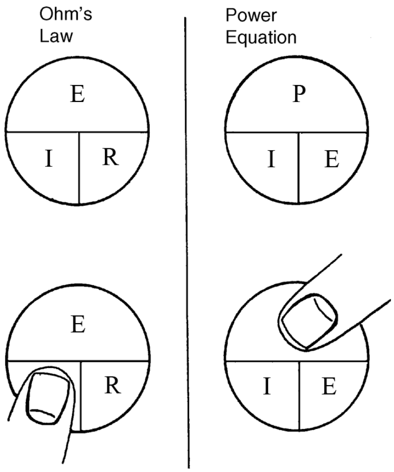


FIGURE 13.2

A simple way to remember the most common equations in Figure 13.1 is to use "magic circles." On either of the circles shown, cover the symbol you want to find with your finger. The relationship that remains is the formula. For example, to determine amperage (*I*) from a known resistance (*R*) and voltage (*E*), put your finger on the *I* and read *E* divided by *R*. To determine wattage (*P*) from amperage and voltage, put your finger over the *P* and read *I* times *E*.

resulting from all the electrical devices connected to the circuit. If there is a 4 V drop in a length of cable carrying a 40 A load, the resistance of that length of cable is:

$$R = \frac{E}{I} \quad \text{or} \quad \text{ohms} = \frac{\text{volts}}{\text{amps}}$$

$$\frac{4\,\text{V}}{40\,\text{A}} = 0.1\Omega$$

If we know the resistance per foot of a given cable, we can estimate the voltage drop for any length of cable. We'll come back to this in Chapter 17.

Using Ohm's law

$I = E/R$ calculates the amperage drawn by a particular load, knowing the line voltage and the load's resistance. To see how this equation works, let's use it to illustrate the dramatic effect of *voltage drop* and *line loss*.[3]

[3] Line loss and voltage drop are related but they are not the same thing.

In a long length of cable, this resistance causes a perceptible drop in voltage from source to load because resistance turns some power into heat in the cables. The reduction in voltage is the *voltage drop*.

Line loss is the loss of usable power from the power source as a result of power lost to heating the cables. Line loss increases as the *square* of the current ($P_{loss} = I^2R$). Line loss reduces the available capacity of the source.

Looking at $I = E/R$, we can see that if voltage decreases due to cable resistance, amperage also decreases. There is less electromotive force to drive the current through the resistance of a light. For example, a 2000 W bulb has a resistance of 7.36 Ω; so, 120 V can push 16.6 A of current through that resistance. However, if the voltage drops to 108 V, the lower voltage can push less current through the lamp's resistance. Using Ohm's law, we can calculate the actual current:

$$I = \frac{E}{R} \quad \text{or} \quad \frac{108\,\text{V}}{7.36\,\Omega} = 14.7\,\text{A}$$

The actual current is only 14.7 A, instead of 16.6 A. Now, using the power equation, we can calculate the actual power output of the 2000 W lamp:

$$W = I \times E \quad \text{or} \quad 108\,\text{V} \times 14.7\,\text{A} = 1588\,\text{W}$$

The output is sliced down to 1588 W.

The problem is compounded by the fact that a light operates at full efficiency only at its rated voltage. Operating at 108 V (90 percent of its rated power), the 2k in fact produces only about 68 percent of its normal light output. That's one wimpy 2k—a 32 percent loss of output caused by a 10 percent loss of voltage. Light output decreases geometrically with voltage.

Inrush current

A brief explanation of inrush current will provide a further illustration of how resistance works in a circuit. We said a moment ago that the resistance of a lamp filament can be considered a constant. To be more precise about it, the resistance is constant *at a given temperature*. Any metal has less resistance at a lower temperature; as temperature increases, so does resistance. This effect is very pronounced with tungsten—when cold it has very little resistance but when heated it has very high resistance. As a result, from a cold start, tungsten lights have high inrush current (25 times the nominal current) which lasts a couple milliseconds until the filament temperature increases, bringing the resistance up and current down to their nominal values. This is the reason that we use dimmers to bring up 20k lamps—to avoid slamming the (expensive) lamp with high inrush current. Once at operating temperature, however, resistance is constant.[4]

Impedance

So far, we have been talking about purely resistive loads. In AC circuits, for some loads, the opposition to current is a combination of resistance and *reactance*. Resistance and reactance together result in the total opposition to current, called *impedance*. Reactance results from *induction* (components that build a magnetic field—coils) and from *capacitance* (components that store a charge—capacitors). Impedance uses the same units as resistance, ohms (Ω), and is represented by Z when used as a variable in electrical equations. Power factor, inductive, and capacitive loads are covered in Chapter 17.

[4] In contrast, the resistance of copper changes only a little with temperature.

Ohm's law is therefore modified for AC as follows:

$$I = \frac{E}{Z} \quad \text{or} \quad \text{amps} = \frac{\text{volts}}{\text{impedance}}$$

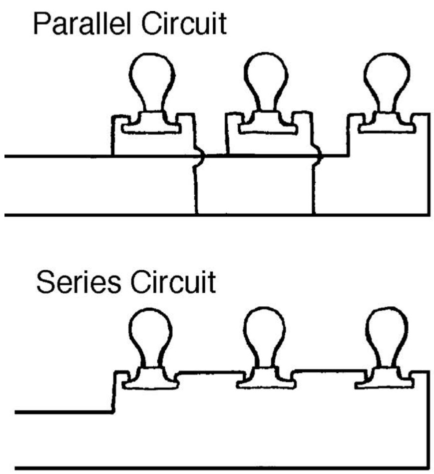
PARALLEL AND SERIES CIRCUITS

Parallel and *series* refers to the way components of a circuit are connected to one another. The relationship between voltage, amperage, and resistance works differently when multiple devices are connected in series than when they are connected in parallel, so it is important to understand the differences.

Earlier we said that the total load is the sum of the amperages of the lights in the circuit. This is actually only true if the lights are connected in parallel. Parallel circuits are familiar because this is how any electrical distribution system provides power to outlets. Figure 13.3 shows several lamps connected in a circuit in parallel and in series.

In a *parallel* circuit (Figure 13.4), each lamp receives the full voltage of the power source. The *voltage* of the power source is the same as the voltage across each and every load on the circuit ($E_T = E_1 = E_2 = E_3$, etc.). Each of the loads provides a separate path for current to flow. The amount of current in each path is inversely proportional to the resistance in that path. The sum of the amperages of the separate loads is equal to the total amperage of the whole circuit ($I_T = I_1 + I_2 + I_3$, etc.).

In a *series* circuit, the components are connected end to end (Figure 13.5). The current has only one path to complete the circuit and must pass through every component to complete the circuit



$$\frac{1}{R(\text{Total})} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc.}$$
$$E(\text{Total}) = E_1 = E_2 = E_3 = \text{etc.}$$
$$I(\text{Total}) = I_1 + I_2 + I_3 + \text{etc.}$$

$$R(\text{Total}) = R_1 + R_2 + R_3 + \text{etc.}$$
$$E(\text{Total}) = E_1 + E_2 + E_3 + \text{etc.}$$
$$I(\text{Total}) = I_1 = I_2 = I_3 = \text{etc.}$$

FIGURE 13.3

In a parallel circuit, voltage is constant everywhere in the circuit and the sum of the amperages of the fixtures equals the total amperage of the circuit. In a series circuit, amperage is constant everywhere in the circuit and the sum of the voltages of each fixture equals the voltage of the circuit.

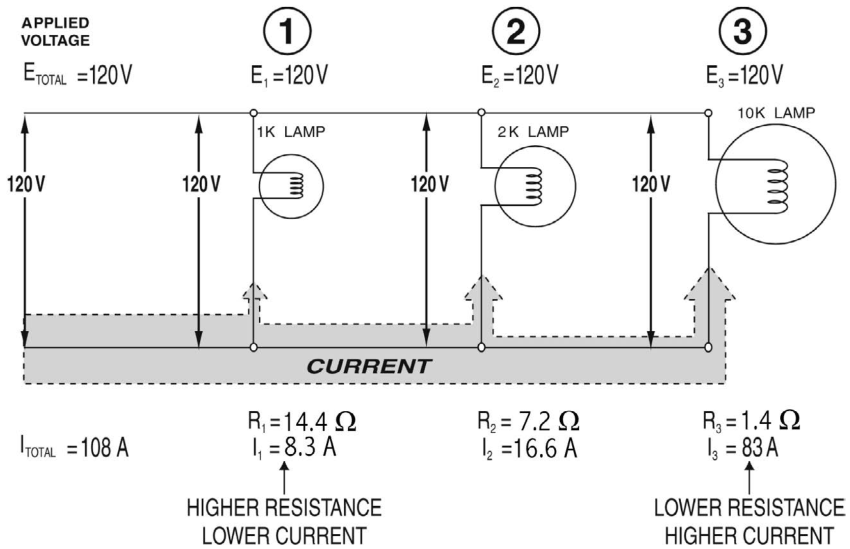


FIGURE 13.4

In a parallel circuit, the same voltage is applied to each load in the circuit. The current divides among paths in inverse proportion to the resistance present in each path.

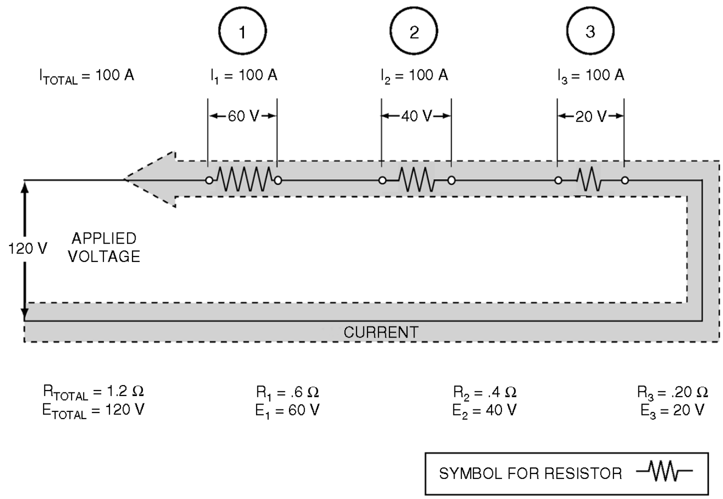


FIGURE 13.5

In a series circuit, the total current flows through every part of the circuit. The total voltage is divided among components in proportion to their resistance.

back to the power source. The *amperage* is therefore the same throughout the circuit; it is the total current (I_T). As you can see, in a series circuit, if there is a break in the circuit at any point, if one of the filaments blows, for example, the entire circuit is interrupted and none of the lights receive power.

In a series circuit, the voltage divides among the components. The sum of the voltages across each component ($V_1 + V_2 + V_3$, etc.) equals the total voltage of the circuit (V_T). The voltage across each component depends on the resistance of that component.

In a series circuit, the total resistance of the circuit (R_T) equals the sum of the resistances of the separate components ($R_1 + R_2 + R_3$, etc.).

It is important to remember that in a series circuit, the total current of the circuit runs through every component. You cannot calculate the current of a single component knowing the wattage and voltage of that component as you can with a parallel circuit, unless the loads are all identical. The current running through each component depends on what other components are connected in the series circuit. Therefore, to calculate the current for any component you must first calculate the total current (I_T). To find the total current, add the resistances of all the components. Then divide the circuit voltage (E_T) by the total resistance, R_T (using Ohm's law to find I_T):

$$\frac{E_T}{R_T} = I_T$$

If all the components in a series circuit have *exactly the same resistance*, then you can simply calculate the current of any individual component ($I_1 = P_1/E_1$) and the result will be the same as calculating I_T.

To help show how voltage and current behave differently in a series circuit than in a parallel circuit, let's look at a simple example of series connected components: a battery pack. A 120 V battery pack consists of ten 12 V batteries connected in series: negative to positive, end to end (Figure 13.6). When connected in series, the total voltage of the pack is equal to the sum of the voltages of the individual batteries. If just two batteries were connected in series, the voltage would be 24 V (12 V + 12 V = 24 V). If five 12 V batteries were connected in series, the total voltage would be 60 V (12 V + 12 V + 12 V + 12 V + 12 V = 60 V). To get 120 V, therefore, you need ten 12 V batteries in series.

If the ten series-connected batteries were connected to a 120 V lamp, you would complete a series circuit. As you know, the total current flows through every component (each of the batteries, and the 120 V lamp), because the series circuit provides only one path through the entire chain of batteries and the lamp. The current is therefore the same measured across any component in the circuit.

In contrast, if any number of 12 V batteries were connected in parallel, the voltage would always remain 12 V. Increasing the number of batteries in parallel would increase the *current* available, or, to put it another way, the load current would divide among the batteries.

To put it simply: voltage is the same across each component of a parallel circuit; current is the same across each component of a series circuit. Current divides among the multiple paths provided by a parallel circuit (in inverse proportion to the resistance in each path); voltage divides among multiple components connected in series (in proportion to the resistance across each component).

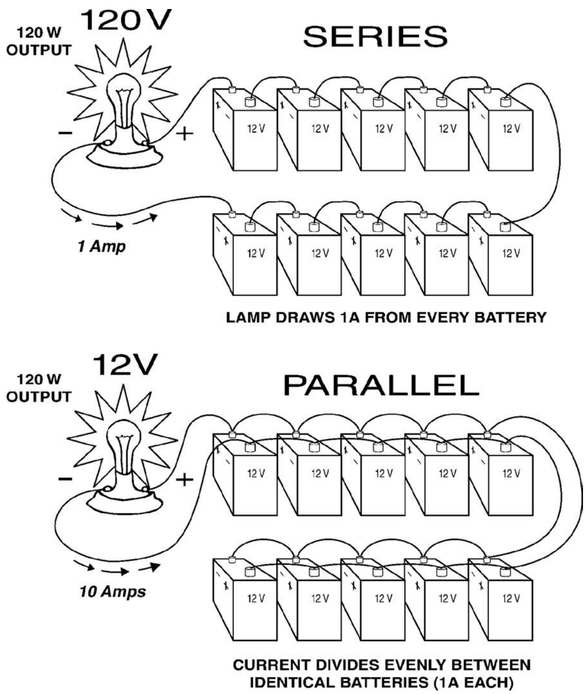


FIGURE 13.6

In the series circuit (top), the voltage across all ten batteries adds up to the total voltage of 120 V. If the lightbulb is a theoretical 120 W, 120 V bulb, the total current (1 A) travels through every part of the circuit. In a parallel circuit (bottom), the voltage is the same (12 V) at every point in the circuit—no matter how many batteries are used. The theoretical 120 W, 12 V lightbulb pulls 10 A, which divides among the 10 batteries (1 A each). Both lightbulbs have the same light output.

HOW NOT TO USE ELECTRICAL FORMULAS

One has to be careful to apply Ohm's law and the power formula correctly. For example, consider what happens when you dim a 1000 W lamp using a variac (variable transformer). As the voltage is reduced from 100 percent to 50 percent, what happens to the current? If watts divided by volts always equals amps, then when the voltage goes to half, you might conclude that the amperage must double:

$$\frac{1000\text{ watts}}{120\text{ volts}} = 8.3\text{ amps}$$

So,

$$\frac{1000\text{ watts}}{60\text{ volts}} = 16.7\text{ amps}$$

However, this is not consistent with our experience. As you dim the light, it should not draw more current. The mistake we made was assuming that wattage is a constant. When you dim the light, wattage decreases. Despite the number that is stamped on the bulb, the output changes. The constant is the lamp's resistance.

$$I = \frac{E}{R}$$

For a 1000 W lamp, R = 14 ohms, so

$$I = \frac{60\text{ V}}{14\,\Omega} \quad \text{or} \quad 4.3\text{ A}$$

At 60 V, the 1k draws 4.3 A—and because watts = volts × amps,

$$60\text{ V} \times 4.3\text{ A} = 258\text{ W}$$

That result is consistent with our experience.

To give a contrasting example, consider what would happen if you were to use a variac to power a 12 V, 100 W lamp. If you did not have a 12 V power supply, you could use the variac dimmer and dial it down to 12 V. If you have 10 such lamps you would have 1000 W load. But could you use a 1000 W variac dimmer and hook them up with #12 wire? How would we figure the amperage? You might think that you calculate the amperage as follows:

$$\frac{1000\text{ W}}{120\text{ V}} = 8.3\text{ A}$$

But this would be a pretty disastrous mistake; you'd blow the fuse in the variac. When you use the variac as a transformer set to 12 V, the 12 V lamps operate at full intensity. The total wattage really is 1000 W, but the total circuit voltage is only 12 V, not 120 V. If you'd turned on all 10 of those little lamps:

$$\frac{1000\text{ watts}}{12\text{ volts}} = 83\text{ amps}$$

You would have been pulling 83 A. That's like hooking up a 10k to a 1k variac. Each of those 12 V lamps is drawing 8.3 A.

There is a way to connect all ten 12 V lamps to a 1k variac without any problem—put them in series. The voltage in a series circuit divides among the components of the circuit in proportion to the resistance of each component. In this case, all the bulbs have the same resistance, so the circuit voltage (120 V) would have divided evenly—12 V per light.

$$12 + 12 + 12 + 12 + 12 + 12 + 12 + 12 + 12 + 12 = 120\text{ V}$$

Remember, current is the same every place in a series circuit, and it is equal to the total wattage divided by total voltage:

$$\frac{1000\,\text{W}}{120\,\text{V}} = 8.3\,\text{A}$$

The moral of this story is to be sure that you have properly identified which quantities are fixed and which depend on other variables. Understand what is going on in the circuit (drawing it helps) before choosing the equation to apply.

AC VS. DC

A *direct current* power source, such as a battery, has a positive terminal and a negative terminal. Electrons flow from the negative terminal through the circuit to the positive terminal. The *polarity* (direction of flow) never changes, and the voltage remains at a constant value. Up until the 1980s, motion picture studios were powered with 240/120 DC systems to power DC arc lights. Tungsten lights run just as brightly on DC as they do on AC, so DC was universally used.

Today, the studio's DC power plants are no longer in service; however, DC is seeing a big resurgence because so many of the power-efficient LED lights can run on low-voltage battery power (various voltages, 6–48 V). Ever-improving battery technology has enabled run times measured in hours rather than minutes in many cases. There is a lot more to know about the safe use of batteries and how to avoid shortening their service life by improper use, which we'll get to in Chapter 18.

Alternating current is supplied by a portable generator or by the power company through a transformer. The amplitude and direction of current flow changes continuously following a sine wave (Figure 13.7). In the first half-cycle, voltage increases in the positive direction, peaks at 170 volts, then heads back toward zero. In the second half-cycle, voltage passes through zero, reversing polarity, and increases in the negative direction, peaks at negative 170 volts, and returns to zero. The polarity changes 120 times/second, completing 60 cycles per second, denoted as 60 Hertz (Hz).

Because the cycles occur rapidly, and because the glow of the filament of moderately large incandescent lamps decays in brightness very slowly, there is no time for the filament of a bulb to dim perceptibly during the short time when the voltage passes zero.

The *effective voltage* (the DC voltage that would produce the same amount of power) is the root mean squared (RMS) of the sine wave, which is calculated as follows:

$$\textit{Effective voltage}\left(\textit{RMS}\right) = \frac{\sqrt{2}}{2} \times \text{peak voltage}$$

$$\text{so } 0.707 \times 170 = 120\,\text{V}$$

A voltmeter gives the RMS voltage.

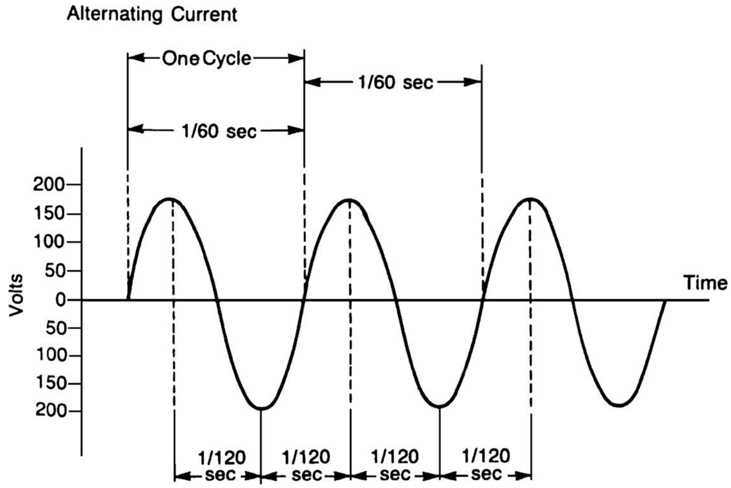


FIGURE 13.7

A 60 Hz alternating current makes one full cycle in 1/60th of a second and hits peak voltage every 1/120th of a second. The effective, or RMS, voltage is 120 V.

POWER SYSTEMS

A power system originates in the coils of a transformer or generator, where voltage is induced in the wires by the movement of a magnetic field through the coil. Without getting into a complete description of transformers, we need to define the terms primary and secondary. The *primary* coils of a transformer receive the input voltage from the power utility. With each oscillation of the 60 Hz sine wave, an electromagnetic field expands and contracts outward from the primary and moves through the *secondary* coil. This field movement induces voltage in the secondary, which powers the downstream system. Schematics of power circuits therefore show coils, which should be understood to represent either the secondary coils of a transformer or the coils of a generator alternator.

If a system has just one coil, one end of the coil is grounded and becomes the *neutral* (sometimes called the *common*, *return* or *grounded* lead[5]). The other end of the coil is a *phase lead*, which provides the potential difference (voltage) to the circuit.

In motion picture production, as in the home, it is convenient to be able to power devices at various voltages. To provide multiple voltages transformers and generators have multiple coils that can be tapped and arranged in various ways to provide two or three phase conductors.

There are three AC power systems that are used in motion picture/television production in North America:

[5] The NEC's official term is *grounded lead*, not neutral. As *neutral* is the more familiar term to most lighting technicians, I use it throughout this text. Officially, however, this is considered incorrect usage; the common wire is not actually "neutral" unless the phase wires are equally loaded. I do not use the term *grounded lead* because it is too easily confused with *grounding wires*.

- 240/120 V single-phase
- 208/120 V three-phase
- 480/277 V three-phase

In the United Kingdom, Western Europe, and Australia 50 Hz systems are used (415/240 V or 400/230 V AC).

240/120 single-phase, three-wire plus ground system

A 240/120 V system consists of two 120 V phase conductors, a common, neutral conductor, and a grounding wire. The neutral wire is color coded white. The grounding wire is coded green. The two-phase conductors are usually coded blue and red (they may be other colors, but never white or green). A load connected to one phase and to the neutral receives 120 V. A load connected between the two phases receives 240 V (Figure 13.8). Figure 13.9 illustrates how this works. It shows the 120 V RMS sine waves of the phase circuits A and B and a third 240 V sine wave that is the difference between wave A and wave B.

A voltage reading between a phase wire and the neutral is referred to as a *phase-to-neutral* reading. A voltage reading between two phase wires is referred to as a *phase-to-phase* reading.

You might wonder whether using the neutral wire to serve two circuits doubles the load on the neutral wire. Would the neutral wire have to be larger to carry twice the amperage? The answer is that the load is not doubled; in fact, one phase cancels the other out.[6] You'll notice in Figure 13.9 that the current flowing through one phase lead always flows in the direction opposite that of the current in the other phase lead. Therefore, when the loads are the same on both legs, the current on the neutral wire is effectively zero. When the load on one phase is greater than that on the other, the neutral wire carries the *difference* in amperage of the two phase conductors.

For example, assume that the red leg and the blue leg are carrying 50 A each. The loads are even, so no current travels on the neutral wire. The opposite-facing voltages cancel each other out. If we remove 10 A from the red phase and put it on the blue phase, making the red load 40 A and the blue load 60 A, the neutral wire carries the difference of 20 A.

Note that this type of power system has four wires and is properly referred to as a *three-wire circuit plus ground*. However, when we order cable, we refer to our cable as *four-wire banded* (single phase) or *five-wire banded* (three phase). The phase wires and the neutral are "current-carrying wires," the fourth (or fifth) wire is a green-coded equipment grounding wire.

Note also that electrical systems are referred to as either *240/120 V* or *208/120 V*. It is not proper to refer to the US system as *220/110 V*. This is misleading and can cause confusion.

Cautions

There are a couple of disastrous mistakes to avoid when cabling. You must be careful not to connect the wires incorrectly. We use a color-coded system for single-conductor distribution cable to prevent connecting the wires incorrectly. If the neutral and one phase wire were reversed, the lights on one circuit receive 240 V, which blows out 120 V lamps as soon as you try to turn them on. This is why it is standard practice to color code all single-conductor cables and to check the voltage with a voltmeter as soon as the system is powered up, before beginning general use of the system.

[6] This assumes purely resistive loads such as incandescent lights. Non-linear loads do not completely cancel. See Chapter 17.

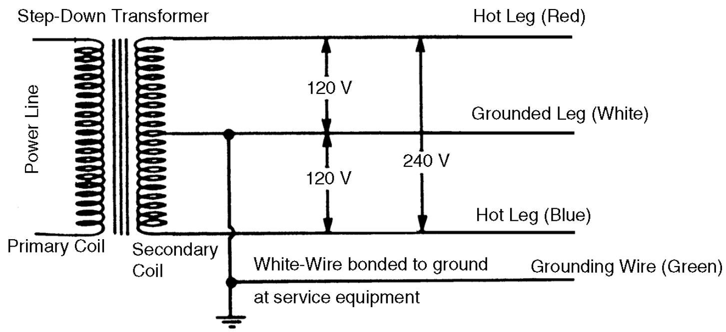


FIGURE 13.8

The three-wire 240/120 V AC configuration common in all types of buildings. The coils represent the primary and secondary coils of the transformer that steps down the voltage from the power lines. The neutral (white) wire taps into the midpoint of the secondary coil and is a grounded wire. The voltage potential is 240 V between red and blue and 120 V between white and red or between white and blue.

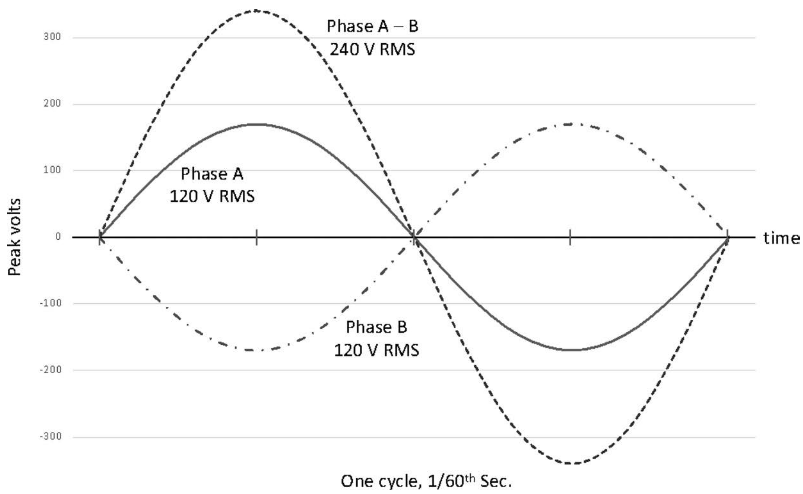


FIGURE 13.9

Sine waves of the three circuits available from a 240/120 V single-phase system. Phase A–B is the difference in potential between phases A and B, the phase-to-phase voltage.

Second, be sure that the neutral wire is never inadvertently disconnected. If the neutral wire is taken out of the circuit, the total load on the red phase is now connected in series with the total load of the blue phase. The applied voltage is 240 V (Figure 13.10). The leg with the smaller resistance will receive the larger portion of the voltage. The voltage on one leg drops, while the other leg shoots up and immediately starts to blow out bulbs on that side of the circuit. A similarly dangerous situation can occur if a damaged neutral cable poses much higher resistance than it should. This is why rigging gaffers test the resistance/continuity of the ground and neutral before connecting the phase conductions to the power source (see Chapters 16 and 17). It is important to be able to recognize the symptoms of an open or high-resistance neutral.

Consider a simple example of a three-wire system with a 5k fixture on the red phase and a 2k fixture on the blue phase (Figure 13.11). With the neutral connected, each light receives 120 V. The 5k pulls 41.67 A and has a resistance of 2.88 Ω. The 2k pulls 16.67 A and has a resistance of 7.2 Ω. If the neutral wire were disconnected, the two lights would become connected in series in a 240 V circuit. As we said earlier, the amperage in a series circuit is the same in every part of the circuit, and the total resistance of the circuit equals the sum of the resistances of all the lights.

We can calculate the amperage for the circuit as follows:

$$I(\text{total amperage}) = \frac{E(\text{total voltage of circuit})}{R(\text{sum of the resistances})}$$

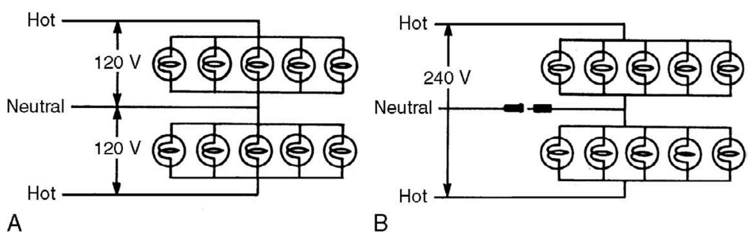


FIGURE 13.10

(A) A typical three-wire 240/120 V system with five lamps connected to each leg. The red and blue legs are separate circuits sharing the common neutral lead. (B) When the white wire is pulled, the red and blue legs become connected in series with 240 V total voltage.

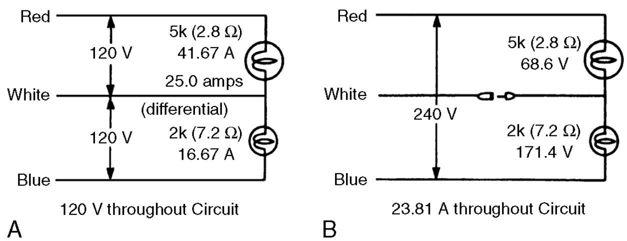


FIGURE 13.11

(A) A three-wire system with a 5k on one leg and a 2k on the other. (B) With the neutral wire disconnected, the two legs are connected in series with 240 V applied to the circuit. The 2k is blown by the 171 V overvoltage. Note that when there are multiple lights on each side of the circuit, a domino effect occurs. As each lamp blows, the imbalance in resistance increases, causing more lamps to blow in quick succession.

$$I = \frac{240\,\text{V}}{2.88\Omega + 7.2\Omega} = 23.81\,\text{A}$$

Knowing the amperage of the whole circuit (23.81 A), we can now calculate the voltage ($E = I \times R$) being applied to each light:

$$\text{Voltage of the } 2\text{k}: 23.81\text{A} \times 7.2\Omega = 171.4\,\text{V}$$

$$\text{Voltage of the } 5\text{k}: 23.81\text{A} \times 2.88\Omega = 68.6\,\text{V}$$

From this, we can see that the fixture with the greater resistance, the 2k, receives a higher voltage, which blows the lamp. Note that the sum of the voltages of the lights is equal to the voltage of the whole circuit (68.6 V + 171.4 V = 240 V).

A little (true) story will help illustrate. A best boy had completed prerigging the cable to a set. The power was brought online, and all the power indicator lights on the distribution boxes lit up. The voltage measured 120 V on each leg, as normal. But when he flipped the switch on the first light, a 10k, nothing happened. He measured the voltage again, with the 10k still turned on, and lo and behold, the voltage now showed zero volts on the leg to which the 10k was connected, and 240 V on the other leg. The best boy was puzzled for a moment until he thought about the strange swing in voltage and realized that this must be due to an open neutral connection. He immediately walked the cable line back to the generator and sure enough, found that a connector had pulled loose on the neutral conductor.

With no load on the system except the indicator lights of the distribution boxes, the voltage readings all appeared normal because the load was balanced. When the neutral became disconnected the red and blue sides of the system became connected in series, so when the10k was switched on, the only current that reached it was the tiny amount that was passed through the high resistance of the indicator lights. Seconds after reconnecting the neutral, the first unit crew arrived on set and started turning on all the lights. The best boy realized how lucky he was to have tried only one light. If all the lights had been energized with the neutral wire disconnected, lamps would have been blowing everywhere.

208/120 three-phase, four-wire plus ground system

Most commercial buildings, soundstages, and location generators provide 208/120 V three-phase power. It is the most widely used power system in the Americas.

Figure 13.12 shows a wye-connected three-phase system. The system is called a *wye* or *star* because of the shape of the coils in the schematic diagram. Note that a three-phase, four-wire system actually uses five wires. The fifth is a green-coded grounding wire (not shown in Figure 13.12). You will sometimes see the word phase abbreviated with the Greek letter phi (ϕ). 3ϕ means three phase.

This three-phase, four-wire plus ground system consists of three 120 V phase leads (phases A, B, and C, color coded black, blue, and red) and a neutral lead (white). Each of the three phases operates at 60 cycles/s. Each phase, however, operates one-third of a cycle out of phase with the next. If you think of one cycle as a 360° circle, each phase begins the cycle 120° after the last. Figure 13.13 compares the generator windings and sine wave of a single-phase generator with that of a three-phase generator.

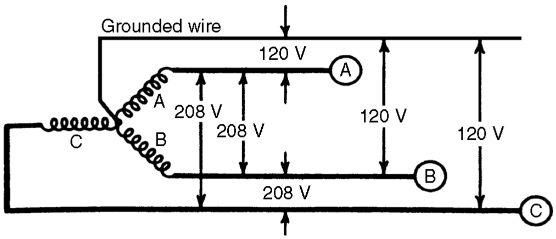


FIGURE 13.12

A 208Y/120 V three-phase system. The three coils shown represent the secondary coils of the transformers that step down the voltage from the power line. A 208/120 V system can supply 120 V single-phase loads, 208 V single-phase loads, and 208 V three-phase loads. Note: the transformer windings are not placed in this geometry (they just sit side by side), but the geometry helps illustrate the relationship of the phases and the neutral.

(*From H. Richter and W. Schwan,* Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill*)

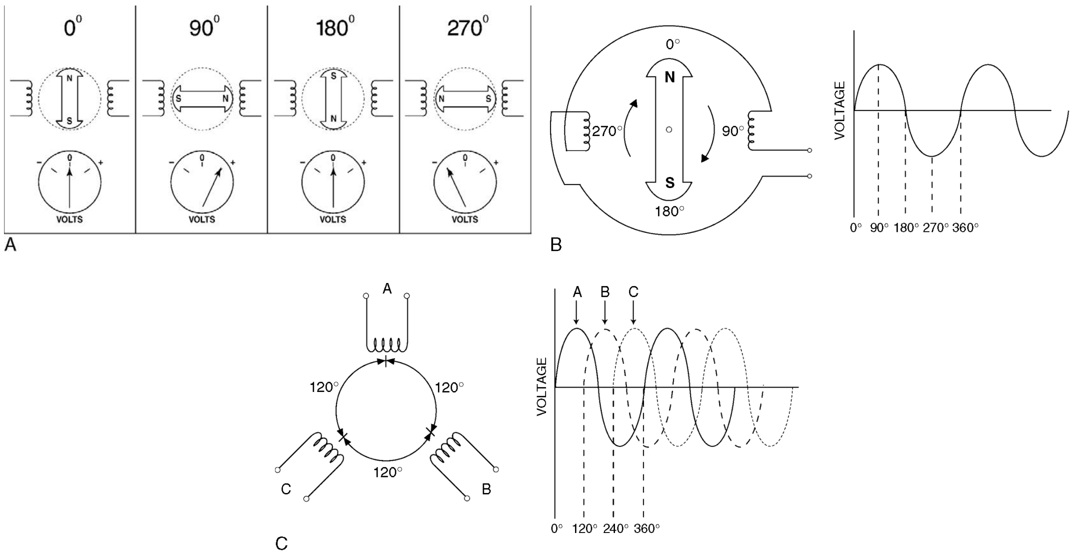


FIGURE 13.13

When a wire moves through a magnetic field, current is induced in the wire (a voltage potential is produced that pushes the current when connected to a complete circuit). (A) This simplified diagram shows how this is used to produce electricity in an alternator. As the rotor (magnetic field) rotates past the armature windings, voltage increases to a maximum; current moves first in one direction (at 90°), then in the opposite direction (at 270°). As the rotor passes 0° and 180°, the voltage passes 0 and the current changes direction. (B) The result is a continuous sinusoidal waveform as the armature rotates. (C) A three-phase alternator has three sets of armature windings (A, B, and C), each spaced 120° from the last. This produces three separate sine waves, 120° out of phase, commonly referred to as the three phases. For simplicity and clarity, all the windings for each phase are represented here by a single winding and the rotor is not shown.

Because the phases are 120° out of phase, the difference in potential phase-to-phase is 208 V. Figure 13.14 shows the 120 V sine waves for phases A and B and the 208 V sine wave when the voltage is measured between phases A and B. You can see that a 208-volt device, connected phase-to-phase, experiences a 60 Hz sine wave at 208 volts (it does not experience multiple sine waves). A 208 V electronic ballast, for example, is a *single-phase load*.

It is easy to get confused by what is meant by single- and three-phase. Single- and three-phase does not refer to the number of phase conductors. With regards to the system, it refers to the number of out-of-phase sine waves present in the system. With regard to the load, it refers to the number of out-of-phase sine waves used by a load. Almost all lighting loads are single-phase loads (including 208 V loads). Only loads that use all three phases and rely on the 120° difference between phases are truly three-phase loads. Large AC motors, for example, use the rotation of the phases to drive the rotation of the shaft. For most lighting loads, we use a three-phase system as if it were three single-phase systems.

As with the single-phase system, if all three phases are evenly loaded, the neutral wire carries no current (assuming purely resistive loads). When the phase legs are not evenly loaded, the neutral carries the difference of the phases. The three-way difference is not as straightforward to calculate as with a single-phase system; it involves vector geometry (because of the 120° phase difference between the legs). To calculate the neutral current (I_N), plug the phase currents A, B, and C into the following equation:

$$I_N = \sqrt{A^2 + B^2 + C^2 - AB - AC - BC}$$

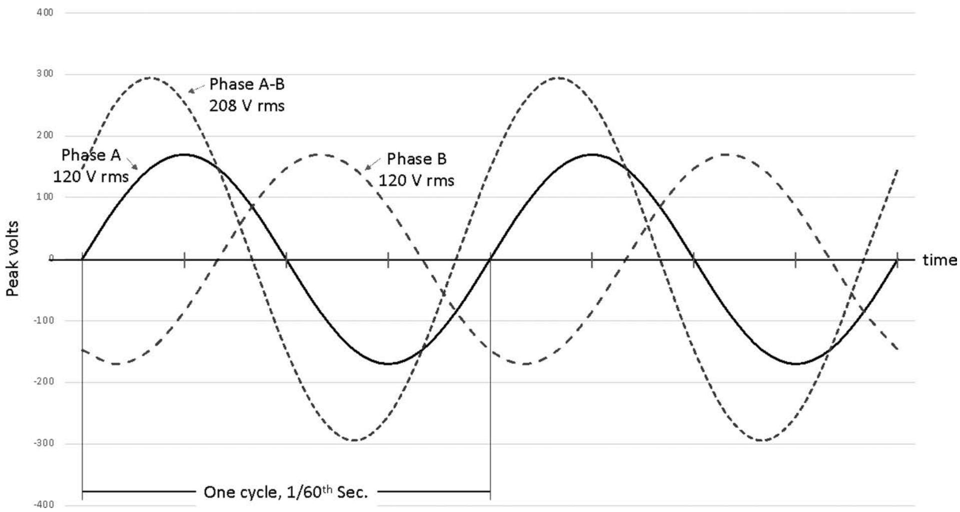


FIGURE 13.14

Phases A and B (120 V RMS) and the 208 V RMS phase-to-phase sine wave (A–B). Note that the 208 V sine wave crosses through zero when A and B are the same, and the 208 V sine wave hits a maximum when the difference between A and B is the greatest.

Where I_N is the current on the neutral, A is the load on phase A, B is the load on phase B, and C is the load on phase C.

If you want nothing to do with the equation above, there is a simpler rule of thumb. The neutral current is roughly the difference between of the lowest phase current and the highest one. For example:

Phase A	300 A
Phase B	250 A
Phase C	225 A

The neutral current will be no more than:

$$I_N = 300 - 225 = 75 \text{ A}$$

The actual current in this example would be 66 A, so the rule of thumb overestimates (by 9 amps in this case) but is close. It becomes more accurate the closer any two legs are to being evenly loaded. There are five types of circuits that can be derived from a wye-connected, four-wire plus ground, three-phase system (Figure 13.15).

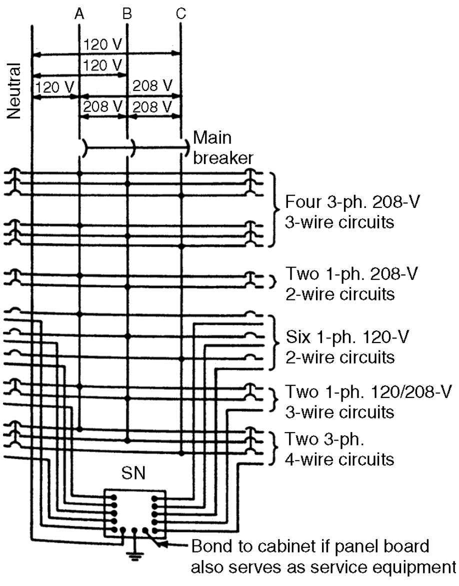


FIGURE 13.15

Five types of circuits can be derived from a 208Y/120 V (four-wire, three-phase) system.

(*From H. Richter and W. Schwan,* Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill*)

120 V, two-wire circuit plus ground, single-phase. Three separate circuits can be made by tapping any one of the phase leads (A, B or C) and the neutral lead. When loading the three phases, it is important to keep them evenly balanced.

208 V, two-wire circuit plus ground, single-phase. This circuit is made by tapping any two of the phase leads. As much as possible, keep the load evenly balanced among the phases by loading A–B, B–C, and C–A evenly.

208/120 V, three-wire circuit plus ground, single-phase. By tapping two of the phase leads and the neutral lead, you have the option of providing 120 or 208 V power. Doing this, you can use distribution boxes made for three-wire systems. Be sure to label each box (red/blue, blue/black, or black/red) so you remember what is plugged into what. Keep the load evenly balanced by tapping evenly.

208 V, three-wire circuit plus ground, three-phase. This type of circuit uses all three phase leads and no neutral. Some chain motors and xenon ballasts require 3-phase, 208 V power. Large machinery, air-conditioning units, and three-phase motors also use three-phase power. This circuit does not provide a neutral, and therefore cannot provide 120 V service. (It is unsafe and prohibited by the NEC to use a ground wire tapped from another circuit to get 120 V single-phase circuits from the legs of a three-wire, three-phase system.)

208Y/120 V, four-wire circuit plus ground, three-phase. Branch circuits with this configuration provide all the possibilities described above.

Single-phase derived from delta-connected, three-phase system

A 240 V, three-phase, delta-connected system gets its name from the circuit's resemblance to the Greek letter delta (Δ). The phase-to-phase voltage is 240 V (Figure 13.16). To supply 120/240 V service, one coil is tapped in the center. The tap is grounded and becomes the neutral lead for a three-wire, single-phase 120/240 V circuit. This is typically how a single-phase, three-wire system (covered earlier) is sometimes derived from a delta-connected transformer. Single-phase 120 V power can be gained by connecting to A–N or B–N. The "high leg" C–N is 208 volts and is not used. Note, however, that when a generator produces 240/120 V single-phase service, it uses a zig-zag circuit, shown in Chapter 18.

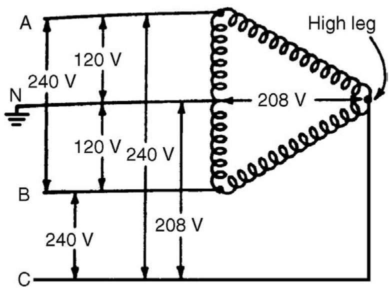


FIGURE 13.16

A 240 V, three-phase, delta-connected system with single-phase 240/120 V derived by tapping one coil in the center.

(*From H. Richter and W. Schwan,* Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill*)

480/277 V three-phase system

Most large generators are capable of providing 480Y/277 V power (selectable by a switch inside the generator). This service can also originate from a service panel on location (stepped down from utility pole via a transformer on site). A 480 V system is used in set lighting for two applications. It is used to power the biggest sizes of Luminys SoftSun units (50,000 W and larger), and it is used to power a step-down transformer. Also, 480-volt power is commonly used for large air-conditioning units and for gimbles, special effects fans, some stunt equipment, and large xenon projectors. Step-down transformers are discussed in Chapter 18.

ELECTRICAL SAFETY SYSTEMS

The essential parts of a safe electrical circuit between the power source and the load are shown in Figure 13.17:

- Control device (such as a switch or dimmer)
- Overcurrent protection (a fuse or circuit breaker)
- Current carrying conductor cables (appropriate to handle the current)
- Equipment grounding conductor

Control devices and polarity

A circuit should not be considered complete without a control device. The control device is used to open and close the circuit. A *closed* circuit forms a complete circle back to the power source. In an *open* circuit, the circle is interrupted by an open switch or lost connection. Plugging or unplugging a cable is not a good way to close and open a circuit, except if necessary in an emergency.

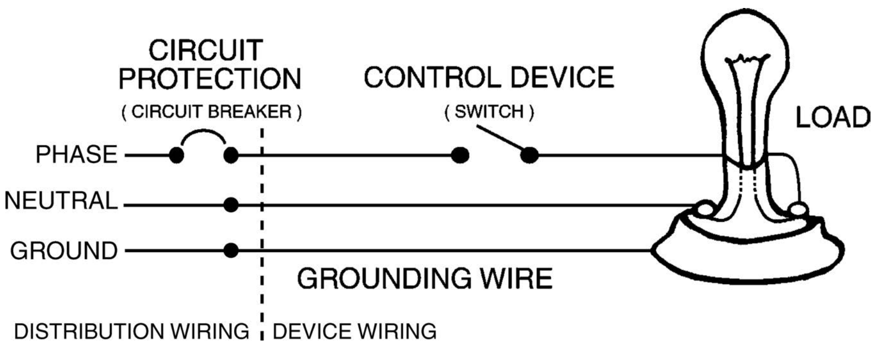


FIGURE 13.17

The components of a safe circuit: circuit protection, control device, appropriate conductors, and grounding wire.

Power switches are either single-pole or double-pole switches. A single-pole switch opens the circuit by interrupting the phase wire. A double-pole switch interrupts both wires (phase and neutral, or two phase wires in the case of 208 or 240 V loads). Most small lights up to 1k use a single-pole switch. Those 2k and higher use double-pole switches. With the smaller lights, it is critical that the connector provide proper polarity so that the phase wire is interrupted by the switch, not the neutral. If the polarity is reversed, then an invisible hazard exists. In the event of a short in the fixture, the housing of the fixture could be energized, even though the light is switched off!

This is the reason that all multipole connectors are polarized and grounded with the ground conductor making contact first when the connector is plugged. If you look at the design of the household Edison plug, for example, the conductors are polarized (cannot be reversed), because one blade of the plug is wider than the other. The ground conductor mates first because it is longer than the flat blades of the hot and neutral conductors. A properly installed multipole connector makes it impossible to reverse the phase or to energize a load without a ground. The same principle applies to the design of Stage Pin connectors (Bates), twist-lock connectors, and all other authorized multipin connectors.

Overcurrent protection

An overcurrent device, a circuit breaker or fuse, interrupts the circuit if it senses either a short circuit or an overload. A *short circuit* occurs if one of the phase wires comes in contact with neutral or ground or another phase wire, allowing current to flow directly across the power source from the outgoing wire to another wire with only the resistance of the wires themselves to oppose the current. A short might be caused by damaged cable insulation, a crushed connector, a loose connection inside a light, or a foreign metal object coming in contact with both terminals somewhere in the circuit.

An *overload* occurs when too large a load is placed on a circuit. If the total load exceeds the rating of the circuit breaker, it trips.

The purpose of overcurrent protection is to prevent overheating which can damage cables and circuit parts and create a serious safety hazard. From Ohm's law ($R = E/I$), you can see that the lower the resistance, the more amperage is allowed to flow. A dead short creates a situation where there is *no* resistance. Without overcurrent protection, the uninhibited current flow would rapidly increase to the maximum available from the power source, which may be thousands of amps—far beyond the amperage capacity of the cables. Wires heat up, burn, and melt, which poses a potential fire hazard, as well as a burn hazard and shock hazard. If the amperage is high enough, it can vaporize the cables. For this reason, every circuit is protected by an overcurrent protection device, a fuse or circuit breaker.

An overcurrent device cuts off power to the circuit if the current exceeds its rating. The amperage capacity of cables downstream of the overcurrent device is normally matched to the rating of the overcurrent device so that the overcurrent protection prevents overloaded conductors.

A power distribution system employs a tiered system of circuit protection—large-capacity over-current protection for the feeder cables (typically 800 A, 400 A, or 200 A at the power source), lower-capacity overcurrent protection for the larger branch circuits (100 A per circuit at the power distribution centers), and smaller-capacity overcurrent protection for smaller loads (such as 20 A per circuit for Edison boxes). Distribution equipment is covered in Chapter 14.

Why all these levels of circuit protection? The reason for the tiered system is twofold. First, it would be undesirable to use only one large-capacity circuit breaker to protect a whole system for practical reasons. If a short happened in one light, the whole set would go dark. However, there is a second reason that is important for safety. Every conductor downstream of the overcurrent protection has impedance. A long length of small wire that is protected at a relatively high overcurrent threshold can create enough impedance that the overcurrent protection will not trip. Meanwhile the wire will overheat causing a hazard.

Circuit breakers and fuses are not designed to protect people from shock. Remember, the smallest circuit breaker rating we commonly use is 20 A, but it takes less than one amp to cause serious internal injury and stop your heart. When a shock hazard may exist, such as in wet locations, ground fault circuit interrupters (GFCIs) must be used to protect against shock hazard from leakage current or equipment faults. GFCI equipment is covered in detail in Chapter 19.

The current-carrying capacity of cable

There are a number of factors that affect the amperage capacity of cables. An amperage capacity or *ampacity* is assigned to each type of cable in the NEC based on the wire gauge, type of insulation, and temperature rating of the insulation. This rating is adjusted for the ambient temperature, the number of conductors in the cable, the length of time it is under load continuously, and the maximum temperature rating of the overcurrent protection to which it is connected. Let's begin with wire gauge.

Wire gauge

Wire sizes are numbered using the American Wire Gauge (AWG) sizes shown in Figure 13.18. For wire sizes from 18 to 1 AWG, the smaller the number, the bigger the wire. Cables larger than 1 AWG are numbered 0, 00, 000, and 0000 (pronounced "one-ought," "two-ought," "three-ought," and "four-ought"). These sizes are usually written 1/0, 2/0, 3/0, and 4/0. 4/0 is the largest size cable commonly used for portable power distribution.

Multiconductor cable is labeled with the gauge and the number of conductors, denoted (for example) as 12/3, where 12 is the gauge of the cable, and 3 is the number of conductors. Tables D.1 and D.2 list the ampacity of various sizes and temperature ratings of cable. The maximum amperage capacity for entertainment feeder cable sizes are summarized in the following table. This is the absolute maximum; under typical circumstances, the cable capacity must be derated from these figures, as we shall discuss shortly.

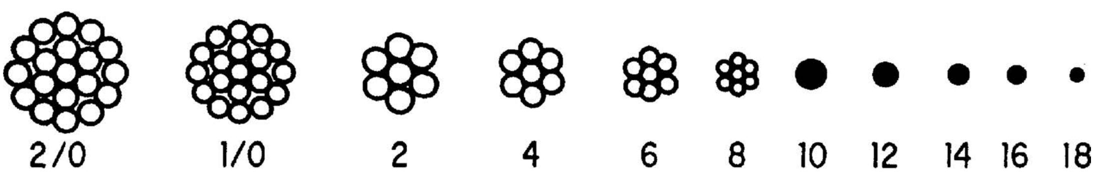


FIGURE 13.18

Diameters of common sizes of copper wires without insulation.

(*From H. Richter and W. Schwan,* Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill*)

Maximum operating temperature

Cable manufacturers test each type of cable insulation and assign it a maximum temperature rating, which is tested and confirmed by nationally recognized testing agencies like UL. The more current runs through the cable, the warmer it becomes. The rating reflects the temperature that the wire can safely reach without damaging the insulation. When insulation becomes overheated, it may become brittle, crack apart, or melt. The temperature rating provides a margin of safety between the maximum operating temperature of the cable and its breakdown point.

Ampacity of feeder cable	**Temperature rating of cable**	
	75 °C	**90 °C**
4/0	360 A	405 A
2/0	265 A	300 A
#2 AWG	170 A	190 A

Note: The figures given here are from the 2020 National Electrical Code Table 400.5(B) for type SC, SCE, SCT, and W flexible cables operated at an ambient temperature of 86 °F, in free air, not placed in conduit or a raceway, where the conductors are not in contact with one another (except in sections not longer than 24 inches in order to pass through an enclosure), and where operated for less than 3 hours continuously.

Circuit breakers and fuses also have a maximum temperature rating. If a cable rated at 90 °C is connected to a fuse rated at only 75 °C, the cable must be derated to the temperature of the fuse. This is necessary because the higher rated cables transfer heat. To prevent heat transfer and work around this limitation, you can use a larger jumper cable between the fused panel and the first junction point. The jumper cable must be sized to carry the needed amperage at the lower temperature rating. The ampacity of a cable rated at 60 °C or 75 °C is substantially lower than that of cable rated at 90 °C. Be sure to assign the proper amperage to the cable you use.

Connectors also have a maximum amperage rating. Obviously, you must not run more power through a cable than the connector is rated for, regardless of the rating of the cable. Connectors tend to be the weakest part of the system. Bates and Edison connectors overheat and melt if they are overloaded or, more commonly, if there is poor electrical contact between mated connectors, or where the wires terminate inside the connector. If a bad contact is left too long, the connector makes a noxious smell as it starts to melt and is eventually destroyed. It could also start a fire or cause injury, so it is good practice to root out bad connectors and take them out of service. The amperage ratings of connectors are discussed further in Chapter 14.

Other factors that affect ampacity

Ampacity is not printed on cable, because outside factors influence the operating temperature of the cable and may lower its effective maximum amperage: the ambient temperature around a cable, the number of current-carrying conductors in the insulation jacket, and the spacing between single-conductor cables, whether the cables are in a raceway or conduit or standing in free air. The NEC specifies how much a cable must be derated in each of these circumstances (NEC article 400, Table 400.5(B)). NEC Table 310.16 provides the temperature correction factor for use when distribution cables are used at ambient temperatures above and below 86 °F. For example, when the ambient temperature is

114–122 °F, a cable with a temperature rating of 90 °C must be derated by a factor of 0.82. Keep this in mind when cabling. When cable runs are in well-ventilated areas, the room temperature is normal or cool, and the loads are used intermittently, no derating is necessary. Cables should never be tightly bundled or stacked one on another. If cables must be placed in narrow raceways, strung out across hot asphalt or otherwise subject to hotter than normal ambient temperatures, the cable should be derated further to protect the insulation from overheating. Keep this in mind when selecting cable gauge under such circumstances.

Continuous loads

A *continuous load* is defined by the code as a load that is expected to continue for 3 hours or more. Because electrical conductors heat up over time, when circuits are to be loaded continuously for more than 3 hours, Articles of the electrical code governing feeders (215) and branch circuits (210) both include requirements that the current carrying conductors be able to carry 100 percent of the non-continuous load *plus 125 percent of the continuous load*. This means the portion of the load that is running for greater than 3 hours must be calculated at 125 percent. There is an exception made if the assembly including the overcurrent protection is listed for operation at 100 percent of its rating, in which case the ampacity required is simply 100 percent of the total load. Some modern distro boxes do use 100 percent continuous-rated breakers. If it is not rated for continuous duty, a circuit protected by a 100 A breaker, for example, may not be loaded beyond 80 A continuously for more than 3 hours.

Types of feeder cable

Type W cable

Type W cable is a portable, extra-hard-usage power cable, manufactured to meet the requirements of NEC Article 400 (portable cords and cables) and is acceptable for temporary wiring according to Articles 520 (Theaters and Similar Locations) and 530 (Motion Picture and Television Studios and Similar Locations). It is very durable, flexible, and abrasion-resistant and usually double-insulated. It may be oil-, solvent-, and sunlight-resistant and flame-tested. Insulation can remain flexible in very low temperatures, which is handy in cold climates.

Entertainment Industry and Stage-Lighting Cable: EISL (types SC, SCE, and SCT)

EISL cable, commonly called *entertainment cable*, is a portable, extra-hard-usage cable with the same insulation characteristics as type W cable, but is 20 percent smaller and lighter than type W, and also slightly less durable. You often see 105 °C-rated entertainment cable used, but the 105 °C rating is not listed in the NEC's ampacity tables. You must use the next lower temperature rating (90 °C), and again, the temperature rating of the overcurrent protection may require the cable be derated further to the 75 °C rating.

The NEC prohibits the use of welding cable in motion picture distribution systems.

Decoding feeder cable labels

Lighting technicians learn to identify wire gauge by appearance. Occasionally, however, you have to check the gauge by reading it off the insulation. For example, 2/0 type W cable is almost as large as type SC 4/0 cable, because the insulation is so thick.

Single-conductor feeder cables are imprinted something like this "Royal Type SCE Entertainment Industry & Stage-Lighting Cable 2/0 AWG 90 °C 600 V (UL) NEC 520 & 530 Outdoor," which means:

- Royal is the manufacturer.
- Type SCE is the insulation type.
- Entertainment Industry & Stage-Lighting Cable is the trade name of the type of cable.
- 2/0 AWG is the size of the cable.
- 90 °C is the maximum operating temperature of the insulation.
- 600 V is the maximum voltage of the cable.
- UL indicates that the cable is listed with Underwriters Laboratories.
- NEC 520 and 530 indicate that the cable meets the requirements of NEC Articles 520 and 530, which apply to the entertainment industry.
- Outdoor indicates that the cable is approved for outdoor use.

Decoding multiconductor cable labels

Multiconductor cable, used for stingers and power cords, is marked as follows: "12/3 Type SJOW-A 90 °C P-123-MSHA—Type SJO 90 °C," which means:

- 12/3 indicates the gauge (12) and the number of conductors in the cable (3).
- Type SJOW-A is a code for the type of insulation: (S) type cord, (J) junior service, with an (O) oil- and (W) water-resistant jacket.
- 90 °C is the maximum operating temperature of the cable.
- P-123-MSHA indicates that the cable is approved by the Mine Safety and Health Administration (MSHA).
- Type SJO 90 °C is an alternative designation given to this particular cable.

Table 13.3 gives the meaning of some common insulation designations. *Junior service* cable such as SJO is rated as "hard usage" cable, which is permitted to be used only if it is not used in audience

Table 13.3 Insulation designations (for small cables)

S	Portable cord designed to withstand wear and tear, consisting of two or more stranded conductors with a serving of cotton between the copper and the insulation to prevent the fine strands from sticking to the insulation. Fillers are twisted together with the conductors to make a round assembly held together by a fabric overbraid. The outer jacket is of rubberlike thermosetting material.
SJ	Junior service. The same as S, but with a thinner jacket. Junior service cord may not be used in areas governed by NEC Section 520–53(h), 520–62(b) (live audience situations). It may be used in other situations, as long as it is not subject to abuse (continually stepped on or rolled over).
SV	Junior service. The same as S, but with an even thinner jacket.
SO	S cord with an oil-resistant neoprene jacket. Designated for extra-hard usage.
SOW	S cord with an oil- and water-resistant jacket.
SPT	Standard two-conductor "zip cord" or household lamp cord. Cord with thermoplastic insulation. Zip cord is not hard-usage or extra-hard-usage cable as required by the NEC for use by a film or TV production, except when it is part of a listed assembly.

areas, and areas where it might be subject to physical damage. In these cases, “extra hard usage” cables are required, such as SO cable.

EQUIPMENT GROUNDING

Don’t confuse or conflate equipment grounding and system ground. They are two entirely different things. Equipment grounding refers to the ground wire that is on nearly every electrical device. It is the U-shaped prong on an Edison plug. It is the green-coded wire in the distribution system. The equipment grounding wire does not carry current under normal circumstances. The equipment ground is a safety circuit that works in conjunction with the overcurrent protection to protect people against being shocked in the event that a malfunctioning piece of equipment develops a ground fault—a situation where a phase conductor makes contact with the casing of the fixture. The grounding wire provides a low-resistance path that completes the circuit from the grounded parts of a device, like a metal housing, back to the power source. It does this in order to trip the circuit breaker and remove power to the faulty equipment. If no grounding wire were connected (Figure 13.19A), anyone who touched the metal casing would complete a circuit to ground through his or her body and would receive a shock. The equipment grounding wire makes it so the circuit breaker sees a ground fault as a short circuit.

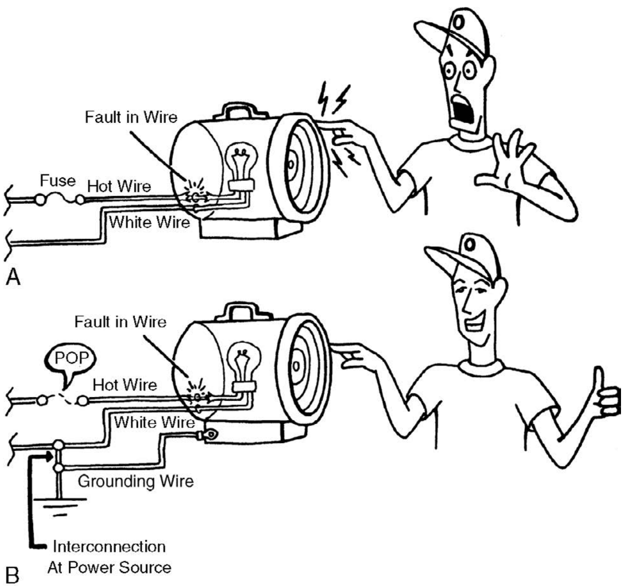


FIGURE 13.19

(A) A fault in a metal fixture energizes the entire housing. Anyone who touches the electrified fixture may complete a circuit to ground and get a shock. (B) The equipment grounding wire carries the fault current back to the service panel creating a short circuit that will trip the circuit breaker if the fault current exceeds the breaker rating.

However, it is important to understand the limits of this protection. If the ground fault contact is weak (high resistance), it may not permit enough current to flow to trip the breaker. It may just create a lot of heat. Or if the grounding wire is too small, not properly connected, or not present, the equipment ground cannot function as it should. The NEC provides a table indicating the minimum sizes for grounding wires (see Table D.3).

Another way to think of equipment grounding is the intentional connection of all exposed metal parts of the system together; this way all exposed metal parts are at the same potential. A person touching any two metal surfaces will not experience a difference in potential—they won't be shocked. Proper equipment grounding is essential to safety. It is one of the things that the fire safety officer and electrical inspector look for on the set.

SYSTEM GROUND

In a permanent installation, at the main panel where power enters the building, the grounding bus is grounded to earth. This is the *system ground*. The *grounding electrode conductor* runs from the panel and connects to a grounding electrode sunk in the earth. The grounding electrode may be a ground rod, sunken building steel, or a made electrode, which is a large electrode placed in the ground during the building's construction.

The system ground performs two functions: first and foremost, it provides a way for electricity from an external source, such as lightning or a downed power line, that comes into contact with an electrical system to be carried safely to earth. This helps protect the wires and devices connected to the system from damage. Second, the system ground stabilizes the relationship between the system and earth.

Generators

For a portable generator, the frame of the generator is bonded to the ground bus and, if approved by the local authority (AHJ[7]), may serve as the system ground in lieu of a bond to earth. A generator may be run as an isolated system without a grounding electrode or may be required to be grounded via a grounding electrode. Generators are discussed in more detail in Chapter 18.

Ground rods

The NEC is specific about what constitutes a safe ground rod. It is a copper rod, at least ½ inch in diameter, that is driven 8 feet into the ground. If this is not possible, under certain circumstances it may be driven diagonally. In any event, driving a ground rod is not as simple as pounding a rod a couple of feet into the ground with a sledgehammer. It typically requires construction machinery.

Before driving anything this far into the ground, it is required that the production determine the location of any underground utility services such as gas lines, electrical lines, communications

[7] The Authority Having Jurisdiction is the person or municipality with the responsibility for enforcing applicable codes, regulations, and federal, state, and local laws. Depending on where the work is taking place the Authority Having Jurisdiction (AHJ) may be the local city electrical inspector, or the fire marshal also known as a Film Safety Officer. The AHJ is the ultimate authority for what practices will be allowed on set.

cables, sewage and water pipes. The steps for using the national 811 phone service are provided at usanorth811.org. Advanced notification is required.

In Los Angeles and some other cities, the local authorities agree that regularly sinking ground rods at shooting locations presents a greater hazard than running the generator as an isolated system and the Occupational Safety and Health Administration (OSHA) also recommends this. It is preferable to avoid sinking ground rods where possible. It is preferable to avoid sinking more than one ground rod when using one is necessary.

Bonding power sources

When two or more independent power sources are used in proximity to one another, a bonding cable must be used to connect the grounds of the two systems. Without something to establish a relationship between the power sources, we do not know what potential may exist between them. If a person were to touch the casing of a piece of equipment grounded to one power source and at the same time touch the casing of another piece of equipment grounded to the other source, they might find a dangerous potential existing between them. A bonding conductor establishes a zero-potential relationship. Here again the bonding conductor does not carry any appreciable current, but once the grounds are bonded, all the equipment used on both power sources will have the same zero-potential to ground and to each other.

In the case of two generators, the bonding wire simply connects from one generator's ground buss to the other's. In the case of bonding a generator to a building's ground, the bond must be made to the building's grounding electrode conductor. If the grounding electrode conductor is exposed, the connection can be made easily without requiring special qualifications. If there is an uninsulated copper wire that exits the main panel and goes into the ground, that is the ground electrode conductor. Sometimes access to the conductor can only be gained by removing a panel cover or entering a restricted electrical room. In such cases, the bond must be made by a qualified person such as an electrical worker using appropriate protections and procedures.

Bonding is not necessary if the two systems do not operate in close proximity to one another. Industry safety bulletins[8] interpret this to mean that no piece of equipment connected to one power source is within 20 ft. of any piece of equipment connected to the second power source. Twenty feet is the length of the largest piece of metal generally carried by a film crew (a 20 × 20 aluminum frame).

[8] Safety Bulletins 23, 23A, 23B, 23C, 23D, and 23E cover safety using portable power systems. Bulletins are available for download at www.csatf.org/ under Safety Bulletins.

CHAPTER 14

Power distribution equipment

This chapter is about how we safely bring the power from a power source to the lights. A portable electrical distribution system is used to deliver the power from the generator or main lighting electrical panel to the lighting equipment.[1] The *power* infrastructure consists of cable and a tiered system of electrical boxes. *Data* distribution infrastructure has to be considered at the same time. Power and data are typically co-located, so boxes are available that integrate them together. We'll look at some of those solutions later in the chapter as well.

COMPONENTS OF A SIMPLE PORTABLE DISTRIBUTION SYSTEM

A distribution system has two functions:

- It provides a tiered structure of overcurrent protection so that each size of cable and cord are appropriately protected from overloads and short circuits.
- It subdivides power into smaller-sized circuits and provides appropriate receptacles to accommodate the various connectors on the lighting equipment.

Let's begin with the basic components common to virtually any distribution system. Figure 14.1 shows a basic distribution system setup.

Main disconnect: Every system is required to have a main switch or circuit breaker at the supply panel (Figure 14.2), sometimes called *cans* or *bull switches* in sound stages or called *company switches* in theater/concert venues. On a generator, the output bus is energized and de-energized by a button on the control panel. Either way, this switch shuts down power to all circuits connected to it at the end of the day. A modern lighting panel typically provides Camlock connectors, either panel-mounted or short tails.

Feeder cable: Feeders are single-conductor cable meaning there is only one wire inside each insulated sheath. In the US, feeders use Camlock connectors, which must be color coded at the ends of the cable to identify ground, neutral, and individual phases. Banded cable often uses colored connectors. For 4/0 and 2/0, at least the first six inches of both ends of each piece of cable should be wrapped with colored electrical tape.

Spider boxes: A spider box is a Camlock splicing block. It does not have overcurrent protection. It is also used to do the following:

[1] Strategies for using house circuits on practical locations is provided in Chapter 18.

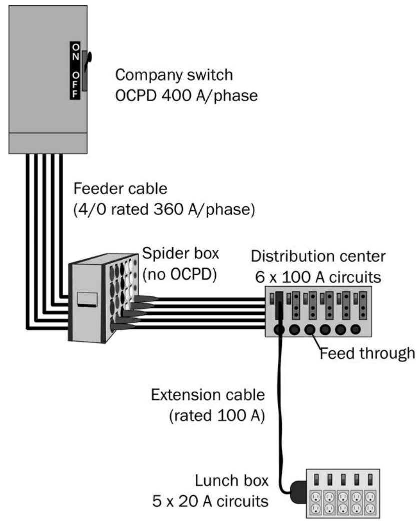


FIGURE 14.1

Basic portable power distribution system.

FIGURE 14.2

Studio lighting supply panel.

(*Courtesy LEX Products*)

- Provide Camlock receptacles for loads, such as dimmer packs and some 18k and 24k lights.
- Branch-off feeders.

Distribution centers: The feeder cables terminate in distribution centers, which provide individual overcurrent protection for multiple, lower-amperage outlets (as required by NEC Article 240–21). A wide variety of distribution boxes are available configured with different combinations of output connectors, most commonly:

- 100 A, 120 V Stage pin—to power larger 120-volt lights (6k, 9k, 10k, 12k) and to power subsequent 100 A receptacle boxes. The 120 V circuits are identified by phase: red, blue, or black.
- 100 A, 240 V Stage pin—commonly a yellow connector, these are used to power large lights operating at 208–240 V (12k, 18k, 20k). These circuits are identified red/blue, red/black, and blue/black.
- Other 120 V and 208 V receptacles:
  - At 120 V: Edison (20 A), Socapex (6 ×20 A), Stage pin (60 A), Stage pin (20 A)
  - At 208 V: Socapex (6 ×20 A), L6–20 (20 A), L6–30 (30 A), Neutrik PowerCON True1 (20 A) on some moving lights and other international lights.
  - Camlock feed-through—to continue the feeder run to another distribution center.
  - Courtesy Edison outlet—handy for plugging a small work-light in a dark set.

100 A and 60 A Stage pin extension cables: Extension cables run from the distribution centers to large lights and power receptacle boxes.

120 V receptacle boxes: *Lunch boxes*, *gang boxes*, *quad boxes*, typically take 100 A Stage pin in, and provide appropriate overcurrent protection for multiple smaller circuits. The most common is Edison (5 ×20 A) or Socapex (6 ×20 A), but boxes are available for just about any other connector type used in entertainment. There are also 208 V, 100 A receptacle boxes.

Stingers: Edison extension cables typically come in 25- and 50-ft. for running from the receptacles to lights.

Note: The equipment covered in this chapter is limited to *portable* electrical distribution equipment used in *dry* locations (see Chapter 19 for wet locations). NEC regulations authorize portable systems for *indoor and outdoor* use provided it is supervised by a qualified person (such as a knowledgeable lighting technician) whenever it is energized.

208 V vs. 240 V systems

As described in the last chapter, on many generators you can opt to run a three-phase, 208/120 V system consisting of three phase wires, neutral, and ground, or to run a single-phase, 240/120 V system having just two phase wires, neutral, and ground. The advantage of a 208/120 V system is that it allows you to utilize the maximum capacity of a generator. A 240/120 V system can only use about two-thirds of the full load amperage of the generator (see Chapter 18).

Some gaffers love the 240/120 V system. The advantages are that HMI ballasts run cooler and perhaps more reliably because they require less current at 240 V than when run at 208 V. It is easier to balance loads (240 loads are automatically balanced), the distro boxes are smaller and lighter, and a single-phase run requires 20 percent less cable and less labor. You can make a four-piece run instead of a five-piece run, or a seven-piece run instead of a nine-piece run.

OVERCURRENT PROTECTION AND CABLE AMPACITY

Protecting cable at its ampacity

As a rule, the NEC requires that feeder cable sizes are matched with the overcurrent protection that is upstream of the feeder so that cables can safely carry the full load allowed by the overcurrent protection devices (OCPD) without exceeding the cable's ampacity. For example, 100 A Stage pin extensions use #4 AWG (American Wire Gauge) cables, have an ampacity of 125 A, so the cable is thick enough to handle the full 100-amp load. In addition, whenever there is a step down in cable size, overcurrent protection should be provided that protects the new cable size.

When the ampacity of the cable falls between standard circuit breaker sizes, it is permissible for the cable to be protected at the next higher standard OCPD rating (NEC 240.4(B)) as shown in Table 14.1. However, this does not mean it is permissible to exceed the ampacity of the cable.

Table 14.1 Ampacity of cable and rating of overcurrent protection

Cable size (AWG)	Ampacity rating Cable insulation rated 70 °C	Ampacity rating Cable insulation rated 90 °C or more	Maximum OCPD rating
4/0	360 A	408 A	400 A
2/0	265 A	300 A	300 A
#2 AWG (banded)	170 A	190 A	200 A

STANDARD OCPD RATINGS (100–800 A)

100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800

Cords and cables running to the loads (downstream of the last overcurrent device) only have to be a sufficient size to carry the load. These are called *branch circuits* which do not follow the same sizing requirements as *feeder circuits*.

Step-down box

You may be wondering what happens if the supply panel has a 400 A circuit breaker, but we want to use 2/0 or banded cable (#2 AWG). In that case the circuit breaker is too big to protect the cable at its ampacity. There are currently two permissible ways to handle this. The first is to provide appropriate overcurrent protection using a step-down distribution box. The second is to rely on a special exception on the NEC known as *the 400 percent rule*.

A step-down box (Figure 14.3) provides overcurrent protection which is matched to the size of the downstream feeder cable. The box is connected to the power source with short jumper cables. The length of the jumper cable (NEC 240.21(B) calls them *tap conductors*) is required to be limited as follows:

No more than 25 ft. provided the rating of the upstream overcurrent protection is not more than *three* times the ampacity of the tap conductors, and the tap conductors terminate into a *single* circuit breaker or set of fuses that limit the load to the ampacity of the tap conductors.

No more than 10 ft. if the upstream overcurrent protection is more than *three* times the ampacity of the tap conductors. The ampacity of the tap conductors must be sufficient to power the combined calculated load on the circuits supplied, and the ampacity of the tap conductors must not be less than the OCPD of the step-down box.

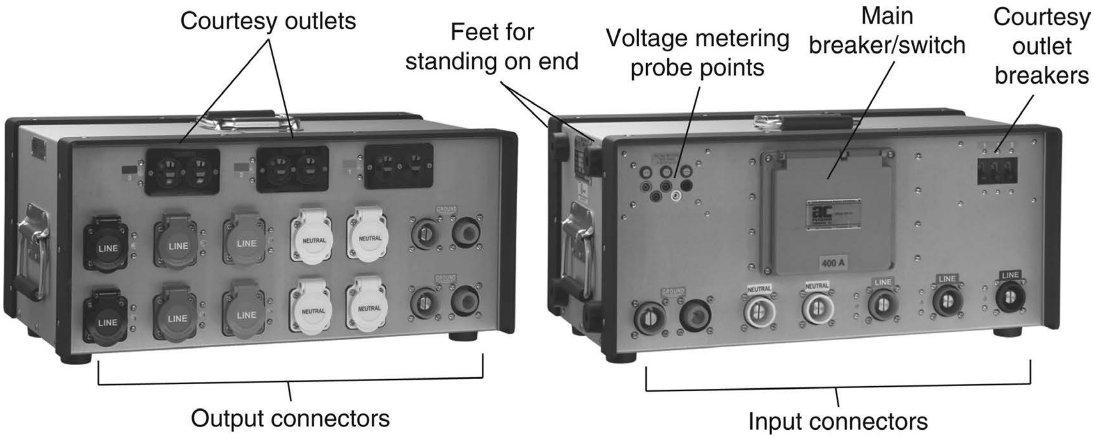


FIGURE 14.3

Portable Company Switch. This particular model is rated for outdoor applications (NEMA 3R) and has an adjustable overcurrent device that can be set for amperages of 160 and 400 A, depending on the size cable being protected. The breaker is rated for 100 percent continuous duty. The outputs provide for paralleled cables and double neutral.

(*Courtesy AC Power Distribution, Inc.*)

The 400 percent rule

Section 530.18 of the NEC allows an exception for motion picture set lighting work, known as the 400 percent rule. According to this rule, the overcurrent protection may be up to 400 percent of the capacity of the cables provided that the cable is never loaded beyond its ampacity. For example, if the cable terminates into a distribution box that limits the total load to no more than 200 A per phase, then the 2/0 cable cannot be overloaded.

It is important also not to ever connect a cable for which the circuit breaker rating is *more* than 400 percent of the cable ampacity. For example, if the generator can provide 800 A per phase, you could not connect banded (#2 AWG) cable directly to the generator or a spider box. The circuit breaker is too oversized (400 percent of 170 A is only 680 A). You'd have to provide appropriate overcurrent protection before stepping down to the smaller banded cable.

The 400 percent rule may not be permitted in every jurisdiction. The Authority Having Jurisdiction (AHJ) can require overcurrent protection regardless of the 400 percent rule.

The Authority Having Jurisdiction is defined by the NEC (Art 100) as "An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure." For our work, the AHJ may be the city electrical inspector, a fire safety officer, or a facility engineer or similar safety authority associated with the shooting location. Studio safety reps and OSHA inspectors may also have a say in enforcing safe practices.

FEEDER RUNS

Camlock connectors

The code requires that single-conductor cable use locking connectors such as lugs or Camlocks. Cam-Lok™ is the trade name of a particular manufacturer. However, in the film and television industry Camlock has become the generic term for Camlock 16-series (also called CLS or E1016 series) connectors rated at 400 A.

Male and female Camlock connectors are mated by lining up the arrows, inserting the male connector, and then twisting the male 120 or 180 degrees depending on the manufacturer, which engages a locking pin into a cam mechanism that pulls the connectors tightly together. No tools are necessary, but it is a good idea to protect your hands with work gloves. The cam ensures full contact, yet is relatively easy to connect and disconnect. To ensure a good connection, the connectors must be twisted until tight, not simply inserted.

The male and female Camlock connectors have overlapping insulation which ensures that no bare metal is exposed as they mate. Nonetheless, Camlock connectors should never be connected or disconnected under load. This is true for all connectors, but especially so for connectors that carry large potential loads. Arcing causes the pins to become pitted and warped. The connectors can become permanently stuck together.

Camlock connectors are somewhat protected from water (the rubber shell type are typically rated NEMA 3R or 3R and 4; see Appendix E).

There are various kinds of Camlock splitters and adapters (some of which are shown in Figure 14.4). A Camlock-T or three-fer allows two or three Camlock connectors to be plugged into one. It is often desirable to have multiple Camlock outputs available on the feed-through side of a distribution center; however, the hard Ts and three-fers tend to run into each other. A "soft two-fer" or "soft three-fer" solves this problem. It provides a short piece of flexible cable between the male connector and the female three-fer.

A suicide pin is a male-to-male adapter typically used to reverse the direction of the connectors on the grounding wire. Some equipment runs the ground in reverse; some doesn't. Obviously, you should never leave a bare suicide pin plugged into a phase or neutral.

There are other sizes and types of cam connectors. Minicams (CLM or 1015-series connectors) are smaller 150 A connectors used more typically in touring and live events. 1018-series Camlock connectors are used for feeder cable in Canada. They are larger and not compatible with 1016 connectors used in the US.

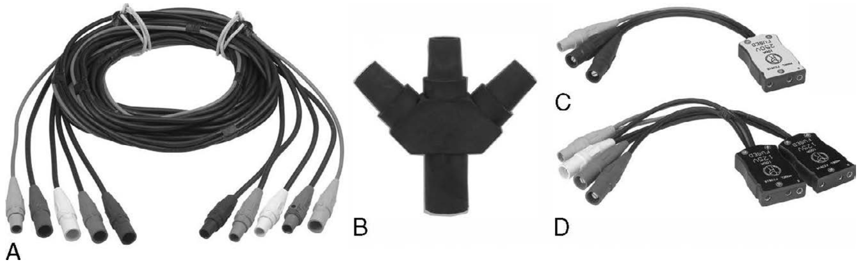


FIGURE 14.4

(A) Camlock banded #2 cable. (B) Camlock three-fer. (C) Camlock to 100 A, 240 V Stage pin adapter; (D) Camlock to two 100 A, 120 V Stage pin adapter.

(*Courtesy Mole-Richardson Co., Los Angeles, CA*)

Reversed ground system

Connectors are oriented with "pins to power," meaning that the male pins point toward the power plant and the female end goes toward the lights. This is true for feeder cable as well, except for the ground. In our industry, a reverse ground system has been widely adopted. Most equipment, including banded cable and distro boxes, is set up with the ground reversed. The male connector on the grounding wire points downstream, toward the load. The idea is to make it impossible to plug a hot wire into the ground by mistake. Because this system is not universally used, you will find distribution boxes that provide both male and female connectors for the ground (as shown in Figure 14.3).

Parallel cable

In our industry we do not use cable bigger than 4/0, because it's not portable. When a larger size conductor is needed we increase the number of 4/0 conductors used for each phase and for neutral. This is called *paralleling* the cable.

There are two separate reasons that paralleling may be called for: to carry higher amperage loads or to lower voltage drop over long distances. For example, doubling the number of 4/0 cables per phase can either double the ampacity or double the distance of the run. Feeder distribution boxes usually feature double neutral connectors for handling high neutral currents from nonlinear loads (more about this in Chapter 17).

When cables are run in parallel, they must all be the same length, gauge, and type of cable. Any difference between cables causes an imbalance of resistance between them; a cable with even slightly lower resistance will take a disproportionate portion of the load and could be overheated.

Test jacks

Test jacks in spider boxes and distribution centers provide the safest and most convenient location for electrical metering. They eliminate the need to insert meter probes into connectors to find bare copper.

There is potentially a lot of energy traveling through the upstream distribution equipment. The safest metering technique is the one that provides the least risk of hazard. Test jacks limit the available current in the event of an arc.

Camlock spiders

The Camlock spider shown in Figure 14.5 is a 2400 A spider box, which can carry 800 A per phase using the two rows of parallel inputs. It feeds six rows of outputs. This box accommodates a double 4/0 run input (2400 A max). It also features indicator lights on each phase and test jacks that are protected by small circuit breakers.

Note that regardless of how many connectors are available on a spider, the maximum amperage is rated based on the size of the buss bars inside. Check the manufacturer's rating of the buss bars. Some manufacturers make 1200 A spiders with four parallel input connectors, for example. This does not allow you to put 4800 A through the spider; it simply allows the use of parallel cables for voltage drop mitigation, but the current is still limited to 1200 A. There are spiders built for larger amperages as shown in Table 14.2.

When a spider box is used to splice smaller subfeeders to the main run, overcurrent protection is required as discussed previously, unless the 400 percent rule can be used. It is perfectly fine to connect loads that provide their own circuit breaker (e.g., an HMI ballast) directly into a spider box, as long as the power cord is not more than 25 ft. long. Dimmer racks can also be connected directly to the main run; however, if the rack or pack does not provide a *single* main circuit breaker on the input side, the tap conductors must follow the 10 ft. rule.

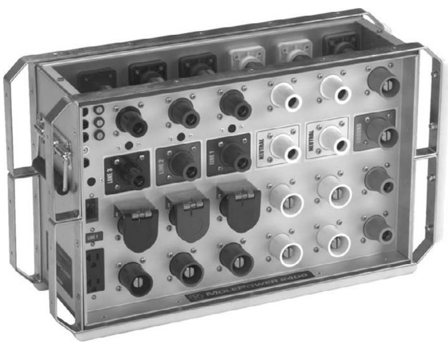


FIGURE 14.5

This 2400 A Camlock spider has two rows of parallel 4/0 inputs (note that the second set of male connectors are capped when not in use). The spider can branch to as many as six rows of outputs. The neutral is doubled. It also features test jacks, indicator lights, and a courtesy outlet (handy for a work light).

(*Courtesy Mole-Richardson Co., Los Angeles, CA*)

Table 14.2 Three-phase Camlock spider boxes

Camlock spider box (three-phase)	Number of parallel cable inputs	Number of parallel outputs
1200 A Spider	1	3
1200 A Spider	1	7
1200 A Spider	2[†]	6
1200 A Spider	4[†]	4
2400 A Spider	2	6
4800 A Spider	4	4

[†]Note that the number of parallel inputs is not necessarily an indication of the maximum capacity of the spider. The ampacity may still be only 400 A/phase despite having two or four inputs per phase.

DISTRIBUTION CENTERS

Some common configurations are described in Table 14.3. Almost all boxes are available in either single-phase or three-phase versions. Figure 14.6 shows some typical distribution boxes.

Useful features on distributions boxes include the following:

- Phase indicator lights, which help with troubleshooting and alert you when the system is energized.
- Courtesy outlets, which provide power for work lights on a dark stage (and charging your phone).

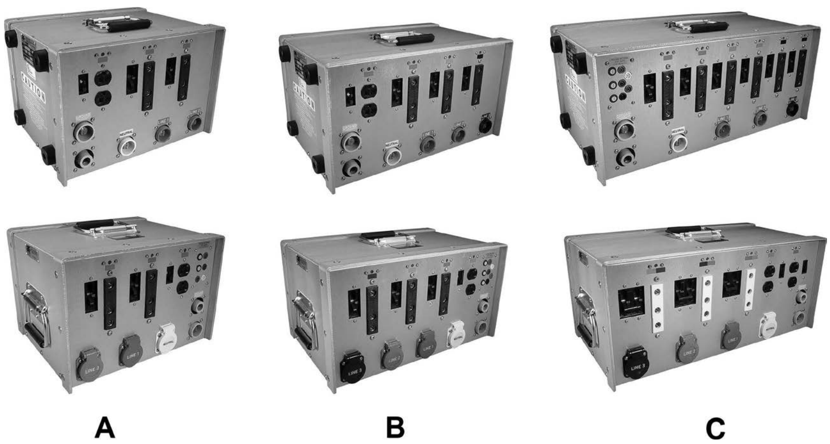


FIGURE 14.6

Stage Pin distribution boxes: (A) 400 A single-phase (4 x 100 A, Edison courtesy), (B) 600 A three-phase (6 x 100 A, Edison courtesy), (C) 1200 A three-phase (6 x 100 A @120 V, 3 x 100 A @ 208 V, Edison courtesy).

(*Courtesy AC Power Distribution, Inc.*)

Table 14.3 Common configurations of distribution boxes

Distribution box	Input		Output connectors
400 A Single-phase box	Single-phase Camlock	4	100 A Stage pin (120 V)
			Camlock pass-through
			Duplex Edison courtesy outlet (120 V)
600 A Single-phase box	Single-phase Camlock	2	100 A Stage pin (120 V)
		2	240 V, 100 A Stage pin
			Camlock pass-through
			Duplex Edison courtesy outlet (120 V)
600 A Three-phase box	Three-phase Camlock	6	100 A Stage pin (120 V)
			Camlock pass-through
			Duplex Edison courtesy outlet (120 V)
900 A Three-phase box	Three-phase Camlock	3	100 A Stage pin (120 V)
		3	208 V, 100 A Stage pin
			Camlock pass-through
			Duplex Edison courtesy outlet (120 V)
1200 A Three-phase box	Three-phase Camlock	6	100 A Stage pin (120 V)
		3	208 V, 100 A Stage pin
			Camlock pass-through
			Duplex Edison courtesy outlet (120 V)
1200 A Three-phase box	Three-phase Camlock	12	100 A Stage pin (120 V)
			Camlock pass-through
			Duplex Edison courtesy outlet (120 V)
1200 A Three-phase box	Three-phase Camlock	6	208 V 100 A Stage pin
			Camlock pass-through
			Duplex Edison courtesy outlet (120 V)

- Test jacks (banana plug outlets) for metering system voltage.
- On catwalks, it is often preferable to use boxes that feed in and out along only one axis (Figure 14.6). This keeps the cable runs a lot neater than boxes that feed out in four directions. Some boxes can be stood on end, taking up less horizontal space.

MULTI-PIN CONNECTORS AND RECEPTACLE BOXES

There are a variety of power connectors used in entertainment: Stage pin, Edison, twist-lock (L6–20 and L6–30), powerCON, TRUE1, and Socapex are among the most common. Connectors rated for 120 V provide ground, neutral, and one phase. Connectors rated for 250 V (used on 208–240 V circuits) provide ground and two phases to power 208–240 V circuits. For all multi-pin connectors, the pins are sized so that ground makes contact first and breaks last, and the connector maintains proper

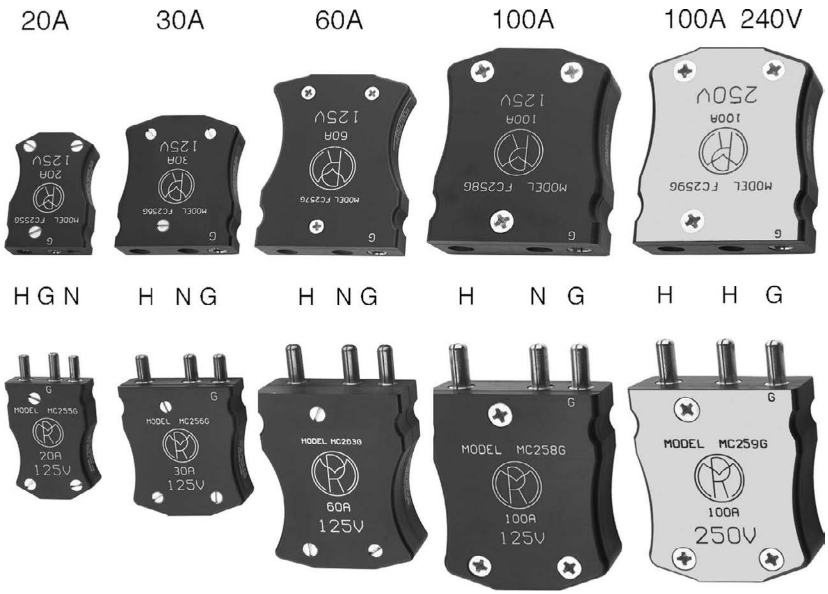


FIGURE 14.7

Pin configurations for Stage pin connectors of various sizes. The 100 A 240 V connector is similar to the 100 A connector, but the center pin carries a phase instead of neutral. The center pin is positioned closer to the center of the plug. The 240 V connectors are yellow.

(*Courtesy Mole-Richardson Co., Los Angeles, CA*)

polarity by having the pins positioned asymmetrically so that the neutral and phase cannot be incorrectly connected by turning the connector upside down. It only goes in one way.

Stage pin (Bates) connectors

In the United States, Stage pin connectors are widely used connectors for lights. In Europe and Canada, Stage pin connectors are not permitted. Stage pin connectors can be traced back to the first pin connectors made for Kliegl Bros. in the 1920s. They are commonly called Bates connectors.[2] Stage pin connectors come in 120 V: 20, 30, 60, and 100 A, and 250 V: 60 and 100 A (Figure 14.7).

Stage pin connectors are flat connectors so that they do not roll when stepped on; they do not stand much taller than the cable itself. Most Stage pins are not locking connectors. Where one Stage pin cable plugs into another, tape the connection so that they don't pull apart (Figure 14.8), and/or tie the cables together using the cable ties.

[2] The Bates name has stuck from many years ago when Union Connector Company made the connectors for Bates Electric, a theatrical lighting company on Bates Street in LA. Because all their equipment was identified with "Bates" written on the plugs, the connectors came to be known as Bates connectors. In the 1990s, Marinco bought the "Bates" name. Until then, it was not a trademark.

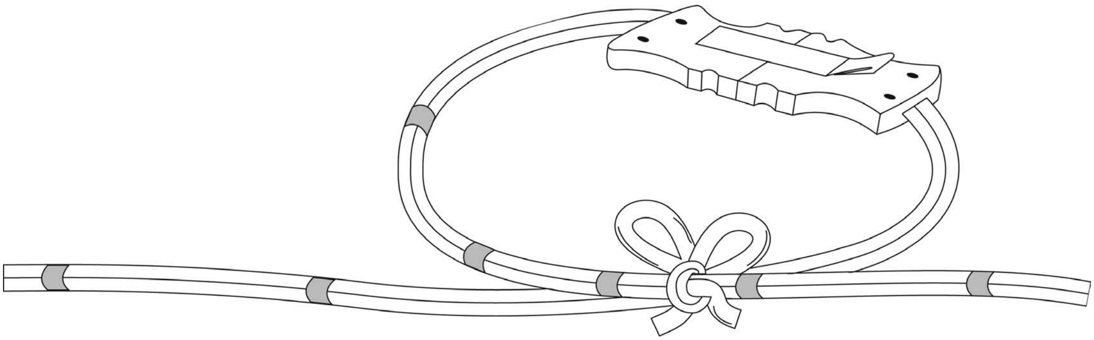


FIGURE 14.8

Stage pin connectors often need to be held together by tape or by making a loop and wrapping one of the cable ties around both cables.

The 100 and 60 A extensions (100, 50, or 25 ft.) run from the distro boxes to the lights and gang boxes. A 100–60 A adapter/splitter is used to connect 60 A plugs to the 100 A outlets. Table 14.4 gives some examples of how Stage pin connectors are typically used in motion pictures and television.

Vendors who supply lights for theatrical and concert venues sometimes supply ellipsoidal spotlights and PAR cans fitted with 20 A Stage pin connectors. To be used with an Edison distribution system, these lights must be ordered with a “pigtail” adapter (Edison male/Stage pin female). Some television studios that do primarily in-studio productions rather than location work also use only Stage pin connectors rather than Edison. Such facilities are typically installed with permanent Stage pin sockets with numbered circuits distributed around the stage, on the walls, in the floor, and mounted to overhead pipes. This permanent feeder system is hardwired to a patch panel and dimmer systems. In this situation, 20 A Stage pin extensions are used instead of Edison stingers. If you are using a large number of Stage pin-fitted lamps, distro boxes with 20 A Stage pin outlets can be ordered, but ordinarily in motion picture work we use Edison outlets for lamps that are 2k or less.

Stage pin connectors are not made to a single industry standard. Two listed plugs from different manufacturers might fit tight mechanically but not make a good electrical connection. To check for a good fit, insert the single hot pin into the female and check for snugness. Inspect the pin and sleeve. Look for discoloration due to overheating, burnt, pitted, or deteriorating pins due to arcing, and signs of overheating inside the plug due to a weak connection to the cable.

Edison

A *lunch box* is a 100 A box that provides five 20 A duplex circuits (10 Edison outlets) with 20 A circuit breakers and indicator lights on each circuit (Figure 14.9). The connectors are a heavy-duty type commonly known as *hospital-grade outlets*, denoted with a green dot. They are designed for constant use, plugging and unplugging equipment. Most lunchboxes also provide a 100 A female outlet so that you can feed through to subsequent boxes. Lunch boxes are also available with 20 A Stage pin, Socapex, twist-lock, powerCON and TRUE1 receptacles.

Table 14.4 Common applications for connectors

Connector	Typical light wattage range	Examples
20 A Stage pin	0–2k	Ellipsoidal (Leco) 750 W, 1k
		Par cans up to 1k
		1k and 2k Fresnels used in theaters or television studios (location lights use Edison plugs)
30 A Stage pin	Not used in our segment of the industry	
60 A Stage pin	2.4k–6k	2.4k HMI
		4k softlights
		4k HMI (120 V)
		5k Fresnel
		5k SkyPans
		9-light FAYS (5850 W)
		6k coops, 6k space lights
100 A 120 V Stage pin	6k–10k	8k softlights
		9k Maxi-Brutes
		10k Fresnels
100 A 240 V Stage pin	4k–20k	HMI ballasts 9k,12k, and 18k
		20k tungsten

FIGURE 14.9

Edison boxes: (A) the classic 100 A lunch box with five duplex outlets, (B) a 60 A gang box with three 20 A duplex outlets, (C) a 100 A gang box with five single 20 A Edison outlets.

(*Courtesy Mole-Richardson Co., Los Angeles, CA*)

NEMA L6–20 and L6–30

Many 208 V moving lights, LED light fixtures, video walls, and follow spots use either L6–20 (20 A, 250 V) or L6–30 (30 A, 250 V) twist-lock connectors. These and other NEMA-rated plugs and sockets are shown in Figure 14.10.

L6–30 connectors have been used in place of 60 A Stage pin connectors on 2.5k 240 V HMI ballasts to solve the mess created by multiple 60 A splitters. Using an L6–30 box (Figure 14.11A) enables four 2500 ballasts to be connected using one 100 A, 240 V circuit. Each circuit is protected by a double-pole 25 A breaker. The ballasts require an adapter to a male L6–30 twist-lock. This method can also be used for 4k ballasts if they are power factor corrected and operating on a 240 V system. However, 4k power factor corrected ballasts and ballasts running on 208 V will draw more than 25 A and require higher overcurrent protection.

PowerCON and TRUE1

Many modern moving lights and LEDs are universal and auto-sensing, meaning they will operate on US or European voltages (100–240 V, for example). As there is often an advantage to running lights at a higher voltage, the connector for these lights needs to be capable of operating on either voltage. Neutrik is the original manufacturer of PowerCON connectors, which are locking 20 A, 250 V connectors.

You often see PowerCON connectors used to connect power cord to the light fixtures. You will sometimes come across lights that must be plugged to a PowerCON receptacle (Figure 14.12A).

For the older style gray and blue PowerCON connectors, the gray end connects the cord to power, while the blue end connects to the light. These connectors are not designed to be connected or disconnected under load. They are being replaced by the newer, TRUE1 connector, which is black with yellow highlights. The TRUE1 is rated for breaking under load (although doing so is never recommended). It is a locking 16 A, 250 V connector (Figure 14.12B).

Socapex

Socapex cable,[3] also called *19-pin* or *multiconductor cable* or *Soco* for short, carries six separate 20 A circuits together in one multiconductor cable.

Socapex connectors are commonly found in the following applications:

- Socapex cable is handy for feeding power to lights as separate circuits, which allows you to perform a power reboot on an individual light from the ground. 120 V and 208 V moving lights and LEDs sometimes need to be rebooted.
- Dimmer racks and packs with 1.2, 1.8, and 2.4 kW dimmer circuits are often configured with Socapex outputs for direct connection to Socapex cable. Consolidating six circuits into one cable cuts down on labor and mess.
- Socapex boxes provide manual on/off control of the individual circuits, and some provide DMX512-controlled remote switches (Figure 14.13).
- Some six-circuit light fixtures, such as coops and space lights, use Soco input connectors, which provide individual control over each lamp in the fixture.

[3] Socapex is a trademarked name owned by Amphenol-Socapex, the original manufacturer. But other companies also manufacture 19-pin-compatible connectors, and refer to their products as Socapex.

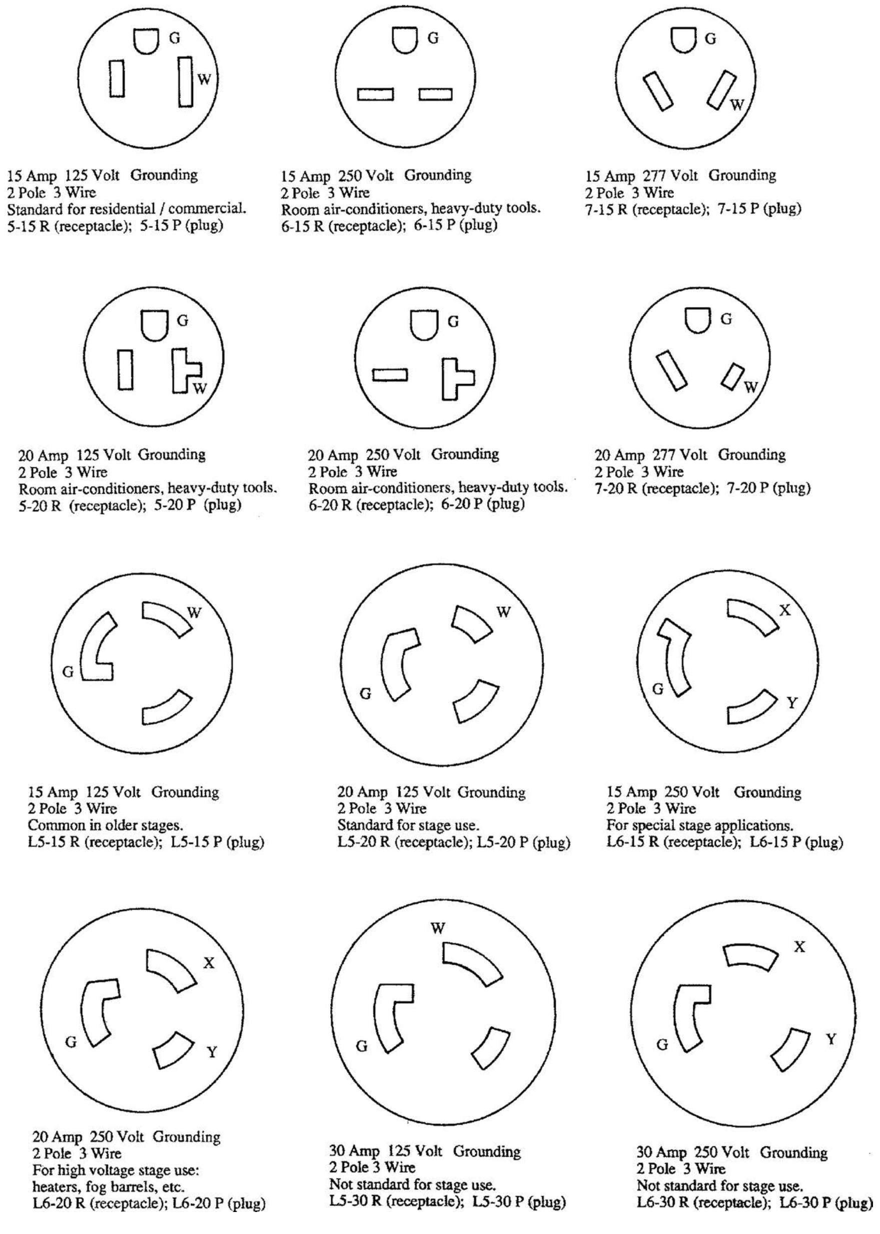


FIGURE 14.10

Edison and Twist-Loc NEMA-rated connectors.

(*Reprinted with permission from* Backstage Handbook *by Paul Carter, New York: Broadway Press, 1988*)

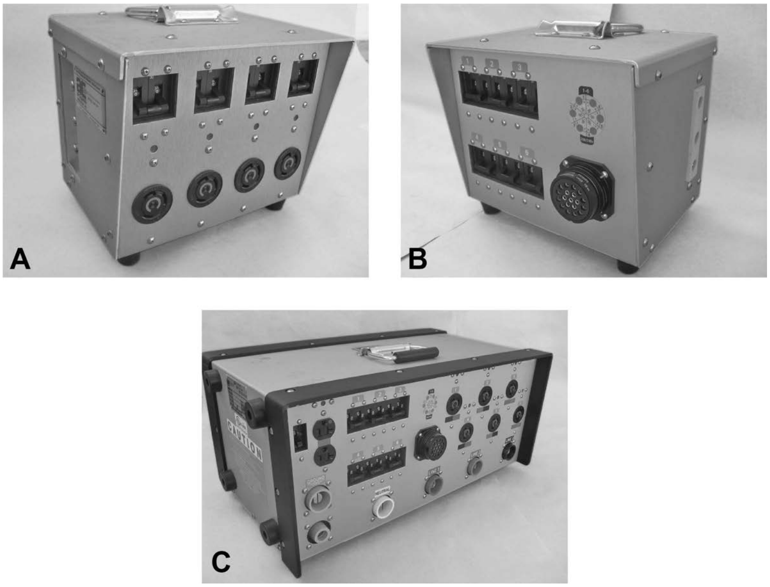


FIGURE 14.11

208–240 V distribution: (A) 240 V 100 A Stage pin input, lunch box with four 240 V 30 A twist-lock outlets (NEMA L6–30); (B) Stage pin 100 A, 240 V input with Socapex (208–240 V) output; (C) moving light distro box with Camlock inputs and multiple L6–20 and Socapex (208–240 V) output connectors.

(Courtesy AC Power Distribution, Inc.)

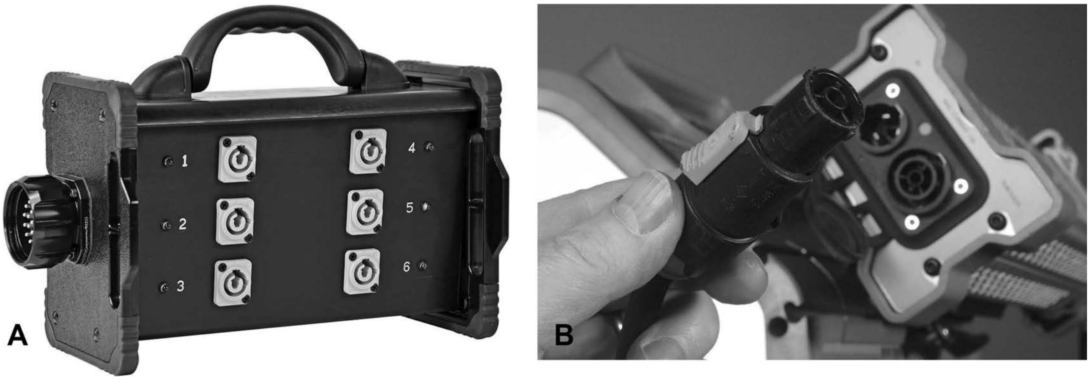


FIGURE 14.12

(A) Neutrik PowerCON 20A outlets on a Socapex break-out box. (B) Neutrik TRUE1 connector on an ARRI SkyPanel power cord female plug and power supply male receptacle.

(*Courtesy LEX Products*)

A B C

FIGURE 14.13

Socapex distribution: (A) 600 A MolePlex distribution box, Camlock inputs. Four Socapex outputs with six individual 20 A breakers per outlet, six 20 A duplex. (B) Dadco Socapex distro box: Camlock inputs, Camlock flow-through, six six-circuit Socapex outputs with six individual 20 A breakers per Socapex, two 20 A courtesy outlets. (C) A Socapex break out adapter—Socapex male to six Edison female.

(*A and C courtesy Mole-Richardson Co., Los Angeles, CA. B courtesy Dadco*)

When lights are individually controlled on 20 A circuits, Socapex cable makes cabling much less cumbersome. It comes in long lengths to cut down on connection points: 200, 150, 100, 50, and 25 ft. Racks and packs that provide single-circuit outputs (usually 20 A Stage pin) can be fed into Soco cable by attaching a Soco *break-in adapter*. At the load end of the cable, a Soco *break-out adapter* separates the six numbered circuits, providing either Edison outlets or 20 A Stage pin outlets for the lights. The breakouts are numbered 1–6, so it is a good idea to label both ends of the cable with the actual dimmer channels.

Rating Socapex cable

Socapex cable normally contains fourteen #12 or #14 AWG wires. Twelve of the wires carry current. The NEC requires that the ampacity of the wire be derated when there are more than three current-carrying wires in one sheath. When the cable is connected to a heat producing light, the cable must be derated to 10 A for #12 wire and 7.5 A for #14 wire (per NEC Table 400.5(A)(3)). However, if the Socapex cable is connected to a break-out or outlet box (and not a heat-producing device), some individual circuits could carry as much as 20 A for #12 wire and 15 A for #14 wire, provided that the total amperage of all six circuits does not exceed 60 amps (50% diversity factor per NEC section 520.44(C)(2)). In other words, if three circuits carry 12 amps each, the other three can carry no more than 8 amps each (12+12+12+8+8+8=60).

Keep connectors and cable well ventilated. Avoid piling connectors or conductors on top of one another. Cables in contact with each other cause excessive heat buildup. Dimmers and distribution boxes with Socapex outputs often supply two parallel Socapex output connectors for each group of six circuits and use 20 A circuit protection for each circuit. This allows two 1k fixtures to be plugged to the same circuit, through separate Socapex cables, thereby avoiding putting a 2k load through one Socapex cable.

Socapex pin configuration and troubleshooting

The 19-pin connector is shown in Figure 14.14. Pins in the outer circle are the phase and neutral wires of the six circuits. Those in the inner circle are grounds for each circuit. The center pin, 19, is not used

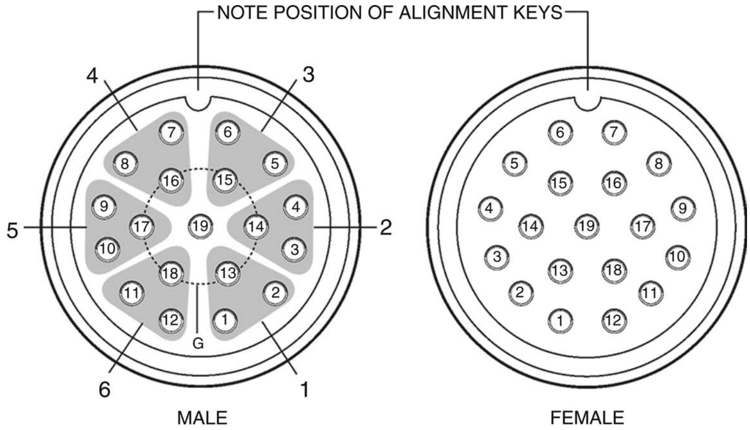


FIGURE 14.14

Each of the six circuits in a 19-pin Socapex cable has its own hot, neutral, and ground wires (shown here in gray). The proper position of the keyway and good condition of the pins are essential to proper function.

or may be used as an additional ground. If the cable used is 18- or 19-conductor cable, each circuit gets an individual ground wire. If used with 14-conductor cable, all the ground pins are bussed together.

Multiconductor connectors and cables are susceptible to damage that can result in shorts between conductors or breaks in a conductor. A Socapex tester like the one shown in Figure 14.13A is a very handy troubleshooting aid. Some distribution boxes come equipped with circuit indicator lights that also serve this function. Figure 14.15B and C show 120 and 208 V indicator lights, respectively.

The male Soco connector has a key at the top to orient the connectors and a threaded collar that twists and pulls the connectors together, then click-locks with the female. A keeper inside the connector keeps the key properly oriented. If it breaks, the whole connector can spin and you can end up with the wrong dimmer number coming up. The key should always be located between pins 6 and 7 (as shown in Figure 14.14). When checking over cable before installation, be sure the connector's strain relief is tight. If the outer insulation has pulled out of the strain relief and you can see the inner wires, do not use the cable. When the strain relief is loose, the bare pins (male end) or receptacles (female end) start to pull out of the insulating housing into the connector. The wires can get pulled and twisted when the connector is handled—bad things can result.

Adapters

There are as many kinds of adapters as there are different combinations of connectors. When ordering equipment, the best boy must take care to order the adapter needed to connect each piece of equipment. When referring to an adapter, designate the male end first (for example, a Stage pin to Edison adapter has a male Stage pin and gives you a female Edison).

100 A to two 100 A splitters: The idea of this splitter is to give you more 100 A outlets. Of course, the total amperage still can't exceed 100 A.

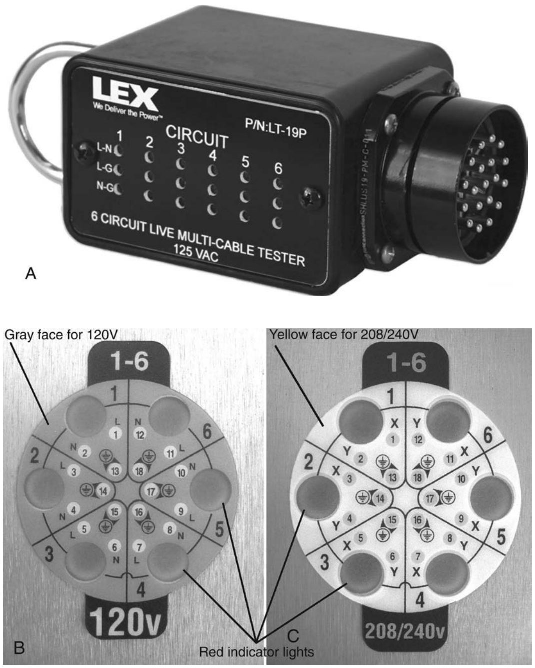


FIGURE 14.15

(A) A LEX six-circuit live multicable tester plugs directly into a 120 V multiconductor cable. When the circuits are energized, green LEDs indicate the presence of voltage potential between LINE and NEUTRAL (L–N), yellow LEDs show voltage between LINE and GROUND (L–G), and red LEDS indicate voltage between GROUND and NEUTRAL (G–N). A correctly functioning cable will show green and yellow LEDs for all six circuits, but should not light any red LEDs. To check for cross-wiring, bring each circuit up to full separately. Note that the tester will give a positive result even if only one strand of wire is still making contact in the connector. (B) The six indicator lights on this distribution box show which circuits have power. The pins are labeled LINE (L), NEUTRAL (N), and GROUND. (C) A 208/240 V Socapex outlet indicator uses a yellow face color to distinguish it from a 120 V one. The pin labels X and Y indicate two phase wires.

(*A Courtesy Lex Products Corp. B and C Courtesy AC Power Distribution, Inc.*)

100 A to two 60 A splitters: Order as many of these as you have lights and Edison boxes with 60 A tails. Note: Some adapters are fitted with inline 60 A fuses. Be sure to stock spares and be on the lookout for burnouts.

240 V 100 A Stage pin snakebites (Camlock to Stage pin adapters): If you get caught without a 240 V Stage pin outlet for a 20 kW or 12/18 kW, this adapter solves the problem. As explained earlier, the circuit breaker on a 20 kW stand-alone dimmer or HMI ballast serves as branch over-current protection. This allows you to connect directly to a flow-through Camlock connector or spider box in accordance with the 25 ft. tap rule.

Three-wire 100 A Stage pin snakebites (three-wire Camlock to two 100 A Stage pin): In the absence of a distro box, a snakebite patches directly into three-fers. Note: there is no overcurrent protection here.

Edison to 20 A Stage pin pigtails: You may need adapters with any theatrical lights you order. *100 A Stage pin to Camlock adapters*: Be sure to ask the type of connector for any large lights you order. If the light has Camlock, you may need to adapt to 100 A Stage pin.

Socapex break-in and break-out adapters: A break-in adapter has six numbered male connectors (usually either 20 A Stage pin or Edison) leading to one female Socapex connector. They are used to channel power from separate circuits into a Socapex line. A break-out adapter is used at the load end of the Socapex cable to go from male Socapex to six numbered female connectors.

Adapters for big lights

24k lights (PAR arrays, Fresnels, and HMIs) cannot be powered continuously from a 240 V, 100 A Bates outlet: it would be running constantly at the maximum rating of the connector and the circuit breaker, and breaker trips and meltdowns would be inevitable. These lights typically have Camlock connectors and can be powered from a special distribution box with female Camlock outputs protected by 125 A circuit breakers.

A similar problem exists with connectors used with 12k tungsten lamps such as the ARRI T-12. When fitted with a 100 A connector and run for hours at a time, the connector is being seriously overstressed. A solution some gaffers and best boys employ is to use a 240 V lamp in the light. Use an adapter that gives you a 240 V, 100 A Stage pin connector to plug in the light. This eliminates problems with overheating the connectors, because the current is sliced in half. This also helps balance the large load between separate phases of the distribution system. GE does not make a 208 V version of the 12 kW tungsten lamp, but they do make a 230 V version, which has a color temperature of 3400 K. If you are using 208 V power, you can use a 230 V lamp with only a slight sacrifice in output, and the color temperature will wind up close to 3200 K.

DMX-CONTROLLED DISTRIBUTION AND POWER WITH DATA

With so much lighting equipment being DMX-controllable, there is a need for distribution equipment that: 1) is itself DMX controllable and 2) distributes network data. Power/data boxes (like RatPac's PDB boxes) are lunchbox-sized electrical distribution boxes that also provide data (Figure 14.16). Boxes are available from a few manufacturers that incorporate an optical splitter for DMX (XLR 5-pin) outputs for wired connection to nearby lights. Power/data boxes can be connected to the control network via built-in wireless DMX transceiver (CRMX) or by DMX cable. RatPac also makes boxes with DMX-controlled power circuits for each outlet (PDB 6, 8, and 12).

Each box has a power indicator, DMX signal indicator, over-temperature light, and bump buttons for each power circuit. If the box provides remote switching, a DMX address wheel, panic button, and reset button is provided. For wireless, an RF link indicator light, signal strength indicators, and antenna are provided. The box also has manual-reset overcurrent protection for each circuit. Boxes are available in various configurations as shown in Table 14.5.

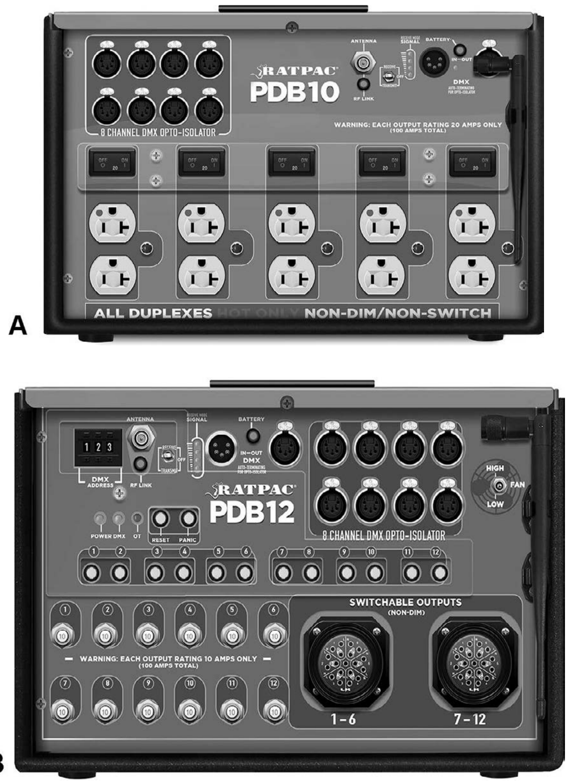


FIGURE 14.16

Power/data boxes (PDB). (A) PDB 10, 100 A Stage pin in, 5 duplex hard power circuits (non-dim), plus wireless CRMX (select either transmit or receive), and optical splitter with 8 DMX data link outs. (B) PDB 12, with similar options as the PDB 10 but with two 6-circuit Socapex connectors.

(*Courtesy RatPac*)

Table 14.5 Sample of some power/data boxes

Product	Power circuits	Output connector	Input connector	Data
RatPac				
PDB 6	6 DMX -controlled	1 × Socapex	100 A, 220 V, Stage pin	CRMX Tx or Rx DMX opto-splitter, 1 in, 1 thru, 8 isolated ports
PDB 8	8 DMX-controlled	8 × Edison (single) @ 10 A	100 A, 120 V, Stage pin	CRMX Tx or Rx DMX opto-splitter, 1 in, 1 thru, 8 isolated ports

Continued

Table 14.5 Continued Sample of some power/data boxes

Product	Power circuits	Output connector	Input connector	Data
PDB 10	5 hard power	10 × Edison (5 duplex), 100 A pass thru	100 A, 120 V, Stage pin	CRMX Tx or Rx DMX opto-splitter, 1 in, 1 thru, 8 isolated ports
PDB 10	5 hard power	10 × Edison (5 duplex), 100 A pass thru	100 A, 120 V, Stage pin	Two Universe CRMX Tx or Rx DMX opto-splitter, 1 in, 1 thru, 8 isolated ports
PDB 12	12 DMX-controlled	2 × Socapex, @ 10 A	100 A, 120, Stage pin	CRMX Tx or Rx DMX opto-splitter, 1 in, 1 thru, 8 isolated ports
Blackcat				
OctoCAT-N	8 hard power	9 × Edison (duplex) @ 20 A, plus USB 5 V	100 A, 120 Stage pin	Ethernet node: RJ-45 in, 8 × DMX/RDM (XLR 5-pin) out
OctoCAT-W	8 hard power	9 × Edison (duplex) @ 20 A, plus USB 5 V	100 A, 120 Stage pin	Duel CRMX two universes Tx or Rx. Opto-splitters, XLR in, XLR out, 4 × DMX ports
OctoCAT-P	8 hard power	9 × Edison (duplex) @ 20 A, plus USB 5 V	100 A, 120 Stage pin	Programmable DMX/RDM Opti. 2 XLR in, 8 XLR out.
OctoCAT-R	8 hard power	9 × Edison (duplex) @ 20 A, plus USB 5 V	100 A, 120 Stage pin	DMX/RDM splitter with 1 in and 8 out.

CHAPTER

Dimming equipment

15

Dimmers enable remote control of incandescent, LED, and certain fluorescent lights. The dimmer can be controlled directly via a control knob or slider on the dimmer or via a control protocol like DMX512.

A dimmer reduces light intensity of an incandescent light by reducing the effective wattage of the light, either by reducing the voltage (with a variac or resistance dimmer) or by reducing the time within each AC cycle that voltage is present. This is called *phase control* dimming. Forward-phase control dimming is performed by a solid-state relay (SSR) such as a silicon controlled rectifier (SCR) or by a triac. Forward- and reverse-phase dimming can also be performed by IGBT or MOSFET switching electronics, which have certain advantages over SCRs.

COLOR TEMPERATURE

Either method reduces the color temperature of an incandescent light, turning it gradually more yellow and orange as it is dimmed, as shown in Table 15.1. As a rule of thumb, the light changes 10 K per volt. Ten volts over or under line voltage increases or decreases the Kelvin temperature by 100 K. Dimmers are therefore useful only to the extent that the color change is not noticeable or when it is acceptable for the scene.

DIMMING TYPES AND APPLICATIONS

There are a variety of types of dimmers. It is important to understand how the dimmer is controlling the load so that lights may be paired with a control device that works with the device and maximizes

Table 15.1 Color temperature and output at various voltages

	Color temperature		
Voltage (V)	**Kelvin (K)**	**MIREDs**	**Light output (%)**
120	3200	313	100
110	3100	322	75
100	3000	333	55
90	2900	345	38

its dimming capability. Failing to do so can result in a light going out rather than dimming beyond a certain point or flickering either visibly or when photographed. The set lighting department has the responsibility to ensure that any lights can be controlled. Prior to approval, any untested light fixture or lamp should be powered up using the proposed type of control device in as true-to-life conditions as possible.

Household dimmers

Small 600 and 1000 W household AC dimmers (*hand squeezers*) are often used to control practical lamps and small fixtures (Figure 15.1). These are triac, or more formally a bilateral triode thyristor, a type of forward-phase solid-state relay (SSR). They are designed for incandescent and will usually be problematic with fluorescent and LED lights. A 150 W socket dimmer screws into the bulb socket. They are handy for controlling low-wattage practical incandescent lamps.

Variac dimmers

The variac is a variable transformer called an *autotransformer*. It dims incandescent lights by controlling the voltage. It can boost the voltage up to 140 V or decrease it to zero. These dimmers come in 1k, 2k, and 5k sizes (Figure 15.2). Typically, they are fitted with an on/off switch as well as a large rotary knob. Some have a three-way 120 V/off/140 V switch.

FIGURE 15.1

“Hand squeezer” or household dimmer.

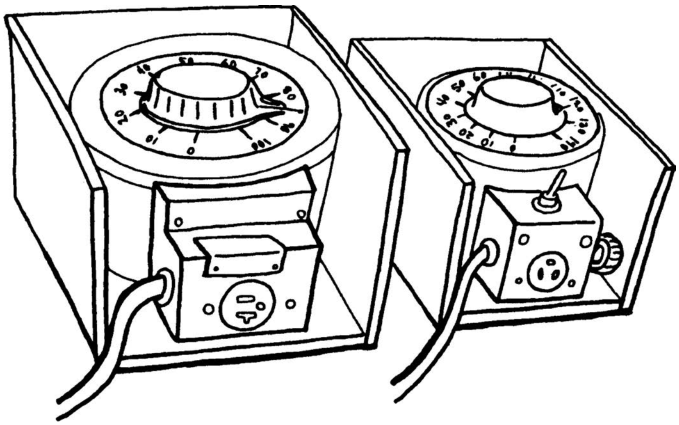


FIGURE 15.2

Variac dimmers in 2k and 1k sizes. The 1k dimmer knob is marked in volts, from 0 to 140 V. The scale on the larger variacs runs from 0 to 100 percent, which does not refer to volts. When set at 85 percent, the dimmer delivers line voltage (120 V). At 100 percent, the variac boosts voltage to 140 V.

Lunchbox dimmers and silent on-set dimmers

100A lunchbox dimmers, like those from RatPac, are SSR-type dimmers that are designed to run virtually silently for near-set/on-set use (Figure 15.3A). They feature a built-in wireless DMX (CRMX) receiver and come in a variety of configurations including Edison and Socapex outlets.

Dimmers tailored for LEDs and small incandescent lamps

Some LED tubes from Quasar Science, Colt, Sourcemaker, and others, do not have dimming built in. The manufacturer intends for them to be dimmed externally using phase control dimmers. These tubes do not operate properly on household-type triac dimmers. Typical 2.4 kW dimmer packs are not designed to control loads of less than 75 W. LEDs are often too small to operate properly resulting in flickering or blacking out early. The dimmer may require a *ghost load* to get the light to operate properly. A ghost load is a small additional tungsten load, typically 15 W or more, that you add to the circuit to stabilize it. According to Quasar's literature, some dimmers require a ghost load for loads under 50 W (ETC Smart Module, Elation Cyber Pack, American DJ, Leprecon dimmers).

Another complicating issue is power factor. It is more difficult to dim tubes that have low power factor. For example, a tube with a power factor of 0.95 can be dimmed more reliably than one with a PF of 0.69. Power factor should be published by the manufacturer, otherwise the light can be tested with an electrical meter capable of reading power factor (see Chapter 17).

RatPac's 12 x 200 W unit uses low-wattage, revere-phase, MOSFET dimmers that are capable of controlling LED tubes down to as low a dim value as possible (Figure 15.3B). They are also great for low-wattage incandescent bulbs.

Dimming an LED with a phase control dimmer is unusual because the 60 Hz input power to an LED has no direct connection to the high-frequency DC pulse width modulation (PWM) dimming that

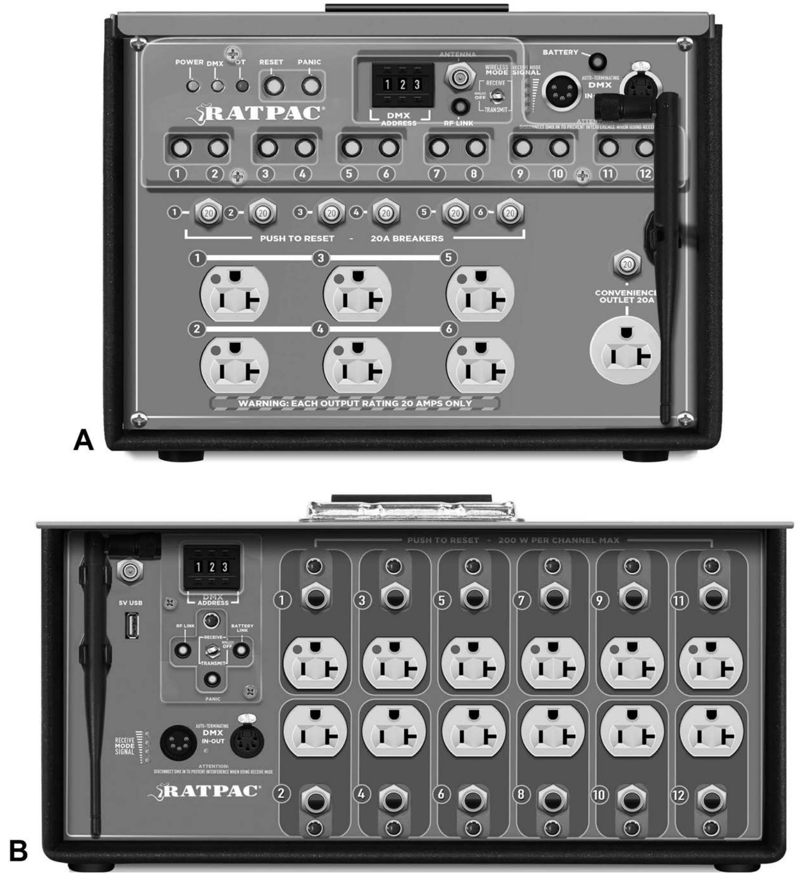


FIGURE 15.3

(A) RatPac 6 × 2.4 kW Edison Lunchbox Dimmer. Also available with Socapex output. (B) The 12 × 200 W is designed for 120 V LED tubes and low-wattage practicals that require a smooth dimming curve down to 1 percent. The dimmer also has a USB out for convenient device charging. Both dimmers have CRMX wireless DMX receivers.

actually controls the apparent brightness of the LED emitters. What is actually happening is that the LED's electronics have been designed to use the 60 Hz phase controlled waveform as a signal for how much to dim the LEDs. There comes a point where the phase control dimmer is not providing enough current for the LED's controller to operate, and it just shuts off.

Stand-alone dimmers

Dimmers, like the Strand CD80 240 V 20k SCR dimmer and RatPac's 24k dimmer (Figure 15.4), are so large that they are typically housed as stand-alone units. When powering 20k tungsten lights, a dimmer should always be used to protect the lamp from high inrush current on start-up.

FIGURE 15.4

RatPac 24k Single channel dimmer.

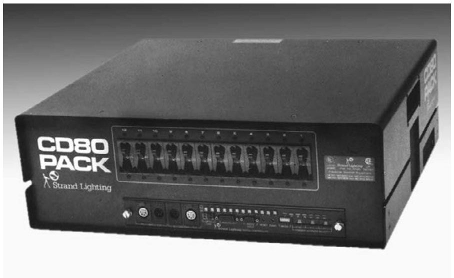


FIGURE 15.5

CD80 Digital Pack 12 x 2.4 kW.

(*Courtesy Philips Strand Lighting*)

Dimmer packs

Dimmer packs (Figure 15.5) may house six to twenty four SCR dimmers. Output circuits can be 1.2, 2.4, 6, 12 kW. Electronic dimmer packs are controlled via DMX512 using a control console. RatPac makes dimmer packs that include built-in ghost loads and other circuitry to help LEDs operate properly without having to add a ghost load to every circuit.

Dimmer racks

When a large number of incandescent lights are to be controlled, electronic dimmer racks provide 24 to 96 SCR dimmers controlled via DMX512 or Ethernet (Figure 15.6).

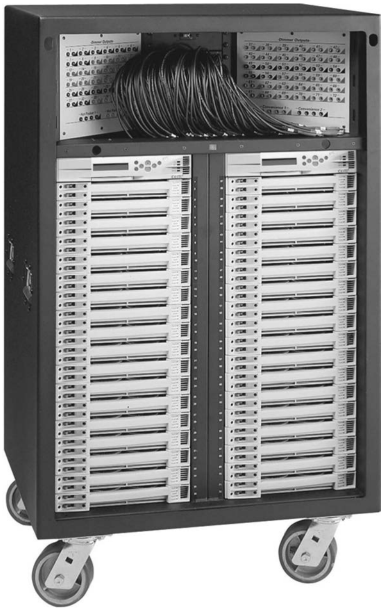


FIGURE 15.6

ETC's Touring Sensor Dimmer Rack.

(*Reproduced by permission of Electronic Theatre Controls, Inc.*)

WIRELESS DMX ON-SET DIMMERS

RatPac's lunchbox dimmers are an example of a fully integrated, modern approach to providing on-set lighting control. Traditional SCR packs and racks are too noisy to be used on set; they have to be placed in another room. This makes it necessary to run power to the room and then run all the individual dimmer circuits back to the set, which involves a fair amount of cable and work. Having the dimmers on set, just like any other distribution box, enables the lights to be immediately plugged to DMX-controlled dimmer circuits. If hard power is needed for some circuits, that circuit can be set to non-dim, so the lunchbox dimmers don't add to the distribution, they mostly just replace it (Table 15.2). RatPac's equipment is equipped with LumenRadio wireless DMX, so it integrates right into the rest of the control network, eliminating DMX cables if desired. The units also have 5-pin XLR in-out for wired DMX.

On sets that are dressed with lots of small practicals—sconces, table lamps, etc.—where you want to have individual control of each item, and for sets that employ externally dimmable LED tubes, it makes sense to have small circuits available like 200 W or 1.2 kW. Reverse-phase dimming, which we'll explain in a minute, is better for dimming LED tubes and eliminates the filament vibration in

Table 15.2 RatPac dimmers

Dimmer	Output	Input	Wireless DMX
Quiet Dimmers (lunchbox dimmers)			
12 x 200 W	Edison	PowerCON 120 V, 20 A	√
10 x 1.2 kW	Edison	100 A Bates	√
12 x 1.2 kW	2 Socapex	100 A Bates	√
24 x 1.2 kW	4 Socapex	CamLok 80 A/phase	√
6 x 2.4 kW	1 Socapex or 6 Edison	100 A Bates	√
12 x 2.4 kW	2 Socapex	CamLok 80 A/phase	√
3 x 12 kW	3 100 A, 120 V Bates	CamLok 100 A/phase	√
3 x 24 kW	3 100 A, 240 V Bates	CamLok 200 A/phase	√
Stand alone dimmers			
2.4 kW	20 A PowerCON	PowerCON 120 V, 20 A	
12 kW	100 A Bates	100 A Bates	√
24 kW	100 A, 208 V Bates	100 A, 208 V Bates	√
Packs			
24 x 2.4 kW	4 Socapex	CamLok 160 A/phase	√
6 x 12 kW	6 100 A Bates	CamLok 200 A/phase	√
Rolling racks			
48 X 2.4 kW	4 Socapex	CamLok 320 A/phase	√
24 x 12 kW	24 100 A, 120 V Bates	CamLok 800 A/phase	√
6 x 24 kW	6 100 A, 208 V Bates	CamLok 400 A/phase	√

tungsten lamps that can cause singing or buzzing. MOSFET and IGBT dimmers are completely silicon-based and operate silently without the use of chokes, and do not produce the mechanical hum associated with SCR dimmers. They are smaller, lighter, and generate fewer neutral harmonics than SCR dimmers.

The RatPac units are designed for practicality on-set. They have battery backup for the wireless link, so you can operate the transceiver without AC power. The casing has rigging points (threaded holes and metal straps) on the top so it can be hung or secured wherever it needs to be rigged. There is a 5 V USB out for charging your phone or for recharging battery-powered equipment. The dimmers are designed to eliminate points of possible error by being self-terminating. The units are set for DMX status quo, which means in the event that the control signal is interrupted, the dimmers will stay at their last setting. Indicator lights on the pack tell you if you have power, DMX signal, and give wireless signal strength.

DIMMER PACKS AND RACKS

For many years the Strand CD80 and ETC Sensor Racks have been the dominant types (Table 15.3). Manufacturers have been able to design lighter, smaller more densely packed dimmer systems. The Strand LightRack and ETC SmartPack are examples of the newer generation of touring systems ideal when a few dozen 10 and 20 A circuits are sufficient to cover your lighting needs. The Strand LightRack series use quieter, lighter, reverse-phase dimmers (explained shortly), and can also be fitted with 208 V constant power modules to serve as a distribution hub for 208 V moving lights. These mini racks are

Table 15.3 Common dimmer configurations and power requirements (per phase)

		Amps Per Phase at 120/208 V Three-Phase (A)	Amps Per Phase at 120 V Single-Phase (A)
Strand CD80 Packs			
12	1.2 kW dimmers, 15 A circuits	60	90
24	1.2 kW dimmers, 15 A circuits	120	NA
12	2.4 kW dimmers, 20 A circuits	80	120
24	2.4 kW dimmers, 20 A circuits	160	NA
6	6 kW dimmers, 50 A circuits	100	150
6	12 kW dimmers, 100 A circuits	200	NA
1	20 kW dimmer, 240 V, 100 A	NA	NA
Strand CD80 Touring Racks			
48	2.4 kW dimmers, 20 A circuits	320	NA
96	2.4 kW dimmers, 20 A circuits	640	NA
24	6 kW dimmers, 50 A circuits	400	NA
24	12 kW dimmers, 100 A circuits	800	NA
ETC Sensor Packs			
12	1.8 kW dimmers, 15 A circuits	60	NA
24	1.8 kW dimmers, 15 A circuits	120	NA
12	2.4 kW dimmers, 20 A circuits	80	NA
24	2.4 kW dimmers, 20 A circuits	160	NA
6	6 kW dimmers, 50 A circuits	100	NA
12	6 kW dimmers, 50 A circuits	200	NA
3	12 kW dimmers, 100 A circuits	100	NA
6	12 kW dimmers, 100 A circuits	200	NA
ETC Sensor Touring Racks			
24	1.8 kW dimmers, 15 A circuits	120	NA
48	1.8 kW dimmers, 15 A circuits	240	NA

Table 15.3 Common dimmer configurations and power requirements (per phase)

		Amps Per Phase at 120/208 V Three-Phase (A)	Amps Per Phase at 120 V Single-Phase (A)
96	1.8 kW dimmers, 15 A circuits	480	NA
24	2.4 kW dimmers, 20 A circuits	160	NA
48	2.4 kW dimmers, 20 A circuits	320	NA
96	2.4 kW dimmers, 20 A circuits	640	NA
24	6 kW dimmers, 50 A circuits	400	NA
48	6 kW dimmers, 50 A circuits	800	NA
12	12 kW dimmers, 100 A circuits	400	NA
24	12 kW dimmers, 100 A circuits	800	NA

Note: 15 and 20 A Sensor modules are available as dual dimmer modules (one or two dimmer circuits per module). This allows a rack with 48 module slots to house 96 15 or 20 A dimmer circuits.

modular systems with interchangeable parts, so they can be configured to custom specifications for each show—ampacity and number of dimmers, type of modules, and type of output connector are all easily configured.

The other major advance is in communication protocols and equipment feedback. In film work, we tend to stick with simple DMX512 control; however, dimmer racks can also use RDM and Ethernet control protocols which the programmer can use to address the rack and read-out data about each rack, and each dimmer including ambient temperature, voltage and frequency, dimmer load, and other diagnostic data.

Dimmer rooms

Ideally, the rack is mounted in a special air-conditioned, soundproof room, which eliminates the problems of both cooling and noise. When a large number of dimmers are used, we often build a shack outside the sound stage to house them. The shack protects the dimmers from sun and rain. It provides a floor that is raised above grade level. It has windows or vents in several walls to allow air to circulate through the shack or air-conditioning units are installed to force air circulation. It is a good idea to monitor the room temperature with a thermometer in the dimmer shack.

ELECTRONIC DIMMER DESIGNS

Forward-phase control electronic dimmers (SCR) have been the dominant technology since the 1960s; however, there are actually several types of dimmer circuits currently available including reverse-phase control (IGBT or MOSFET), and sinewave dimmers.

Forward-phase control dimmers—SCR

Forward-phase control dimmers use a very simple, reliable device called a *solid-state relay* (SSR) that is made up of a pair of *silicon controlled rectifiers* (SCR) to regulate power. An SCR is a type of *thyristor* (a solid-state latching relay) that conducts electricity in one direction only. By connecting two SCRs in parallel but in opposite directions in a circuit, one can make a solid-state device that regulates alternating current in both directions. Rather than increasing or decreasing voltage (the *amplitude* of the AC sinewave) as with a variable transformer, an SCR dimmer increases and decreases power by regulating the *duty cycle*, the on/off time, chopping up the sinewave as shown in figure 15.7. The brains of the dimmer, the controller card, detects the incoming control signal (such as DMX512 or Ethernet), decodes it, and produces *pulse-width modulated* signals in sync with the dimmer's power phase to tell each SSR when to activate. Thus, during each half-cycle of the AC sinewave, the dimmer controls output by varying how long the dimmer waits before it activates. The circuit automatically deactivates each time the wave passes through zero. This is known as *forward-phase control* dimming.

Forward-phase control is fairly simple and very reliable, and is an effective way to dim incandescent lights. Because the sinewave is chopped up, phase control dimmers cannot be used on line with HMI fixtures or electric motors (such as motorized stands and fans). Using forward-phase electronic dimmers with such loads can cause damage to the load.

The disadvantages to phase control dimmer technology are as follows:

- Phase control dimmers are *nonlinear* loads (the current is not in proportion to the voltage). When dimmed, they draw current during only part of each line cycle. This creates harmonic distortion of the mains current. These harmonic currents add up on the neutral conductor. The neutral conductor may have to carry as much as 1.3 times the phase current even when the loads are equally distributed between phases. To carry the additional current, the neutral conductor size must be increased on the feeder cable and the power source.
- The on/off switching of the SCRs creates vibrations in the lamp, which produces buzz or "sing" when dimmed. This noise is worst at 33 percent and 66 percent intensity. Dimmers use toroidal filters (doughnut-shaped coils) commonly called *chokes*, which round-off the abrupt rise of voltage and inrush of current with each half-cycle. The bigger the choke, the longer the rise-time and the less

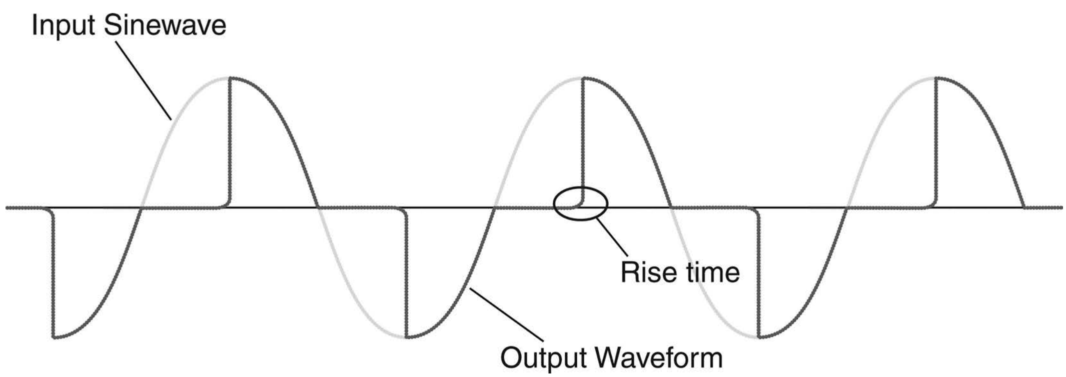


FIGURE 15.7

Forward-phase dimming regulates power by varying the duty cycle. At 50 percent power, the circuit remains off during the rise in the sinewave, then switches on at the peak of the wave.

“sing.” Phase control dimmers with 800 μs rise time are significantly quieter than those with 350 μs rise time; however, lamp noise is not eliminated.
- The vibration also reduces lamp life.
- The chokes cause heat losses that result in a typical SCR efficiency of about 95 percent. The chokes also account for a lot of the weight of a dimmer.
- With very small-filament lamps, phase control dimming at 60 Hz can cause flicker at certain frame rates and dimmer settings.

Most of the time, SCRs do not cause flicker, because the glow of filament in the lamp does not have time to decay appreciably between half-cycles, when using very small lamps at very low dimmer settings and filming off-speed, you can have flicker register on film, just as you would with HMIs using magnetic ballasts. A friend of mine was filming a large sign fitted with hundreds of tiny 100 W bulbs. The sign was patched into the SCR dimmer system and was set at 35 percent. For normal filming (24 fps), this was fine; however, when the camera was set to 48 fps and the shutter angle set to 90° (giving an effective shutter speed of 1/96 of a second, which is not a flicker-free speed), the lights flickered on film. The main ingredient to this snafu was the small size of the lamp filaments. The smaller the filament, the more quickly it responds to changes in voltage. Lamps with larger filaments do not cause this problem. In this case, if variac dimmers had been used instead of SCR dimmers, if the dimmer setting had been higher, or if the camera had run at 40 or 60 fps (which are flicker-free speeds), the lights would not have flickered on film.

Reverse-phase control dimmers

IGBT dimming was introduced in 1992 by Entertainment Technology as a way to reduce lamp and dimmer noise. An IGBT (Insulated Gate Bipolar Transistor) is a type of high-speed switch device, developed in the 1980s, that is used in power electronics. The idea is to employ IGBTs to perform *reverse-phase control* which will reduce the high inrush current that causes lamps and dimmers to vibrate. This is the same idea as forward-phase control, except that instead of chopping the front of the sinewave (using SCRs), IGBT dimming chops the back (Figure 15.8).

A MOSFET is another type of transistor that can be employed for reverse phase-control dimming, usually for dimmers of 200 W or less.

This way the current rises smoothly up to the cutoff point. This eliminates the need for chokes, making the dimmer smaller and lighter, with around 3 V less voltage drop, and reduces the lamp noise. The rise time or fall time used by an IGBT dimmer can be varied by the electronics, and is often automatically reduced to counteract a rise in dimmer temperature. Thus, lamp noise may increase if the dimmer temperature increases. Harmonics and excessive neutral current are about the same as forward-phase control dimmers.

The likelihood of recording flicker is the same as with forward-phase dimmers (when filming at nonstandard camera speeds and low dimmer settings using small-filament lamps). Strand Lighting (LightPack and LightRack) and Entertainment Technologies make IGBT dimmer packs and dimmer strips in 1.2 and 2.4 kW sizes as well as small stand-alone devices.

A dimmer like the Bak Pak dimmer (Intelligent Power Systems), or Strand LightPack has some good applications in film work. The small stand-alone 750 or 1200 W IGBT dimmer can be set to either forward-phase or reverse-phase dimming. It is completely silent, so it can be used on set, hung on the light stand and used close to actors, with no sound issues from the lamp or the dimmer. Figure 15.9

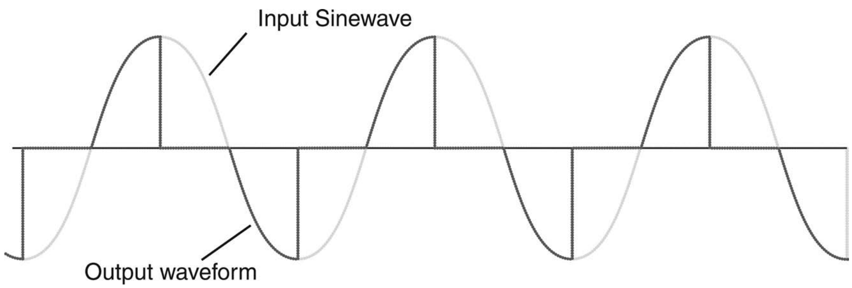


FIGURE 15.8

Reverse-phase control dimmer waveform at 50 percent intensity.

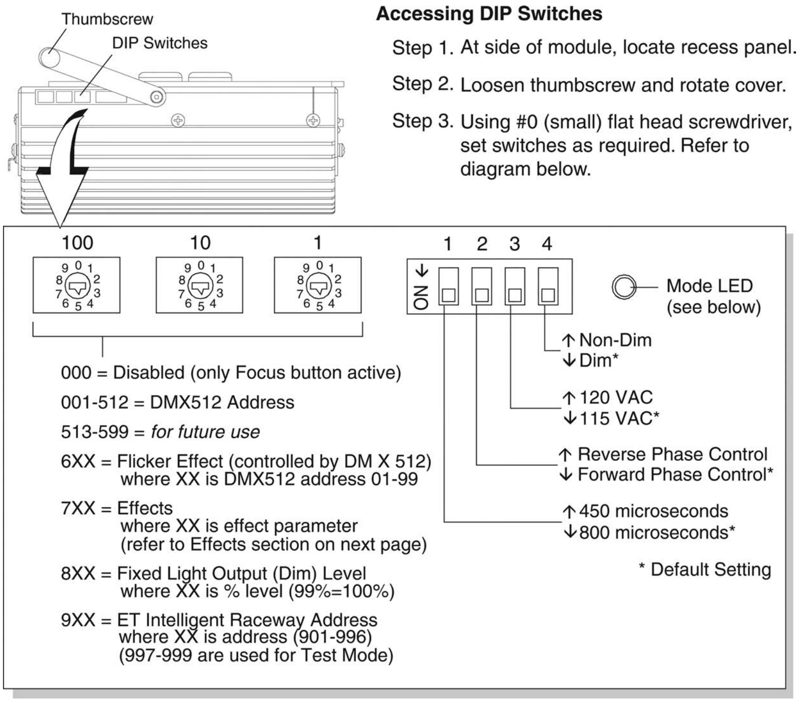


FIGURE 15.9

Bak Pak IGBT dimmer, also branded as Strand LightPack dimmer. The three-digit address you enter determines the functionality of the dimmer. Entering 000 allows local control via the "focus" button located at the bottom of the unit. Hold the "focus" button down to run the level up or down. The Mode LED indicates the mode entered, and the presence of a DMX512 signal by blinking in one of several patterns (see operation manual).

(*Courtesy Philips Entertainment Technology*)

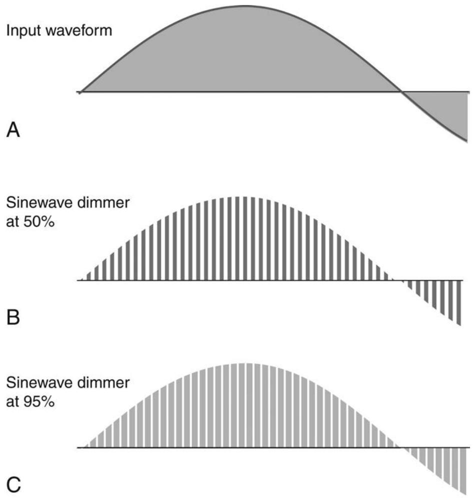


FIGURE 15.10

Sinewave dimmers divide the input sinewave (A) into very short periods and then control the duty cycle within those very short periods. When the duty cycle is set to 50 percent (B), the resulting output voltage waveform delivers half the input voltage. With the duty cycle set to 95 percent (C), the resulting output is 95 percent of full power.

shows the many features these flexible little devices incorporate, including: DMX512 control of dimmer, DMX512 control of flicker effects, dimming and flicker effects without any DMX512 control, rise time, and so on. You can also create coordinated effects between multiple Bak Pak units using one Bak Pak unit as a DMX512 transmitter by adding a small accessory called an Intelligent Effects Network Coupler.

Sinewave dimmers

In contrast to phase control dimmers, sinewave dimmers produce a *full sinewave* (Figure 15.10). It is essentially an electronic version of the old autotransformer or variac dimmer. This technology *completely* eliminates the problem of lamp noise and harmonic currents on the neutral.

At this writing, sinewave dimmers are available in North America for permanent installations only, not in portable rack or pack versions. The Strand SST Series is available in 1.2 and 2.4 kW, and the ETC Sensor Sinewave in 2.4 kW. Larger sizes are available in Europe. Sinewave dimming is not currently used in motion picture and television applications, and may not ever be.

STRAND CD80 DIMMER PACKS

Two of the most commonly used dimmer systems for motion picture and television applications are the Strand CD80 series and the ETC Sensor series. Dimmer manufacturers provide operation manuals and all kinds of other information about their equipment online. It is a good idea to download the information for the model you are using so that you have setup and troubleshooting information right at hand.

Installation and setup

CD80 packs must receive adequate ventilation and be kept below 104 °F and no more than 80 percent humidity with no condensation. If the heat sink exceeds its temperature limit, it will shut down automatically. The CD80 packs are about 95 percent efficient; that means that 5 percent of the power has to be dissipated as heat. As many as eight packs may be stacked vertically. Do not place more than two units side by side unless there is at least 24 in. between packs. Otherwise, the exhaust heat from one pack is blown directly into the intake vent of the next pack. The packs are not designed to be used outdoors. Keep vents clear from obstruction, dirt, fibers, paint particles, and so forth. Sometimes it is convenient to mount the pack vertically on the wall. Orient the pack so the intake vent is at the bottom. Heat from the dimmer creates a chimney effect; you want the intake at the bottom and the outlet vent at the top; otherwise, the fans are fighting the natural airflow.

The brain of the CD80 pack is the *digital pack controller* commonly known as the *card*. The digital controller comprises a faceplate mounted on a control card. The control card slides into slots in the front panel of the dimmer pack. Two thumbscrews secure it in place (Figure 15.11). In case of failure, the entire card can be replaced in the field. With the input power turned off, the digital pack controller can be removed and installed without disconnecting any wiring. Loosen the thumbscrews and pull on the thumbscrews to slide the controller straight out of the pack.

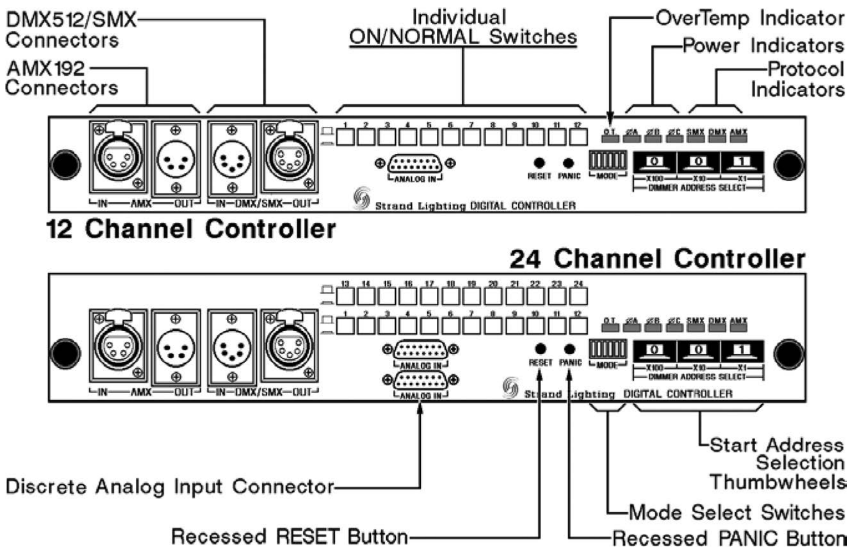


FIGURE 15.11

CD80 digital pack controller card.

(*Courtesy Philips Strand Lighting*)

To install the controller (again, power off), line the controller up with guides on each side of the slot and slide the module in carefully until it touches the connector in the pack. Firmly set the controller by pressing on both ends of the module. Tighten in place with thumbscrews.

The faceplate contains the connectors, buttons, and indicator lights that affect everything the dimmer pack does. Later models of the CD80 use a digital control card with a menu-style interface, but perform all the same settings as the original.

- Input and output connectors for AMX-192 control cable (four-pin XLR). AMX-192 is obsolete.
- Input and output connectors for DMX512 control cables (five-pin XLR).
- Input connectors for 12 or 24 discrete analog control signals on a multipin connector. Analog is sometimes used in theaters to control house lights. It is not used for our work.
- Three power indicator lights (green) that show each input power phase present (ϕA, ϕB, ϕC). Use these to check the input power lines.
- Three protocol indicator lights (yellow), which show the protocol currently being decoded (AMX-192, DMX512, or analog).
- Six mode-select dip-switches, used to set various important parameters of operation. Table 15.4 outlines the function of each of these six dip-switches. Be especially sure that switches 2 and 6 are set correctly or the dimmer pack may not work properly. If you change dip-switch settings during operation, press the reset button to enter changes.

Table 15.4 Dimmer controller card dip-switch settings

Position 1	**Off:** No effect
	On: No effect
Position 2	**Off:** Three phase
	On: Single phase
Position 3	When using analog and multiplexed protocol simultaneously, this switch determines if the output signal to the dimmer is the sum of the two signals (up to 100%) or the higher of the two signals (pile-on)
	Off: Highest takes precedence (pile-on)
	On: Dimmer level is analog + protocol
Position 4	Off: 0–15 V DC input level for analog input
	On: 0–10 V DC input level for analog input
Position 5	**Off:** In the event of loss of control signal, the dimmers retain current levels for 30 minutes
	On: In the event of loss of control signal, the dimmers black out
Position 6	**Off:** Uses every other control signal, starting with the thumbwheel number (use with 6 kW and 12 kW dimmers when using Strand lighting systems AMX-192 where 6 kW/12 kW dimmer assignment is made in the control console)
	On: Uses consecutive control signals starting with the thumbwheel number

Notes: Normal settings are shown in **bold**. Press the reset button to enter changes during operation. The control board reads these settings only during start-up or when you press reset.

- Over-temperature indicator light (red)—the dimmer pack shuts down automatically and this light comes on if the heat sink temperature exceeds 85 °C. This would happen if the vents were blocked, if ventilation were inadequate, or if the fan motor failed.
- Three numbered thumbwheels used to assign the start address for the dimmer pack. Addressing is also discussed in Chapter 12.
- Recessed "panic" button. When pressed, this button turns all dimmers on. Push it again to return dimmers to normal operation. Use a bent paperclip or other small probe to get to the recessed button.
- Recessed reset button. When pressed, this button tells the card's processor to restart.
- 6, 12, or 24 two-position circuit test pushbuttons. When set to the IN position, each button turns on the associated dimmer to full and overrides the control signal or operates the dimmer in the absence of a control signal. When the button is in the OUT position, the dimmer operates normally and the backlit button shows the approximate level of the associated dimmer.

Three small (0.250 A fast-blow) phase fuses are located on the controller card. If a phase B or C fuse blows, the dimmers connected to that phase will not function. If the phase A fuse blows, the controller is completely disabled. Replacing the fuses requires no special tools or procedures. With input power turned off, remove the controller card from the pack, replace the faulty fuse, and carefully reinsert the controller module.

Troubleshooting

Problems affecting the entire pack

No phase LED lit:

- No power to the dimmer pack. Check distribution and cable connectors.
- Controller may not be seated correctly. Remove and reinstall the controller.
- Fuse F1 (phase A) may be open (blown). Replace as discussed previously.
- If the fuses are okay and you can turn the dimmers on with their individual pushbuttons, the controller module is defective. Replace it with a spare and return it to the owner or Strand Lighting for repair.

Phase B or C LED not lit:

- Fuse F2 or F3 is probably open. Replace the fuse (discussed previously).

All phase LEDs lit but no protocol indication:

- Check for incoming control signal using a DMX512 tester (see Chapter 12). Control console is unplugged or control cable is disconnected.
- Incoming control wiring may be miswired or one or more conductors broken.
- Replace control cable or check its continuity and wiring.

No control of dimmers (dimmers are always off):

- If the overtemp light is on, the pack has shut down from overheating. Make sure that the air intake and exhaust ports are not blocked and wait for the thermostat to reset.
- The thumbwheel settings may be set to an incorrect address. Double check your settings.

No control of dimmers (dimmers are always on):

- The "panic" button may be on or the individual dimmer pushbuttons may be on.

Problems confined to one phase

- Problems that are confined to one phase are usually related to controller problems or to the dimmer pack being incorrectly set up for the type of power in use.

Consecutively numbered dimmers will not go on:

- One phase of the power feeding the pack is off or not connected (for example, on a 12-dimmer pack, phase A powers dimmers 1–4, phase B powers dimmers 5–8, and phase C powers dimmers 9–12).
- The controller module may be incorrectly inserted. Remove it and carefully reinsert it into the dimmer pack.
- One or more output control circuits (in the controller card) have failed. Swap the controller card with a known good spare. If the problem goes away, return the defective controller for repair.

One or more dimmers on the same phase do not come up to full or do not track correctly:

- The mode-select switch (in position 2) may be incorrectly set. Make sure the pack is set up for the type of power being used.
- The phase fuse may be open.
- One or more output control circuits (or the controller) may be defective. Replace the controller with a spare and return the defective card for repair.

Problems with individual dimmers

Check the following:

- Dimmer circuit breaker on.
- Load wiring and lamp operating properly (not burnt out). Check the load wiring and lamp by turning on the pushbutton switch for that dimmer circuit. If nothing comes on, the problem is in the wiring or the lamp itself.
- If you still have a problem, it is either a defective controller, defective discrete analog control wiring, or a defective SSR, circuit breaker, or choke. Each of these parts is designed to be easily replaced in the field. But of course this takes time and may involve moving the packs around in order to get to the affected pack.
- Check the controller module by replacing it with a known good spare. Make sure the mode-select switches are set the same way on the replacement controller. If the problem goes away with the new controller, return the defective controller for repair.
- Check for defective SSR, choke, or circuit breaker by checking the voltage at the circuit breaker output, choke output, and SSR output with the dimmer on. The component with an input but no output is defective (most commonly the SSR). Replace the defective component.
- If the dimmers flicker when at 50 percent, the control card is defective. Replace it.

Periodic maintenance

Strand recommends periodic maintenance every 6–12 months. Maintenance may or may not actually ever be performed by the rental house. Strand recommends consulting with a Strand field service technician to learn more about maintenance procedures. The short list includes:

- Power disconnected. Open the pack.
- Inspect for loose connections between components inside the pack.
- Vacuum out any dust buildup.
- Remove the control module, dust it off using a soft natural bristle brush, and clean the edge connectors with a mixture of 70 percent denatured alcohol and 30 percent distilled water, or other cleaning compound intended for gold edge connectors.
- Reinstall the power module and close the cabinet.
- Connect power to the pack. Connect a load to the dimmer outputs.
- Exercise each of the circuit breakers by turning them on and off several times while under load (the arc produced when the circuit breaker engages and disengages cleans corrosion and dust off the contacts).
- Connect control cable and verify proper dimmer function.

ETC SENSOR DIMMER SYSTEM

The Sensor series is a modular dimmer system (Figure 15.12). Dimmer modules can slide into and out of the rack, and once fully inserted all power and control connections are automatically made. If a module starts to act up, it can be replaced easily with a spare without opening or disassembling anything.

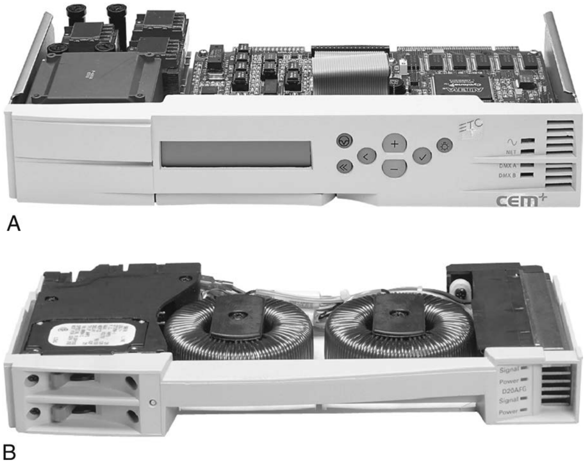


FIGURE 15.12

Sensor racks use a system of interchangeable dimmer modules: (A) Control Electronics Module (CEM), the brains of the Sensor Rack, (B) Class A GFCI Dimmer module (this module contains a pair of dimmers. Note the pair of circuit breakers. The two big windings are the choke coils).

(*Reproduced by permission of Electronic Theatre Controls, Inc.*)

To remove a module:

1. Turn the module circuit breakers off.
2. Press on the module retainer if installed (left side of module) to retract it.
3. Grasp the metal lip that extends from the face panel and gently pull the dimmer module out.

Each module has an LED marked “Signal” that will be on whenever the dimmer output is on. Sensor Advanced Feature (AF) modules have a second LED labeled “Output.” The Output LED is on any time the dimmer output is above zero. ETC makes a number of different types of modules that can be used in any compatible Sensor rack or pack:

Standard modules	Provides 100 percent constant use, fully magnetic circuit breakers. The rise time is either 350, or 500 μs depending on the model.
High rise time module	High rise time modules reduce filament buzz by using a longer rise time than standard modules. The rise time is 800 μs.
Advanced feature module	AF dimmers are designed to be used in Sensor+ enclosures. They incorporate an output voltage and current sensor in order to provide feedback to the control console about the dimmer and load circuit via an Ethernet-based protocol—either ETCNet2 or ETCNet3 (ACN). The rise time is 500 μs.
Fluorescent dimmer module	To control particular kinds of fluorescent circuits.
Relay module	On/off switch circuits (15 and 20 A modules only). Power for motors, moving lights, and ballasts.
GFCI dimmers	Dimmers with Class A GFCI overcurrent protection (15 and 20 A modules only).
Constant current CB module	Provides 100 percent constant use, fully magnetic circuit breakers with no control electronics (15 and 20 A modules only). The circuits can only be switched on and off at the circuit breakers, and not remotely. This type of module is used when you want to power a load through the same distribution system but it is not one that you would want to allow to be accidentally switched off—“hard power.”

The design of the ventilation requires that all module slots be filled when running. An *airflow module* is a blank that covers any unused slots to provide proper airflow. Space for spare modules is provided on the right side of the rack at the bottom. Spare modules do not automatically come with the rack; you have to order them.

The Control Electronics Module (CEM) is positioned at the very top of the stack of dimmer modules on the touring racks. The CEM contains all the control electronics. This is where the DMX start address is set as well as all the other setup options and features. There are several generations of Sensor racks in use: CEM, CEM+, versions 1.0, 2.0, and 3.0. The biggest change in each of these iterations is the Ethernet control. The CEM can memorize and playback up to 32 user-programmable backup looks. It can bypass the dimmer electronics to make circuit/lamp tests. It provides five selectable dimmer law output curves. The CEM has three-phase LEDs and an error LED as well as an LCD display that can present helpful information like:

Rack:	Voltage, frequency, start address, DMX512 port status, ambient temperature
Dimmer:	Rating, control level, output level, recorded load (AF only), current load (AF only)

The control module slides out of the rack just as the dimmer modules do, so it can be quickly replaced if it goes down. According to the ETC user manual, the rack does not need to be powered down; however, care must be taken, because the CEM contains exposed electrical components. Two holes in the bottom panel of the CEM expose live power until the CEM is removed from the rack. The correct way to remove the CEM is to slide the retractable handle out of the front (center bottom edge) and use only the handle to pull the module out. Looking at the circuitry of the CEM module, you will see a small fuse at the back of the module. This should be tested if the module fails. There is also a small switch at the front to the circuit board labeled TEST and NORMAL. Be sure this switch is set to NORMAL. TEST puts all the dimmers to full.

Proper ventilation and cooling are essential to all dimmer racks. Cooling air is drawn into the dimmer rack through the dimmer modules. The doors of the touring rack contain an electrostatic filter to keep particulates out of the cooling air. They should be kept closed when the racks are not being worked on. If they are dirty, you can clean them with a vacuum or compressed air hose (blow the dust off *away* from the dimmers not *into* them). A fan exhausts the air through a vent in the bottom of the rack. It is important that this remain clear. Don't let the best boy's *Wall Street Journal* or anything else get underneath the rack and block the air exhaust port. Note that when you are combining Sensor Racks with other kinds of racks in close proximity, you need to be aware of the ventilation patterns of the different racks and avoid feeding exhaust heat from one rack right into a neighboring one.

On the right side of many Sensor touring racks, you'll find a patch panel. This allows the user to customize the patch between the dimmer and the circuit. This feature is very handy for troubleshooting. If you have a bad cable, you can quickly repatch the circuit to a spare cable (you did run some spare cables, didn't you?). Or, conversely, if a dimmer fails, you can repatch the circuit to a working dimmer without having to get into the mass of cables coming out of the back of the rack. The patch panel also has "hot pockets" that allow you to bypass the dimmer and run hard power right to the circuit (convenient for testing). The Patch Panel consists of a panel of numbered patch sockets, one for each dimmer, and a set of cables for each Socapex outlet on the back of the rack. The cables are labeled with the letter associated with the Soco outlet, and the circuits are numbered 1–6, so you have A1–A6, B1–B6, C1–C6, and so on.

The back of the touring rack houses all the input and output connections and also the main circuit breaker. At the top of the rack are the DMX512 IN and THRU data connectors, and Ethernet signal inputs. Sensor touring racks configured with Socapex multipin connectors provide two Socapex connectors for each circuit. The connectors you use have to be patched in the patch panel. You will often only be using every other Soco output from the rack. Because the outputs are packed close to one another, it is convenient to offset the rows of connectors. This provides space to get your hands around the connectors. A Soco rack also provides 20 A Stage Pin connectors (that are hard-wired and cannot be patched). These are sometimes helpful for troubleshooting. Racks also provide hot pockets on the back and Edison courtesy outlets.

The power inputs are Camlock. Test points are provided above each of the power input connectors. Each of the phase inputs has an indicator light to show whether voltage is present. The test points and indicator lights are protected with 2 AG fuses located next to them.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

CHAPTER

16 Electrical rigging

The job of the rigging crew and systems technicians is to install the power and data infrastructure and rig any lights that could be time consuming for the first unit crew. A well-rigged set is orderly, well thought out, well labeled, there is always easy access to power, and everything is well tested. The rigging crew can dedicate the time and forethought to set things up so that everything works smoothly. They can anticipate possible problems or hazards and design solutions.

THE ROLE OF THE RIGGING GAFFER

It is the responsibility of the rigging gaffer to design the rig, oversee its installation and testing, and troubleshoot any problems before the production crew arrives to begin photography. The rigging gaffer works in tandem with several other key people:

- The production manager and production staff who have to approve and order the equipment and expendables from vendors and manage the budget. This includes providing the locations manager with a schedule of the rigging crew's activities, so the manager can make arrangements for parking, bathrooms, and transportation for the rigging crew. Arrange with transportation to have trucks or other vehicles available when needed.
- The rigging key grip and rigging grip team who supply all the physical structures to which the lighting is attached (truss, pipe, Condor rigs, wall spreaders, etc.) and perform all the grip work (blacking out areas, tenting over windows, erecting translights and green screens, etc.). The rigging gaffer coordinates with the rigging key regarding the weight of loads for truss and chain motors and support for waterfalls.
- A large scale production may have a fixtures person (or team), who is responsible for installing, powering, and controlling lighting that is built into the sets and any on-camera lighting elements and practical lights. On a smaller production this may fall to the rigging crew. It is a good idea to work with the set dresser to ensure that any lightbulb they want to use is suitable for photography and can be controlled. Ask to see each of the lamps they plan to use and test them yourself if needed.
- On a big show there will be a lead systems tech who supervises the installation of Ethernet and DMX networks. There may also be a rigging programmer, who prepares the console show file, consults on the design of the network, and may program and test lighting cues that require preparation. On smaller shows, with more modest network requirements, these responsibilities may fall to the rigging crew and first unit programmer.
- Riggers install the rig, and wrap it out again after the shooting is completed.

More specifically, the rigging gaffer and crew are responsible for the following:

- Scout the locations, making notes of the lighting, power, special equipment, and lengths of feeder runs.
- Compile equipment orders. Estimate feeder cable lengths.
- Submit orders for equipment, expendable supplies for approval by production.
- Estimate and submit personnel required for approval by production.
- Submit orders for special equipment, like lightning units, additional generators, boom lifts, hoists, forklifts, all-terrain vehicles (ATVs), as needed to accomplish the work.
- Coordinate with the locations department regarding parking for the rigging crew, access to locations (private property, rooftops, public streets or driveways), placement of generators, turning off unwanted lighting or streetlights, etc.
- Plan the routing of cable to keep it out from under foot and invisible to camera.
- Arrange distribution boxes, outlets boxes, dimmer racks, and dimmer circuits for ease of use.
- Provide sufficient power to the various lighting positions inside and outside the set.
- Mitigate issues like voltage drop and non-linear loads.
- Ensure the rigging is free of hazards and neatly squared away. If a hazard cannot be eliminated, post warnings, use barricades, and notify appropriate personnel. Consider any physical hazards that the crew could trip over, get hooked on, bonk their heads on, get poked in the eye with, get burned by, run into in the dark, fall from, or be electrocuted by.
- Power and test the system from end to end, including the lights.
- Prelight: place, focus, gel, diffuse, and generally rough-in the lighting.
- Label everything and provide a light plot for gaffer, first unit crew, and programmer. Lighting technicians unfamiliar with the rig need to be able to quickly orient themselves to the layout.

RIGGING PAPERWORK

Some of the paperwork that comes in handy for planning a rig are One-Week Summary (Figure 16.1), Rigging Schedule, Daily Hot Sheet, Special Equipment Schedule, Equipment Lists, and Expendable Lists.

A Rigging Schedule breaks down the personnel by date, and set or location. It lists a description of the work to be performed, and the number of crew the rigging gaffer estimates are needed to complete the work. The schedule provides additional columns where the actual numbers of riggers hired can be filled in each day. Keeping an ongoing log of labor makes it possible to shuffle man-days around without giving anyone the false perception that you are adding unauthorized labor. It is quite possible you can save a man one day and use him another day. Presenting the rigging schedule in a format like this makes it easy for the UPM to see how and why you have allocated the work, and helps you get the number of riggers you need.

A Special Equipment Schedule shows when extra equipment is required: stake bed trucks, scissor lift, aerial lifts, ATVs, and so on. Certain special equipment requires additional lighting technicians, such as an aerial lift operator.

A Daily Hot Sheet is made for each day of work, and is filled out on that day. It includes who worked on the crew that day, their in-time, lunch break, and out-time. This makes filling out the time cards a cinch and creates a paper trail for actual labor.

Electrical Personnel and Equipment (Week Summary)									
Show title:				Episode:					
PERSONNEL	To date	Sun 7/12	Mon 7/13	Tue 7/14	Wed 7/15	Thur 7/16	Fri 7/17	Sat 7/18
1st Unit Location:									
1st Unit Move to:									
Programmer									
Extra lamp operators									
Rig gaffer									
Rig Location 1									
Rig Location 2									
Strike location 1									
Strike location 2									
Fixture person									
Total riggers									
TRANSPORTATION									
Crew cab stakebed									
Trailer									
Scissor lift									
Condor									
Tow plant									
Notes:									
SPECIAL EQUIPMENT									
Balloon, Bee Bee									
Equipment drop-load									
Details									
Equipment pickup									
MISC NOTES		Load 1st Unit	Flo tube change			Rig lifts			
LOCATIONS									
Notes: Kill street lights									
Notes to grips:									
Notes to construction:									

FIGURE 16.1

The One-Week Summary is a week-by-week breakdown that brings a lot of information together on one page. It's a helpful tool for determining personnel and equipment and getting those requests approved by production.

Of course, there are lots of Equipment Lists, which many rigging gaffers maintain with a simple Excel spreadsheet. Ninety percent of inventory problems come from someone not keeping careful enough track of equipment as it is added and returned during filming. You need a form to track it. Each time equipment is received or returned, this form is updated, the transaction is noted, the date and time is added, and the form is printed out and placed in chronological order in the binder. The form automatically gives you a running total of the number of each item you have left on hand after each transaction.

Rigging gaffers typically keep everything organized on computer and in big binders. Depending on the show, you might need to make a binder for each stage or rig. Retain all receipts, memos, emails, or other correspondence with vendors, the production office, other departments, and the union local for future reference.

LAYERS OF AN ELECTRICAL SYSTEM

The electrical rig for a television show or feature film usually has three layers: the hard-power layer (Chapter 14), dimmer-circuit layer (Chapter 15), and the control layer (Chapter 12). There may also be additional layers, like multiple power sources, 480 V service, etc.

Hard-power layer

In this layer, feeders are run to the distribution centers. They are typically placed at the four corners of the set and elsewhere as needed. For a constructed set on a sound stage, additional distribution centers may be placed above the set and close to any large loads. To avoid having cables crossing fire lanes and getting under foot, one strategy is to run feeder cable up into the perms. From there, cables run to strategic locations above the set, then drop to the stage floor to power floor-level distribution centers. In addition, feeders power boxes in catwalks or greenbeds above the set. These boxes feed lights that are rigged above the set, suspended on truss or pipe, or mounted to the green beds.

Dimmer-circuit layer

The dimmer layer supplies circuits for controlling tungsten lights and some LED tubes. Traditionally, the dimmer-circuit layer comprises feeders that run to a sound-isolated, air-conditioned dimmer room or dimmer shack. The feeders terminate into a spider that feeds the dimmer racks. From there, individual dimmer lines run back into the sound stage and typically up into the perms. A *waterfall* is a vertical run of cable going up to the perms which may include dozens of 100 A Stage pin and/or Socapex cables from the dimmer room.

There are likely to be specific lights and groups of lights that require dimmers. For any tungsten light that is out of reach, the rigging gaffer will want to consider if it should be on a dimmer, or if it is sufficient to be controlled on a switch. If large numbers of tungsten lights are used for overhead skylight or to light a backing, for example, dimmer circuits need to be distributed to those locations as well.

Depending on the lighting being used, the rig may include unassigned, floor-level dimmer circuits available at each distribution center. These circuits are available as needed for tungsten and practical lights. They may have to accommodate a range of lights from 12k tungsten to 60 W practicals. They may be 10 A (1.2 kW), 20 A (2.4 kW) or 100 A (12 kW) dimmer circuits.

If lunchbox dimmers and other silent-running on-set dimmers are used, they are typically installed as part of the hard-power layer instead of some of the distribution boxes, and no dimmer room is needed (see Chapter 15).

Control layer

Each distribution center also needs to be supplied with DMX and/or Ethernet control data. When lots of DMXable lights are being used, we typically want to provide a DMX port for each light in the same locations as the power.

At this writing, the control layer has begun to be integrated with the hard-power layer, as they are generally needed at all the same locations (see power/data boxes, Chapter 14). We have lunchboxes with built-in optical splitters, fed by *super-bates* cables (a combo 100 A extension with DMX cable) and feeding into *super-stingers* (combo stinger with DMX cable) that run to the lights. And, these boxes may also transmit or receive wireless DMX.

CABLE AND GENERATOR LOADING

The sizing of feeder cable boils down to the management of energy in two ways: the control of heat to keep cable safely within its maximum insulation temperature, and the preservation of voltage to allow proper functioning of the equipment (covered in Chapter 17).

The size selected for the main feeder cable depends on the maximum potential load represented by the lighting inventory. When the lighting package is relatively small, it is usually pretty easy to add up the load and guarantee you have sufficient capacity. When the package is large, it is reasonable to make an assessment of *demand factor*—that is, calculating the capacity of service based on the maximum capacity that could be needed *at one time*, rather than the grand total of all possible loads. You will have loads that are easy to estimate and others that are harder to predict precisely.

For a typical truck package, the large lights in the inventory generally account for the bulk of the power required. Large loads, especially 208/240 V lights on a three-phase system, have to be distributed between the phases in a specific way in order to fit. It is like packing a suitcase with Christmas presents. You need to put the big boxes in first and tuck the socks and t-shirts in around them.

List the lights from biggest to smallest, then assign each load to phase(s), always adding first to the phase with the lowest total load. As shown in Table 16.1, the phase assignment of the 18ks has to be determined first. Note that, despite having roughly 180 A of available amperage, there is no way to add a fifth 18k to this system without exceeding 360 A on a phase, the NEC maximum for 4/0.

As discussed in the previous chapter, there are three commonly used sizes for feeder cable: #2 AWG banded, 2/0 (two ought), and 4/0 (four ought). Table 16.2 attempts to consolidate many factors into a simple form. The tables show the maximum amperage per phase, the number of large lights that can be accommodated by each feeder size, and the minimum size generator (or utility service) needed to supply it.

It is convenient to think of large lights in denominations of 9 kW (the size of an ARRI M90 HMI) or 18 kW. For example, Table 16.2 banded (#2 AWG) feeder accommodates three 9 kW lights.

Table 16.1 Example of a load-balancing calculation

Service: 400 A 208/120 V					
Unit #	**Fixture**	**Total Load (amps)**	**Amps per phase**		
			RED	**BLUE**	**BLACK**
1	18k HMI Fresnel	186	93	93	
2	18k HMI Fresnel	186		93	93
3	18k HMI Fresnel	186	93		93
4	18k HMI Fresnel	186	93	93	
5	6k HMI PAR	66		33	33
6	2.5k PAR	24			24
7	2.5k PAR	24			24
8	1.2k PAR	12			12
9	1.2k PAR	12	12		
10	1.2k PAR	12			12
		894	291	312	291

Table 16.2 Maximum number of 9 kW or 18 kW lights for various feeder sizes

Three phase 208/120 V					
Cable **If you use this cable . . .**		**Maximum lights** **. . . you can have this many lights**		**Generator** **. . . on this generator**	
Cable size (100-ft. run)†	**Maximum amps/ phase**	**9 kW lights (53 A @ 208 V)**	**18 kW lights (94 A @ 208 V)**	**Full-load rating**	**Maximum sustained load per phase‡**
Banded cable	170 A	4	1	90 kW (750 A)	200 A
2/0 cable	265 A	7	3	120 kW (1000 A)	266 A
4/0 cable	360 A	9	4	168 kW (1400 A)	373 A
2 × 4/0	720 A	19	10	288 kW (2400 A)	640 A‡

† For runs longer than 100 ft., increase the cable one size for every additional 100 ft.

‡ Amperage limited by the size of the generator, rather than the cable.

Maximum amps/phase per NEC requirements for cable rated at 70 °C. If system has no components rated less than 90 °C, increase number of 9 kW lights by one for all cable sizes. Generator rated 80 percent of full load rating for continuous operation.

Table 16.2 does not take into account all the things that can affect required cable size. It assumes the main feeder is not more than 100 ft. in length. The tables also do not consider adverse effects of non-linear loads. As a general rule, increasing the cable size by one size for every additional 100 ft. of feeder will keep the voltage drop within acceptable tolerances. See Chapter 17 for a more detailed explanation of voltage drop and non-linear loads.

Sizing neutral conductors

If phase control dimmers are used, the National Electrical Code requires that the neutral be sized at least 130 percent of the ampacity of the phase conductors. In practice, this means the need to double the conductors for the neutral. If the system has one 4/0 conductor per phase, the neutral has two 4/0 conductors.

This precaution also applies when the lighting inventory includes large numbers of non-linear loads like non-power factor corrected LEDs, fluorescents, and HMI ballasts. Unless the manufacturer builds in active filtering and power factor correction, these power supplies create harmonic currents that add to one another on the neutral. European IEC Standards require power factor correction for all equipment above 75 W, but products for the US market have no such requirement. We'll go deeper into harmonics and power factor in Chapter 17.

Sizing equipment grounding conductors

The size of the ground conductor (equipment ground) on the feeder cable is based on the rating of the over-current protection (not the wire gage or number of parallel conductors used for the phase wires) and is reprinted from the National Electrical Code (NEC) in Table D.3 of this book.

Sizing grounding electrode and bonding conductors

The grounding electrode grounds the power source to ground. When using a portable generator or portable transformer, it may be required to be bonded to a building service ground, a copper rod driven into the ground, or some other suitable ground as approved by the AHJ.[1] The size of the conductor that's run from the generator or transformer to the grounding electrode is sized in proportion to the largest phase conductor providing the service. For a system with 4/0 phase conductors, the ground electrode conductor should be #2 AWG cable (NEC Table 250.66).

When multiple power sources are used in proximity to one another, or within the same building, the grounds must be bonded. This is done to eliminate any voltage potential between the ground of one power source and the ground of another. If they are not bonded, it is quite possible to get a shock from a piece of lighting equipment by simultaneously touching building metal such as a metal railing. The size of the bonding wire follows the same rules as the grounding electrode conductor. When attaching the grounding electrode conductor to a building ground, the connection must be made at the main service entrance to the grounding electrode. A standard grounding electrode clamp can be used.

RIGGING CABLE

During rigging, the distribution system remains disconnected from the power source and from the lights and electrical appliances. After the whole distribution system has been laid out and the system

[1] Depending on where the work is taking place the Authority Having Jurisdiction (AHJ) may be the local electrical inspector, the fire marshal (also known as a Film Safety Officer), or the studio's safety department. The AHJ is the ultimate authority for what practices will be allowed on set and has the authority to stop production if the production does not resolve a safety issue. The AHJ will enforce codes and guidelines that have been adopted locally. The AHJ also has the authority to relax certain rules when there is no other way to manage a situation, and the work can be accomplished safely.

has been tested for continuity and shorts, the system can be connected to the power source and the main switch turned on.

In rigging, neatness counts. Keep the cables as out of the way as possible and well organized. A fire marshal or electrical inspector makes his or her initial assessment of safety from a quick look around at the general neatness of the work. If everything is nicely squared away, the inspector knows that it's unlikely that much will be found at fault on further inspection; if the work is sloppy and possible hazards are visible, the inspector is likely to keep looking for a violation until they find one.

Protect your back

Cable is heavy and lifting and moving it can cause injury. Repeated heavy lifting, straining in awkward positions, and yanking on heavy objects are common ways people throw their back out.

Don't carry cable; use carts. OSHA regulations recommend a single person not lift any object greater than 60 lb. alone. Any 100-ft. feeder cable is quite a bit heavier than that. Your employer is required to provide you with a safe, healthy way to move heavy objects around.

Enlist the help of the transportation department to use a stake bed truck to drop or pick up cable when making long cable runs along a street. Never jump off a lift gate with cable on your shoulder.

When coiling and uncoiling 100-ft. lengths of cable, reduce the amount of weight being pulled by working from the center of the cable and pulling only half the length of cable at a time. Do the same when uncoiling it: divide the coil into two halves, place the two coils so the ends pay out from the top, then run them one 50-ft. length at a time.

Naturally there are always physical differences between crew members. What is hard for one person may be easy for another; nevertheless, people naturally try to conform to the culture and perceived expectations around them. Be aware of the culture you are helping to create. Competitiveness and one-upmanship can lead to hasty actions and injuries. Teamwork means crew members look out for one another, maintain reasonable expectations, and work smarter, not harder.

Traffic areas

Avoid running feeder cable on the floor of the sound stage across traffic areas. The stage floor is a freeway of pedestrian traffic and heavy equipment coming in and out: set pieces, forklifts, carts, and so on. It is best to rig these areas so they are completely free of cables, if at all possible. It is better to run the cables up and over the walkway if possible. Grips can construct a bridge of truss, if no other appropriate structure exists.

If a cable must cross the fire lane or other walkway, run it through a cable crossover. Cable crossovers are constructed with channels for the cables that allow air space around the cable. However, multiple crossovers placed side by side are murder to push carts across. Modular crossovers are available that lock together to create an extra wide crossover that allows even large numbers of cables to be protected. It is not a good idea to cover cable with plywood or lauan, as this does not provide ventilation around the cable and has been known to start fires.

Fire lanes

The space within 4 ft. of the outside walls of the sound stage is protected terrain and airspace. The fire codes require that a 4-ft. lane be kept clear of obstructions around the periphery of the stage. This includes cables and distribution equipment. The rule has a very real purpose in the event of fire, heavy smoke, or blackout: to allow people inside the stage to feel their way out of the building without encountering harm. Ladders and similar gear should not be leaned against the outside walls where they could fall over and block the fire lane.

Identifying cable, labeling circuits

Single-conductor feeders

When laying out single-conductor cable, before uncoiling it, identify each end of the cable properly. For single-conductor feeders, the phases, neutral, and ground must be identified with color-coded connectors or colored electrical tape (see color coding in Chapter 13). The code requires a 6-in. section of color at each end of the cable.

At one time, motion picture lighting technicians relied solely on a system of knots made in the tie lines at each end of the cable (Figure 16.2). Fire marshals and electrical inspectors look for color coding. They do not necessarily know anything about the knot system. Lighting technicians still sometimes use knots as a backup because in some situations colors can be hard to see, in dim lighting situations, or under sodium vapor lights.

Distribution boxes

Each spider box and distribution box should be labeled, typically with 2-in. tape and a sharpie marker. The label should include:

1. The power source (e.g., Generator #1 or Panel #4 or Transformer #2).
2. The type of power—voltage (208/120 V AC, or 480 V AC or 240/120 V AC, or 240/120 V DC).

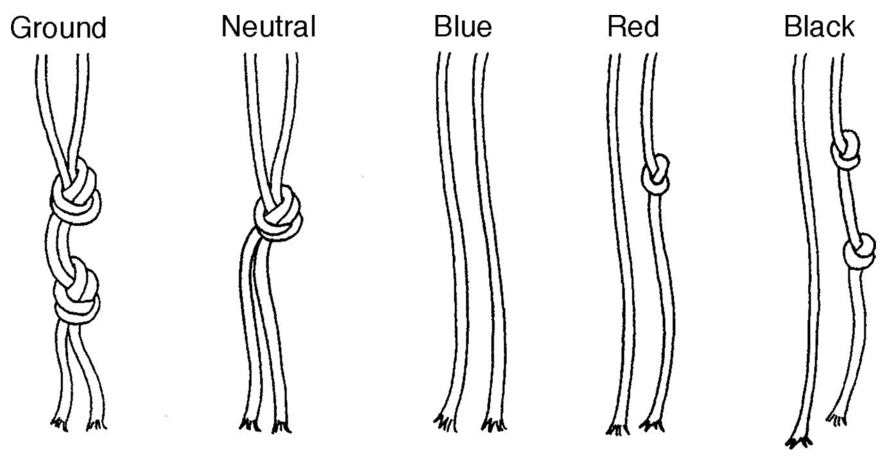


FIGURE 16.2

Knot system. Portable feeder cable comes with #8 sash cord tied at each end of the cable, which is used to tie the cable coil for transport. These tie lines can also be used to identify the cables using this standard system of knots.

3. When appropriate, the function of the circuit, such as "drop-in," "high box," "top lights," and so forth. A set lighting technician who is unfamiliar with the layout must be able to understand what's powering what by reading the labels on the cables and equipment.

When two different kinds of service are being used on the same set (such as 208/120 V AC or 480 V), make the difference immediately obvious by using different colored tape and/or different colored ink on the labels.

Dimmer circuits

Each dimmer circuit has a number (Figure 16.3). When all the dimmers are on a single universe, the circuit number typically corresponds to a DMX512 address of the dimmer. Every cable between the dimmers and the lights is labeled with the circuit number, or in the case of Socapex cable, the range of circuit numbers (e.g., 1–6, 7–12). When rigging lots of dimmer circuits, affix white tape to both ends of all the cable before you run it. That way, it is easy to mark the cable with the right set of numbers right before you run it, and you need not carry tape around with you. Tab spare cable with tape also so that it can be easily labeled when put to use.

Lacing feeders

The conductors of a run of feeder cable are laced together as shown in Figure 16.4. This keeps the cables lying flat and straight, prevents the hazard of cable rolling under foot, and helps identify the

FIGURE 16.3

From the dimmer rack all the way to the final outlet, connectors on dimmer circuits are labeled with the circuit number or numbers.

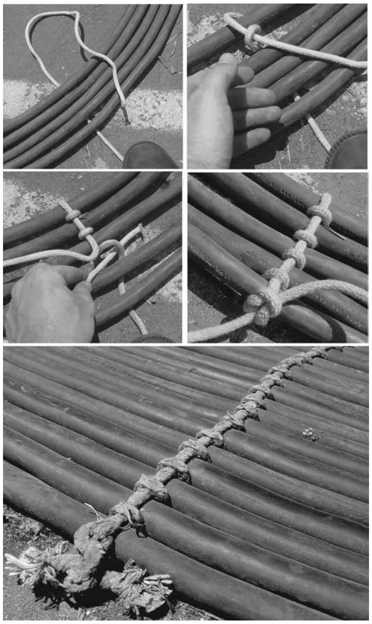


FIGURE 16.4

Lacing cable.

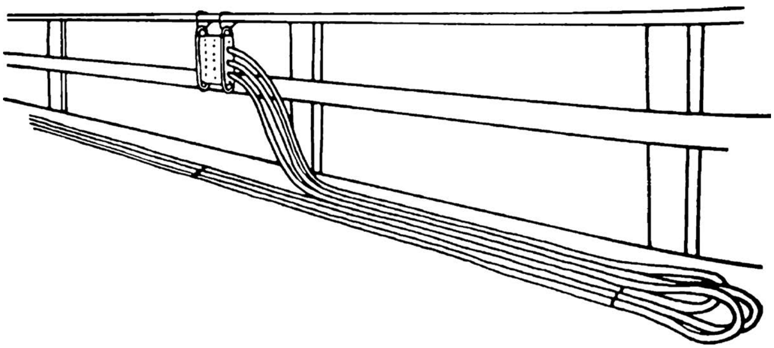


FIGURE 16.5

Extra length should not be coiled.

cables that belong to one run from those of another. Several runs of cable may travel along a single catwalk. It is best to lay out the cables with any necessary turns in them before lacing them, and to lace them in shorter intervals in turns.

Avoid sharp bends in cable. These cause hot spots. Do not leave a live cable in a circular coil, because this can cause heat and line loss. Any excess cable should be left at the load end of the cable, where it will be available if needed later. In green beds and catwalks, excess cable should be run out in a straight line, turned back on itself, and run to its end point (Figure 16.5).

Ventilating and separating runs

If a large cable run crosses another large cable run, it is a good idea to use a bridge to separate them. Stacking one run of cable on top of another can cause problems that you might not anticipate. Not only do the two runs of cable heat each other by conducting and radiating heat, but the heat also increases the resistance of the cable, compounding the problem. Separating the cable runs also separates their magnetic fields. It is important to prevent conducting heat from one cable into another by keeping all cables surrounded by air, and never laying one run of cables directly on another.

Waterfalls

It can be hard to replace a piece of cable once it is rigged in a waterfall. With Socapex cable especially, it is a good idea to rig a spare cable or two into the waterfall from the start, so it is already threaded into the dimmer room and up to the perms.

The rigging gaffer has to determine how much weight a proposed waterfall will put on the structure and work with the rigging key grip to provide adequate support. Table 16.3 gives the weight per foot in lb. of common cables.

Table 16.4 shows an example of how to use these figures to make a load calculation for a waterfall that has a 40-ft. drop.

$$\text{Weight of waterfall} = (\text{number of cables}) \times (\text{weight per ft.}) \times \text{drop in ft.}$$

That is over one ton of cable. With a large waterfall, like this one, the grips would be called upon to rig a suitable member to the building structure. A piece of truss works well for this purpose, sitting atop and spanning the beams of the perms. A load like this would also need to be cleared with a site rep. The truss must be secured so that it will not roll, and be of appropriate size and strength. To give a point of reference, one manufacturer's 10-ft. piece of 12-in. light-duty box truss can support an evenly

Table 16.3 Weight of cable

Cable	Weight (lb./ft.)
4/0	0.96
2/0	0.68
4-wire banded (#2)	1.33
5-wire banded (#2)	1.70
100 A (#4)	0.72
60 A (#6)	0.55
Multiconductor (Socapex)	0.75

Table 16.4 Example of waterfall cable weight calculation

Number of cables	Cable type	Weight per foot	Drop (ft.)	Total (lb.)
32	4/0	0.96	40	1,229
24	100 A	0.72	40	691
12	Socapex	0.75	40	360
				Total 2,280 lb.

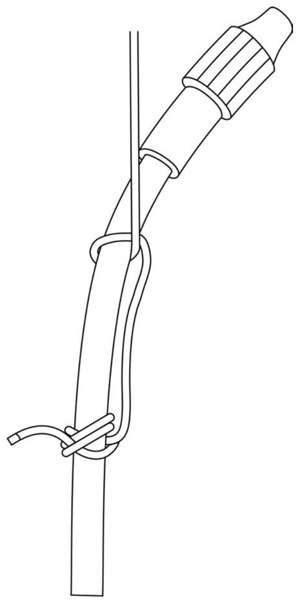


FIGURE 16.6

A binding knot a couple feet from the end of the cable (a rolling hitch is shown here), and one or two half hitches around the cable end help ensure that the cable will not slip when hoisted.

distributed load of 4,460 lb. and a center-point load of 2,231 lb. To distribute the load to the building structure, the truss may need to span several beams in the perms. When heavy loads are anticipated, these details need to be worked out with the rigging key grip and site rep, building engineer, or studio safety department.

A waterfall is rigged by hoisting each cable by one end up to the perms. For hoisting, the line is attached to the end of the cable, as shown in Figure 16.6. Once hoisted, each cable is tied off to a structural member. Cables are secured by tying a binding knot such as a clove hitch around the cable (Figure 16.7) and tying off to the supporting member with a bend, such as a square knot. If a clove hitch

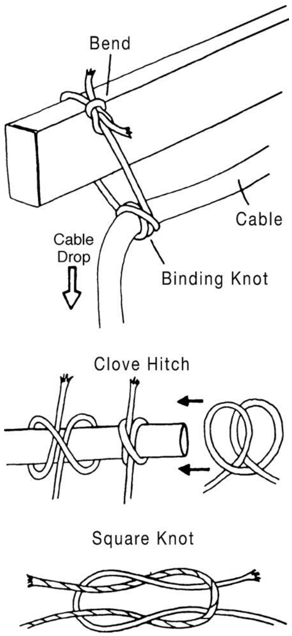


FIGURE 16.7

When tying off a cable drop, a binding knot is used to grip the cable, and a secure bend secures the line to the rail. The cable is typically fastened with a clove hitch around the cable and square knot to tie the ends, but there are other, more secure knots for these tasks as well.

is used, be sure that the knot is on the underside of the cable so that the weight of the cable tightens the clove hitch around the cable and will not let it slip.

PLACEMENT OF DISTRIBUTION BOXES

Here are some rules of thumb for laying out set power on location and sound stages alike. Provide a "ring of fire"—surround the set with power on all sides. No matter where the camera is placed, the lighting crew should have a 100 A gang box ready to pull in behind camera. In each room where action is to take place, have 100 A whips (with gang boxes) coiled outside each door ready to come in when needed. You should never find yourself having to run four or five stingers out a door and around a corner.

In a room with only one door, provide 100 A whips on the opposite side of the room—through a window, through a rat hole in the set, over the top of the set wall, or dropped from the grid—ready to come in should the door have to close. Provide at least 100 A to each side of a room. In a large room, provide 100 A whips every 50 ft. (outside windows, in side rooms, through rat holes, or ready to drop from the grid). Anticipate places the gaffer will need to place lights. In a house with a staircase, you need power at the top of the stairs. Hide cables that cross doorways by routing the cable up and over the top of the door. Work with the art department to create neat access points through the set wall like an air vent grill, or a removable wall panel.

The Gak package

Accessorize each distro location. Next to each distro center, a selection of appropriate extension cables and adapters should be stowed. For example:

2 50-ft. 100 A Bates
2 50-ft. 240 V 100 A Bates (when 20ks or other 240 V loads are being used)
2 100 A lunch boxes
1 Milk crate containing: 4 25-ft. stingers, 4 50-ft. stingers
1 Milk crate containing: 2 100–60 A splitters, 1 100–100 A splitter, 1 100 A gang box
1 Milk crate containing DMX cables

Root out bad contacts

Each time you attach two pieces of cable, check the pins and be sure that each connector is making solid contact. For Stage pin connectors, use a pin-splitter tool to bend apart smooshed pins. Bent pins cause poor contact and can lead to flicker problems which can be a nightmare to troubleshoot. Picture banks of lights going dark one after another as the crew scrambles around behind the sets yelling, "Repatch"—it's the kind of thing that makes the gaffer crazy. Any questionable cable should be put aside and tagged boldly with tape.

TESTING THE SYSTEM BEFORE USE

Once the feeder cable has been run and properly terminated into distribution boxes, there are two simple tests that can be used to ensure no cables have been crossed creating a possible short circuit and double check that the neutral and ground are continuous from the farthest distribution box all the way back to the power source.

Testing for short circuits

Especially when paralleling feeder cables, it is important to test for continuity between the parallel runs and between the phases. A lack of continuity between the paralleled cables indicates that either a cable is not connected or that it may be connected to the wrong bus. A serious arc flash accident could occur if a person were to attempt to connect a system that has a dead short while the power source is energized. This is one reason why the portable system should only ever be connected to the power source with the power source switched OFF.

The short circuit test is performed by metering for continuity at the supply-end of the main feeder cables, with all the cables **disconnected from the power source**. The test should be performed before any loads are connected downstream or with the circuit breakers to those loads shut off. A load, such as a tungsten light, will create continuity between phases and defeat the test.

First test for continuity between the paralleled cables; there should be continuity because each set of parallel cables terminate into the same bus bar at the spider boxes downstream. Next test that there is not continuity between any phase combination (red/blue, blue/black, red/black) nor between any phase and neutral, or any phase and ground. If there is continuity, either something is creating a short circuit, such as crossed cables, or a load is connected that is defeating the test.

Testing neutral and ground continuity and resistance

This test ensures that there are no gaps or high-resistance points in the neutral and ground throughout the system. A gap in the neutral could cause an overvoltage situation and damage equipment. A gap in the equipment grounding wire is a safety hazard.

This test is performed with the ground and neutral connected to the power source, but none of the phase feeders connected. Meter continuity between neutral and ground at the distribution box that is farthest from the supply-end of the feeders. There should be continuity. The equipment ground is bonded to the neutral at the generator or main service panel, so continuity shows that there are no gaps in either the neutral or grounding wire and that the power source is properly bonded.

It is also valuable to test impedance of the feeders. A damaged cable that is not completely broken may provide continuity, but will not be capable of safely carrying its rated current. If there is a point of high resistance on phase cable or a ground cable, that is potentially dangerous. A resistive neutral can cause voltage disparity between phases, can cause the generator to run rough and ultimately lead to damage and failure, and it can burn out ballasts and power supplies. All these things can happen without the lighting technicians having any idea of the cause or that these events are related to one another.

The impedance of a power cable is too small to be read accurately using a multi-meter. The test leads themselves create about 0.2–0.5 Ω resistance, which is more resistance than the cable (4/0 has a resistance of about 0.006 Ω per 100 ft.). With the right equipment, it may be possible to take impedance readings at distribution points along the line moving toward the power source. If there is a point where the impedance suddenly drops dramatically, there may be a damaged cable or bad connector located in the section downstream from that point. (See Chapter 17 for test equipment.)

Making the feeder connections

When feeder cables are added to or removed from a system, the ground connection is made first and broken last. This is called the *make first, break last rule*.

Connect in this order: (1) ground, (2) neutral, (3) phase wires.
Disconnect in this order: (1) phase wires, (2) neutral, (3) ground.

Cable should never be added or removed from a system when it is energized, but the make first, break last rule ensures that in the event the system *is* energized, a ground and neutral will be in place before the phases are connected. Lighting technicians should make it a habit to make connections in the proper order, regardless of whether they think the system is live or not. The idea is that if you get in the habit of doing it the right way every time, you'll be safe when it matters.

Testing voltage

Before throwing the switch or bringing the generator online, always make a radio call to notify the entire electrical crew that the system is about to be energized. Anyone in the process of connecting, disconnecting, handling, or moving connected equipment should step back.

Once the system is live it is good practice to check voltage. There are several reasons that one might want to do this, and it is important to understand what the readings are really telling you and what they are *not* telling you.

First, you are checking the system is providing the expected voltage. Generators can be set to produce 208 V, 240 V or 480 V so you want to check that you are getting the voltage you expected. This is something the generator operator should see immediately on the generator's voltage meters when the generator is brought online, but it is not a bad idea to double check. If magnetic HMI ballasts are to be used, the generator operator should also check the line frequency (see Chapter 18).

By metering the portable distribution system, you are also checking that there are no gaps in the phase connections; that everything is hooked up. This is something you ideally test on each phase at the farthest distribution center of the system. In the process of testing, you may find blown fuses, tripped circuit breakers, bad connections, burnt-out cable, and the like.

You also are checking that the generator's line voltage is adjusted correctly. The generator has an adjustment that generally provides plus or minus 5 percent voltage adjustment.

There are two things that metering voltage does *not* tell you at this stage. It does not tell you anything about the amount of voltage drop within the feeders. Voltage drop is proportional to load, so until the system is under load, the reading will not show the voltage drop.

Metering before the loads are turned on also does not necessarily alert you if the neutral has become disconnected. We described in Chapter 13 how a gap in the neutral can cause an overvoltage situation that quickly burns out 120 V lamps and devices. However, when there is no load connected to the system, the load is balanced and voltage readings appear completely normal. This is why it is important to test the continuity of the neutral before energizing the system. If you connect just one load on one phase, and it turns on, this confirms the neutral is connected.

Once the voltage is tested, the rigging crew can start checking that all the lights are working and that the control system is controlling the lights properly.

Lugs and buss bars

Lug connectors are one of the few remaining components still in commission in some places from the original DC system that was once employed in Hollywood. Lugs are heavy-duty bronze-cast clamps used on 4/0 and 2/0 feeder cable that bolt onto the ¼-inch-thick copper buss bars of the old-fashioned lighting supply panels, generator, or lug-type spider boxes. Bus-bar spiders are necessary to join lengths of lug-cable or divide power in several directions. Today, lugs are typically only used at the point where the portable system connects to the venue's permanent electrical system. Some panels still contain bus bars, so the system may need to be connected using lug-to-Camlock jumpers or adaptors.

When connecting lugs to the power supply busses, ensure that the power is OFF at the switch. Verify the absence of voltage with a meter before contacting the lug nuts. Use a crescent wrench or speed wrench (ratcheted makes the work faster) to ensure a tight connection. Always place the lug nuts on the right side of the buss bar. We do this because the nuts chew up the bars. If you chew up both sides of the buss bar, the flat part of the lug no longer makes good contact with the buss bar.

KNOTS FOR RIGGING

For our purposes, we can think of knots in three general categories: loop knots, hitches, and bends. A *loop knot* is one that provides a closed loop such as might be used to tie a line to a light to hoist it. A *hitch* is a knot used to tie off a rope to a fixed object, or to tie a rope around an item so that the rope conforms to the item to which it is tied, and may even constrict or bind so as to make a tight hold on the item when under tension, such as a vertically hanging cable. A *bend* is a knot that ties one line to another line, such as when passing the two loose ends of the tie-line around the post and tying them together. In each category there are different knots that might be used. Depending on the situation, certain knots provide specific advantages. A rigger needs to learn a variety of knots and know which knot will be safe and secure for a particular application, which will be easy to adjust or untie and which will not.

To be reliable, a knot needs to be tied correctly and dressed and set properly. *Dressing a knot* means making sure that the knot is formed correctly and that the lines pass out of the knot in the correct way. If a knot is not dressed properly, it can capsize or deform under tension. *Setting a knot* means tightening the working end of the rope, so that the knot cannot be shaken loose.

Loop knots

Bowline: A bowline is commonly used to tie the rope to the equipment for hoisting or hanging (Figure 16.8). The bowline is generally pretty strong and secure. However, if the bowline is tied incorrectly, or is dressed improperly, it can fail. A bowline can be tied to create a loop (Figure 16.8A) or it can be tied around an object (Figure 16.8B).

Bowline on a bight: A bowline on a bight (Figure 16.8C) is a loop knot one can tie in the middle of a rope. It makes a pair of fixed loops that will not slip. We sometimes use this knot to suspend a light from two points. The lighting technician attaches the loop to the light by passing the rope through the yoke, hooking the loops over the pin, then tying the two half hitches over the loop on the pin with the standing end of the rope. You can maneuver the light into place by pulling the ends from two different pick points. A bowline on a bight can also be used to form the loop for a trucker's hitch, and it will not jam.

Alpine butterfly: The alpine butterfly (Figure 16.8D) is a loop knot that can be used in the same manner as a bowline. It is considered a very strong and secure knot, superior to a bowline. It is easy to tie and is considered robust—it is hard to tie incorrectly or in a way that might fail.

Binding hitches

Clove hitch: A clove hitch is commonly used to tie a line to a cable, either to suspend a cable drop, or simply as a tie-line for the cable. The weight of the cable makes the knot grip the cable more tightly. A clove hitch (Figure 16.7) is very simple to tie, but it is not considered as reliable as other binding knots offered below. In order for the knot to constrict around the cable, the knot must be oriented so that the rope passes around the far side of the cable first, and not oriented such that the lines converge into the knot before they pass around the cable.

Prusik: A Prusik is a friction knot that can be used like a clove hitch. When weight is put on the knot, the knot binds tighter. The Prusik hitch has the advantage that the position of the knot can be easily adjusted after the knot is tied; when weight is taken off the knot, the knot can be easily slid up or down the cable (Figure 16.9A).

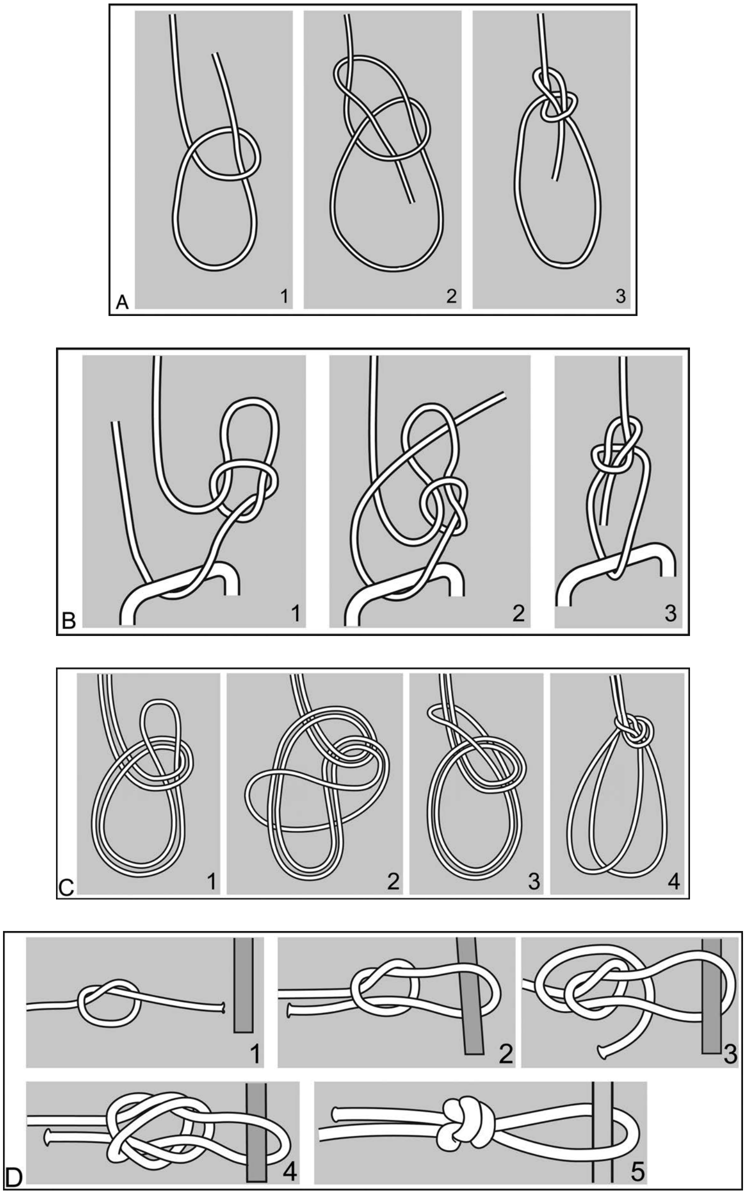


FIGURE 16.8

Loop knots. (A) A bowline. People often remember the bowline using a little narrative: the rabbit comes out of the hole (step 1), goes around the tree (step 2), and goes back into the hole. Note that the loose end is dressed to the inside of the loop. (B) A bowline can be tied around an object. (C) A bowline on a bight is a bowline made in the middle of a line, which provides two loops. (D) An alpine butterfly is a stronger, more secure loop knot.

Rolling hitch: A rolling hitch (Figure 16.9B) is considered stronger than a clove hitch, yet comes out fairly easily.

Constrictor knot: A constrictor knot is considered the most secure of all binding knots. To tie a constrictor knot, start with a clove hitch, but then bring the end of the line back through the first turn as shown in Figure 16.9C. This knot can be difficult to untie once it has been under load.

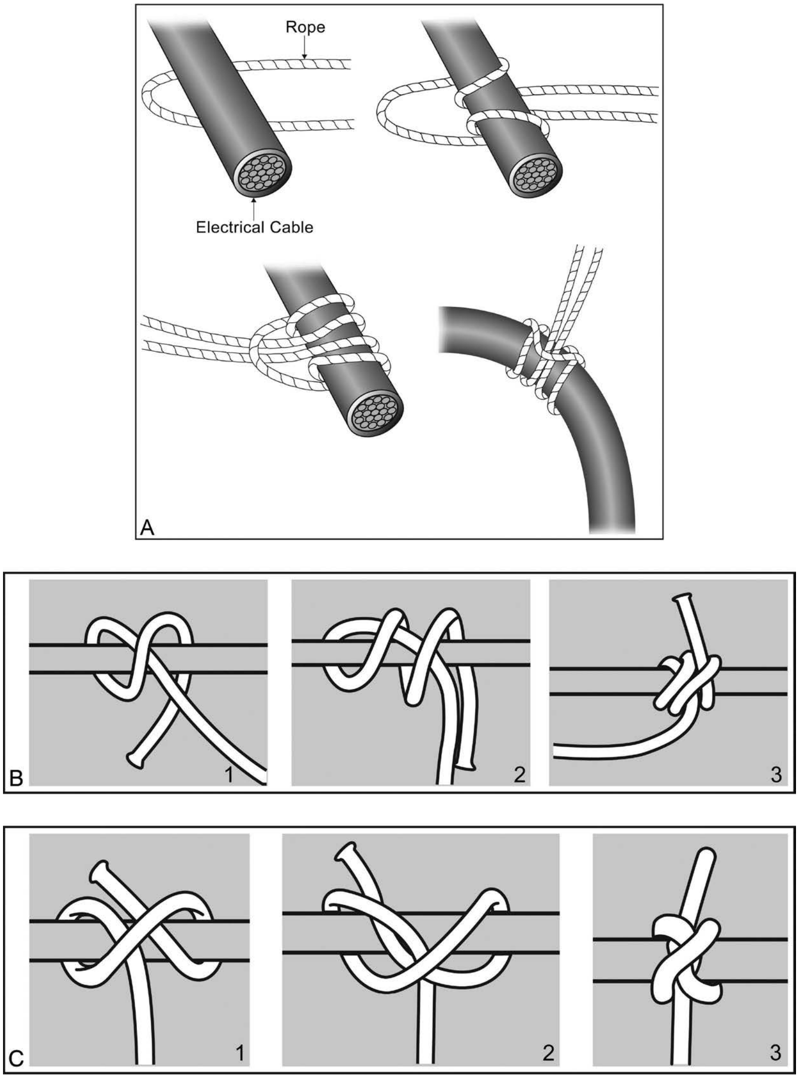


FIGURE 16.9

(A) Prusik knot, (B) rolling hitch, (C) constrictor knot.

Other useful hitches

High safety knot: A high safety knot is used to tie off a line that has tension on it, such as that from a dead weight. The *saddle* cinches the line so that it will not slip while you tie the two half hitches to secure it (Figure 16.10). People who do not know knots often resort to making a single turn, with two half hitches (like the high safety knot, but without the saddle). A single turn with two half hitches is not considered a very strong knot. In tests, the knot will always fail before the rope.

Highwayman's hitch or draw hitch: A highwayman's hitch is a "quick release" knot. It is very handy for securing a light load temporarily, such that the knot can be removed very quickly by pulling the loose end (Figure 16.11). It is not considered a strong or secure knot because it can be shaken loose. Be sure the knot is properly set (by pulling the standing line (F) to snug the knot tight).

Trucker's hitch: There are various ways to make a trucker's hitch. The basic idea is to form a loop in the rope, and use the loop to gain mechanical advantage to pull the rope tight. You could use a trucker's hitch for tying something down or securing a rope around equipment to hold it during travel. The easy way to make a trucker's hitch is to form a loop (by tying a bowline on a bite, or by creating a bend in the rope, and then tying a half hitch or figure-8 knot into the bend). Take a turn

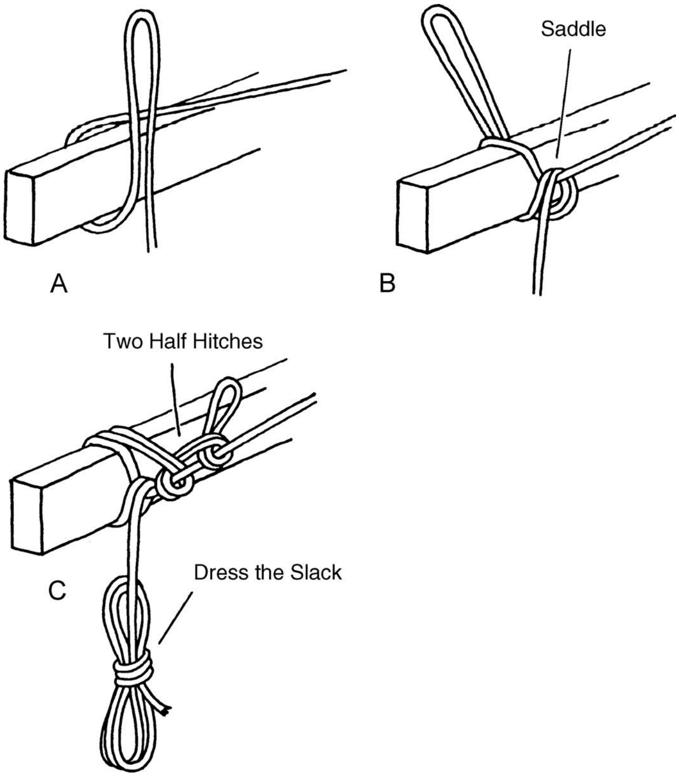


FIGURE 16.10

High safety knot.

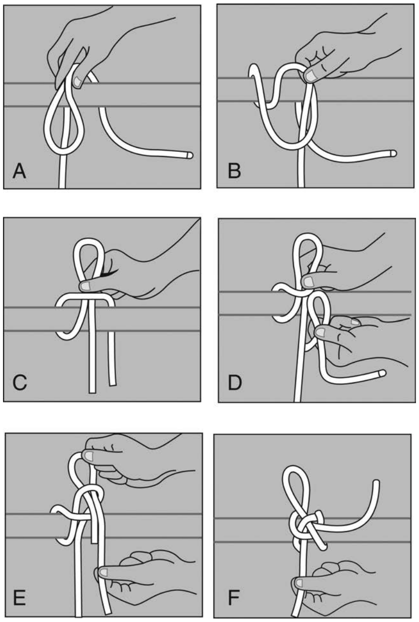


FIGURE 16.11

The highwayman's hitch is easy to untie by simply pulling on the loose end.

around a sturdy post or rail with the loose end, then thread it back through the loop and use the loop like a pulley to cinch the rope tight. The loop knot will often jam and be very hard to untie once it has been under load. (A figure-8 is easier to remove than a half hitch. A bowline on a bight is better still.) The hitch shown in Figure 16.12 is less secure, but it comes out very easily once tension is taken off the line.

Bends

A bend is a knot used to tie two ropes to one another. The ones discussed here are intended for ropes of equal size. We commonly use a bend to tie cables to structural members, as was shown in Figure 16.7.

Square knot: A square knot is very commonly used for this purpose. To remember how to tie it there is an old rhyme that goes "Right over left, left over right, makes a knot both tidy and tight." A common mistake is to tie right over left and right over left again. This makes a granny knot, which is a very poor knot that *will* come loose under tension. You can tell if you have made the knot correctly by its symmetry (Figure 16.7). As knots go, a square knot is not actually considered a very strong or secure knot. Although it serves in many situations, when a knot is under considerable load it is worth knowing a stronger knot.

Alpine butterfly bend: This is a simple knot to remember and easy to tie. It is considered one of the strongest and most secure knots, and is as easy to remove as any other bend (Figure 16.13A).

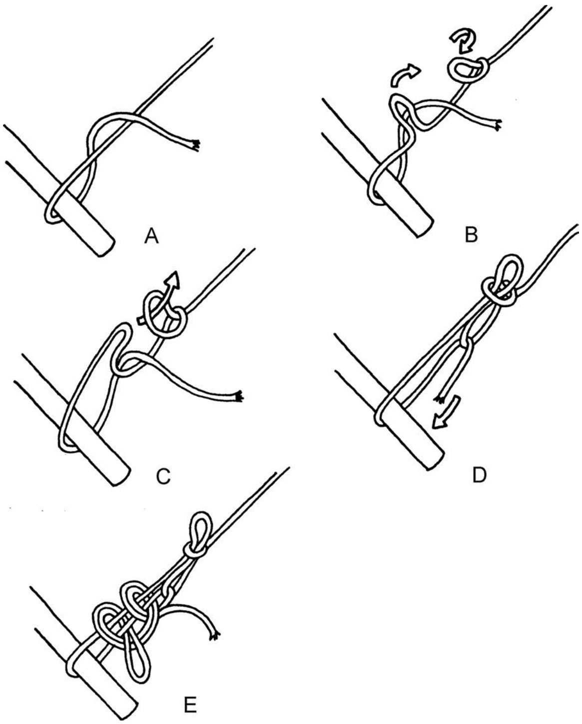


FIGURE 16.12

A trucker's hitch is great for cinching the rope down tight. The version shown here is meant to come out very easily by simply untying the two half hitches and taking the tension off the line. This version is not a terribly strong or secure knot because it relies on constant tension and can be easily shaken out or pulled out if heavily loaded, but it is a great knot for tensioning a taut line.

Flemish bend or figure eight bend: A Flemish bend (Figure 16.13B) is considered a very strong bend, and can be removed more easily than half hitches. It is basically a figure eight knot in one rope, with a second rope rethreaded back through the figure eight. A figure eight bend can also be used to make a loop knot by making a figure eight knot in a rope, then rethreading the loose end of a rope back through the figure eight. This is considered at least as strong a loop knot as a bowline. (There is also another simpler way to make a bend using a figure eight knot, but it is not considered as secure a knot when the two ropes pull in opposite directions. It is made by simply holding the ends of two lines side by side and tying them in a figure eight knot.)

Strength of rope

The strength of rope being used to hang or hoist equipment is dependent on a number of factors, the primary ones: the type of knot you tie, the age and condition of the rope, the type of rope, and the thickness of the rope. The *tensile strength* (or breaking strength) of a rope is the amount of force (in

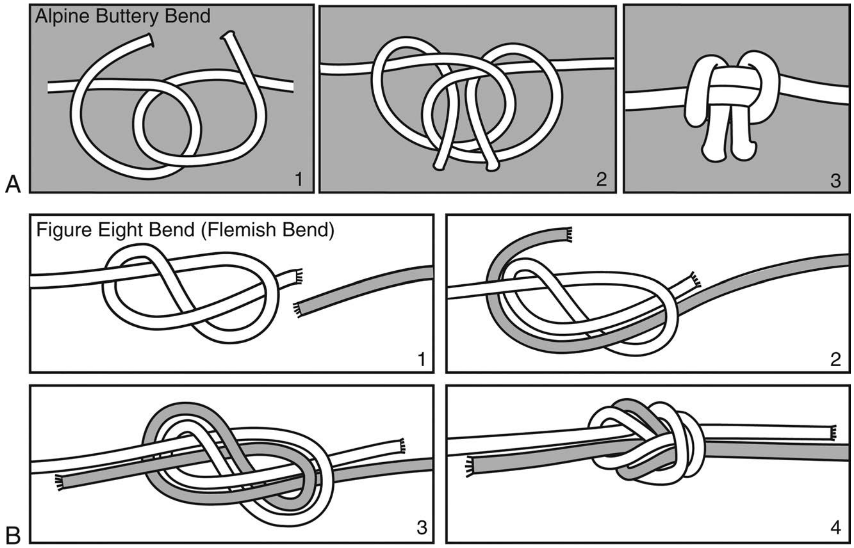


FIGURE 16.13

Bends are knots used to tie one line to another. (A) Alpine butterfly bend. (B) Figure eight bend (Flemish bend).

pounds) that could break the rope when it is brand new under a static load. Rope manufacturers use this figure to work out a recommended *working load limit* (WLL), the load limit that can be routinely put on the rope in straight tension, and builds-in the required margin of safety. The WLL is typically 10–20 percent of the tensile strength, depending on the use. For applications where loads are lifted or suspended over people's heads, the WLL is no more than 10 percent of the tensile strength. The WLL should never be exceeded, even when the rope is new.

A static load is one that just hangs. No load is purely static in reality. When the rope is tugged by the sudden addition of a load, or a sudden stop or start while raising or lowering the load, or if something swings on a rope the load changes constantly—this is *dynamic loading*. Dynamic loading can easily require a rope 10 times as strong as a static load. If the line is used to arrest the fall of an object, the dynamic load is much, much higher, and depends on how far the object is allowed to fall before being caught.

A knot in a line decreases the strength of the line at that point. This reduction in strength varies with the type of knot, and the type of rope, but riggers will typically rate a rope to 50 percent of its nominal strength to account for loss of strength due to knots. Tests indicate that a bowline may retain around 65 percent of its initial strength, a figure eight bend (or bight) around 75 percent, and a butterfly knot as much as 80 percent of its initial strength, but bends such as a fisherman's knot or sheet bend are weakened to around 50 percent of their initial strength.[2] Square knots are not even considered. A particular

[2] These are rough figures summarized from a great deal of data compiled from tests conducted by the Cordage Institute. There are many variables involved, so these figures should not be used for any kind of calculations. This summary is meant to give the reader a general impression of the variance.

Table 16.5 Working load limit of two common rope types

	Manilla 3-strand rope (hemp, natural abaca fiber) WLL = 10% of MBL (lb.)	Samson Pro-Master (polyester blend) WLL 10% of MBL (lb.)
¼ in.	54 lb.	—
⅜ in.	122 lb.	320
½ in.	238 lb.	570
⅝ in.	396 lb.	770
¾ in.	486 lb.	1000

WLL is Working Load Limit (the maximum load that can be safely applied to the rope). MBL is Minimum Breaking Load.

½-in. manila rope has a tensile strength of 2380 lb., its WLL is 264 lb. (roughly 11 percent of tensile strength). If the rope has a knot in it with a 50 percent strength factor, then the maximum static load would be 132 lb. (50 percent of 264).

Table 16.5 shows working load limits for two commonly used ropes when a 10:1 design factor is applied. Check the label on the box for the actual limits of the rope you are using.

Finally, the strength of a line depends on age, wear, and exposure to heat and sunlight. Three-strand twisted manila rope, commonly called *hemp*, is an inexpensive, brown, natural fiber rope that is widely used in our industry. Manila rope holds knots well and it will not melt. However, manila rope will degrade over time, especially when subjected to heat in the perms, or sunlight. It works just great for many of our applications, but when a rig stays in place for many months, under load, another type of material should be used. Safeties (wire rope or chain) should be used whenever rope is used to support weight overhead. Hemp rope should not be recycled for any load-bearing function. Use new rope.

Pro-Master (by Samson or New England Ropes) is a good alternative to manila rope. Like manila, it is 3-strand rope that holds knots well and does not stretch, but since it is synthetic (Polyolefin–Polyester Blend), it is more durable and twice as strong. It is white rope with a green or purple trace.

RIGGING LIGHTS

Lights hung up high are commonly mounted to truss, steel pipe, 1½-in. IPS schedule 40 (1.9-in. OD), or speed rail (aluminum pipe), or suspended using a trapeze. Here are some common conventions for hanging lights above the set:

- Leave two loops of slack cable at each head so that it can be panned and tilted and moved if needed.
- Tie cables neatly to the pipe at regular intervals.
- Each light should be labeled in such a way that the label is visible from below, so that the light's identification (fixture number or dimmer number) can be called out during production. Label the power cord with the same number for easy patching.
- Be sure that the light's power switch is on. Lights that are suspended up high are typically controlled remotely.
- Tighten all the nuts on the C-clamp so that the light is properly locked off.

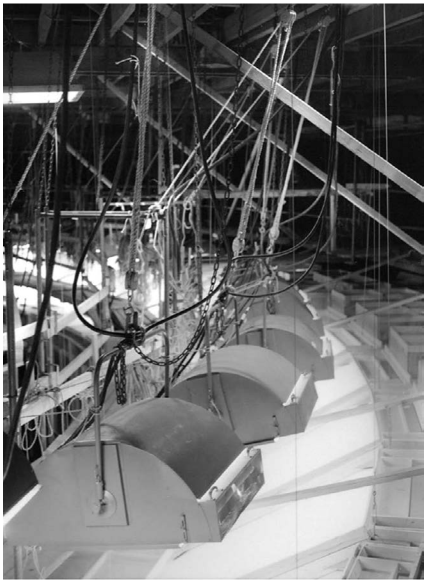


FIGURE 16.14

A row of eight-banger soft lights shine down through the ceiling of the set, rigged to the perms with blocks and tackle. This rig creates a soft top light for a three-level set built for *Star Trek: Deep Space Nine* on stage 17 at Paramount Studios. Note that the blocks and tackle are tied off to the handrail with high safety knots. In addition, each light is tied off with guy lines and secured with chain.

(*Rig by Frank Valdez, photo by author*)

- Every light must have a safety cable looped through the bail and over the pipe to prevent the light from falling if it comes loose. Accessories such as barn doors or chimeras should also have a safety cable. Smaller lights typically use aircraft cable; larger ones may use nylon webbing or chain (Figure 16.14).
- When tying off an individual cable drop from a catwalk or green bed, tie the cable to the knee rail or standing post. Do not tie off to wood smaller than a 2 × 4.

For safety, when working up high, don't wear a tool belt. Tie off any tools you carry to your wrist or belt so they cannot fall and hurt someone below. Anything you carry with you could hurt someone if it falls, including your cell phone. Everything should be secured or in a pouch.

Truss and pipe may be dead-hung on a chain, or suspended using chain motors. When the pipe or truss is dead-hung out of easy reach, lights are hung using a ladder or a lift such as a scissor lift, boom lift, or articulated boom lift. An articulated boom can reach over the top of sets in places that are otherwise impossible to get to.

With chain motors, the rig can be raised and lowered from a central chain motor controller. When floor space is available, it is very convenient to be able to bring the truss down to about a 5-ft. working height, mount the lights and tie off the power cords, then raise the truss into position on the chain motors.

Weight calculations are necessary when a lot of lights or cable are to be suspended. Sizing and hanging the truss and chain motors is typically done by the rigging grip crew.

RIGGING AERIAL LIFTS

Rigging lights to aerial lifts is a common task for rigging crews. Driving heavy machinery requires proper training. Additional training is required to make load calculations for placing loads on the basket of an aerial lift using calculation methods provided by the lift manufacturers. The employer is required to provide training before they can assign an employee to perform such work. Workers who have not received proper training from a vendor or training program that includes hands-on training in the lift, are not permitted to use this equipment. Fatal accidents have occurred when untrained workers were assigned to these tasks.

Various manufacturers make hardware for securely mounting large lights to the basket of an aerial lift (Figure 16.15). A *T-bar* consists of two vertical posts that hold a horizontal mounting bar just above the top guardrail. Junior mounts can be slid around the horizontal mount to support lights. The vertical posts are attached to the guardrail posts using chain vice grips or U-brackets and bolts or chain vice grips. Figure 16.16 shows other rigging solutions. Note that candle sticks attached with chain vice grips should be attached to the vertical members (not the horizontal ones). Use three vice grips per stick and they should be moused (taped) to prevent opening. Modern Studio Equipment makes Candlestick brackets which are more ideal.

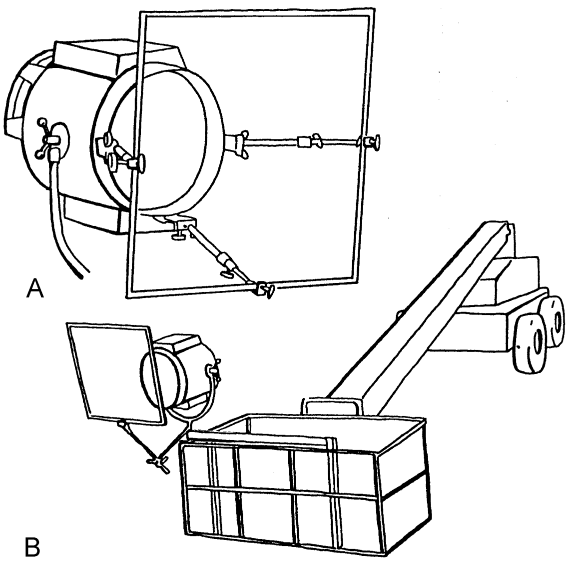


FIGURE 16.15

(A) Ear extensions. (B) Grip helper and Condor bracket.

FIGURE 16.16

(A) HMI Fresnels, pars, and beam projectors mounted on candle sticks. (B) Cantilevered box truss supports beam projectors within the operator's reach. (C) Overhead softlight rigged under the basket. (D) Automated LRX 18k par slung under the basket. (E) ARRIMAX 18k par on a MaxMover remote-operated yoke. Guy lines at each end of the box truss keep the truss from rotating. (F) Automated LRX heads mounted under the basket using the LRX basket rig. On top, moving lights are mounted to a cantilevered pipe rig. When lights are rigged below, it is not permissible to have an operator in the basket.

(*All photos courtesy Mike Bauman*)

FIGURE 16.17

An 8′ × 16′ frame of LiteGear LiteTile Plus 8. Weight of all eight LiteTiles, 61 lb. Power 3200 W (two stingers).
(*Courtesy Mike Bauman*)

Some studios do not permit an operator to be in the basket when lights are underslung. Safety authorities have determined that there is no safe way for the operator to get into and out of the basket when the basket cannot be brought down to ground level. At this writing, a ladder is not considered a safe solution.

When rigging a boom lift or scissor lift, appropriate precautions must be taken to ensure that the lift is not overloaded, that the center of gravity of the load is not shifted outside the lift's area of stability, that attached cables and rigging will not get in the way of the operation of the lift or damage it, and that the increase in surface area due to the attached equipment is taken into account so that wind loads on the lift do not tip it over. The major manufacturers of boom lifts, Genie, JLG, and Snorkel, have developed supplemental rigging manuals that explain how to appropriately reduce the load capacity of the lift to account for loads that are outside of the lift's guardrails, how to safely attach equipment to the lift, and how to determine maximum allowable wind speeds based on the increased surface area of the lift. The methods in the supplemental manuals must be performed by trained and qualified persons.

SUPPLEMENTAL MANUALS FOR CONDOR RIGGING

Boom Lift Platform Capacity Reduction Manual for Set Lighting Technicians and Studio Grips (Part No. 0075625), August 2008. Snorkel International, 2008.

Genie Operator's Manual Supplement: Cribbing Instructions (Part No. 82943GT). First edition: 7th printing, February 2018. Terex, 2003.

JLG Supplemental Operation and Safety Manual: Manual for Cribbing of Approved JLG Products (Part No. 3128168), April 2017. JLG Industries Inc., 2017.

JLG Supplemental Operation and Safety Manual: Supplemental Manual for Authorized and Trained Set Lighting Technicians and Studio Grips (Part No. 3128151), April 11, 2018. JLG Industries Inc., 2018.

Special Supplement to Genie Industries Operator's Manual for Authorized and Trained Set Lighting Technicians and Studio Grips (Part No. 97636). First edition: 6th printing, June 2008. Genie Industries, 1999.

When an 80-ft. arm is resting on the ground, the light mounts are still 6 ft. above ground level. This makes mounting big heavy lights from ground level a challenge. The best way to mount lights onto a Condor mount is to work from the lift gate or a stake bed or other truck. Two lighting technicians can lift a light into place from a lift gate. If no lift gate is available, you can mount the light by tilting the basket forward so that it is easy to reach from the ground. Lift the light onto the mount. Then, while two people hold the weight of the light, hook a safety line from the back of the light to the inside guard rail and tighten it until it takes up the weight of the light. This keeps stress off the junior pin, which is not strong enough to withstand the weight at right angles. With someone stabilizing the light, tilt the basket back to level.

Always tie a safety around the bail to the basket. For big lights, the safety should be 1-in. tubular webbing or ⅜-in. wire rope. A 10-ft. length is sufficient to run a loop through the knee rail and over the yoke with plenty of slack for maneuvering the light. Loop the safety around the knee rail so that if the light falls, it will swing *under* the basket and not smash into it.

Once the lights are rigged on the basket, the operator must use a light touch on the controls and operate the chassis and boom as smoothly as possible. Jerking the lights around with abrupt movements puts a great deal of stress on the mounts.

Grip equipment, such as a four-by gel frame, can be secured out in front of the light. A meat ax is commonly secured to the rail of the basket to provide a means of manipulating nets and flags out in front of the light. A cut is often needed. The grips supply additional flags and nets tied to the basket in case they are needed once you are aloft.

Cabling

Figure 16.18 illustrates how to support and control cables. If HMIs are placed in the basket, normally the head cables are run to the ground and the ballast is placed to the side of the lift. If other lights are placed in the basket, banded or 100 A cable is run to a small distro box in the basket. Never place HMI

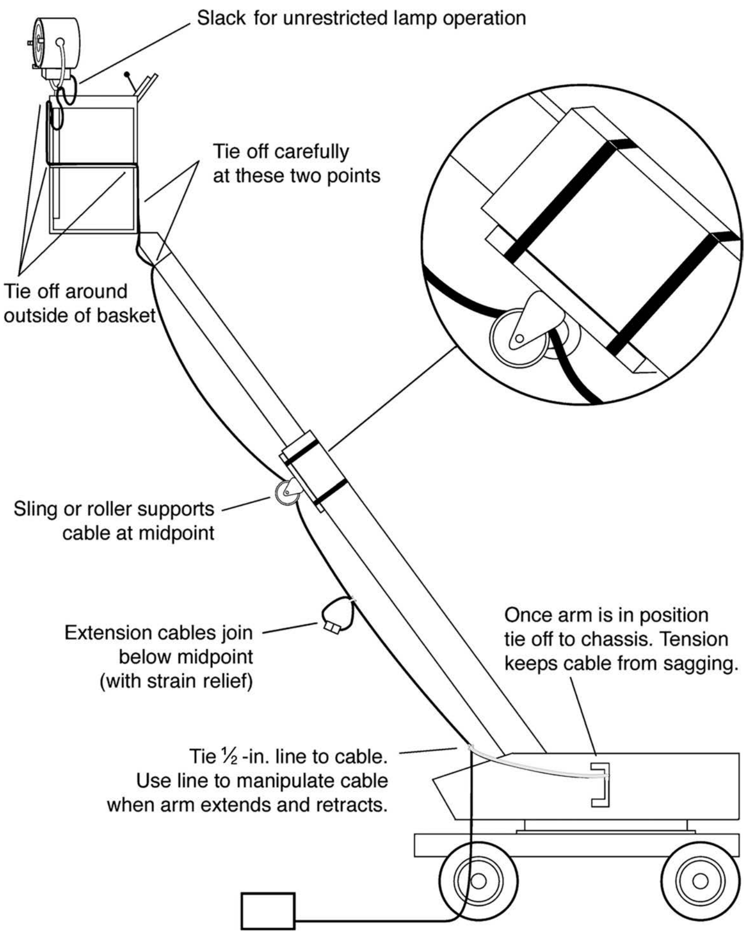


FIGURE 16.18

Cabling the arm.

ballasts and distribution boxes behind or in front of the chassis. If you need to move the chassis, this causes delay. In the worst case, they could get run over.

In either case the cable must be long enough to reach the ground when the boom is at its full height. If the boom is more than 40 ft. in length, a 50-ft. cable will require an extension. Extend the arm out fully at ground level. Leave enough slack cable in the basket so that the fixture can be maneuvered. Tie off the cable to the middle rail, running it around the basket to the center of the basket next to the lift's controls. When there is more than one cable, run all cables together in a single bundle. Tie the cables off securely where they exit the basket. Tie off the cables to the top of the arm leaving enough slack so the basket can be fully rotated left and right.

The cable needs to be supported at roughly the midpoint of the arm, at the top of the telescoping section. Rigging gaffers often strap a boat roller at this point in the arm using a ratchet strap made of heavy webbing. As the arm extends and retracts, the cables should pull freely through this boat roller. The junctions in the cables should be tied securely with a strain relief and should always remain below the roller.

Usually, only one loop or roller is required. The remainder of the cable can be controlled from the ground by tying a ½-in. line to the cable about one-third of the way up. The spotter on the ground uses this line to help control the cables when the arm is moving. Once the arm is set, the line is tied off to the chassis, holding the cables taut along the arm. Always have a ground spotter present when a rigged Condor arm is in motion.

Condor duty

An evening of "Condor duty" is made up of a period of rigging (preferably in daylight), a period of positioning the arm and focusing the lights (usually as night falls), occasional radio calls to refocus, and long hours of sitting at the top of the lift doing nothing. Make yourself comfortable and stay warm. Square away the following items in the basket well before it is time to take the Condor up:

- Walkie-talkie
- Tools (only what you need, and secured so they cannot fall)
- 100-ft. tag line (to pull things up to the basket)
- Furniture blankets (to sit on)
- Apple boxes (to sit on)
- A reading and work light
- Layers of additional clothing
- Warm gloves and hat
- Snacks and drinks
- A good book (this book, for example!)

Once in position, some people like to drape furniture pads or duvetyn around the sides of the basket and put rubber matting on the floor of the basket as protection from the wind. You can construct a very comfortable chair with one furniture blanket and seven to nine large grip clips. Use three grip clips to clamp one edge of the blanket to the top rail on the narrow side of the basket. This will be the back of the chair. Now clamp the sides of the blanket to the knee rail on either side (next to the control console and next to the gate). The sides of the chair provide a wind block. Before lowering the basket, be sure to remove the blanket so that you have an unobstructed view below you.

Very often, as the machinery and hydraulic lines cool, the arm settles. It can suddenly droop a few inches. This happens on all machines and, while it might be a little unnerving, it is not cause for alarm.

If you need to mark the placement of the basket so you can return to that position (to take a meal break, for example), make a plum bob by attaching a weight (a crescent wrench works well) to the tag line. Lower the line until the crescent wrench just barely touches the ground below. Tie off the tag line at that length and have your spotter mark the position of the plumb bob on the ground with chalk. If you have to mark several positions, you can tab the line with tape and label the tabs.

CHAPTER

Working with electrical power

17

In this chapter, we look at electrical phenomena that affect the way we build and maintain the portable distribution system—namely, voltage drop and non-linear loads. We will also discuss ways we can test and measure electrical circuits, and deepen our understanding of the two electrical hazards, shocks and arcs.

VOLTAGE DROP AND LINE LOSS

Voltage drop and *line loss* are terms that are often used synonymously, but they are actually two related but different things arising from the same cause. *Voltage drop* (V_d) is the erosion of voltage over a long distance caused by the resistance of the feeder cables expending some energy as heat. You can think of the cables as a resistance connected in series with the loads, which is why it slices out some portion of the voltage (remember, voltage divides between loads in series in inverse proportion to their resistance).

Line loss is the power (watts) expended. The equation $W = I^2R$ (where R is the resistance of the conductors) shows that the power loss in a given cable increases as the square of the amperage. If you double the current on the cable, the voltage drop also doubles, but the power loss increases fourfold. Line loss is power the generator produced that is not available to light the set. For example, a 4/0 feeder carrying 320 A per phase a distance of 300 ft. would have a line loss of about 3735 W per phase (11,207 W total), which is almost a 10 percent power loss. We don't necessarily think about the efficiency of the portable power system, but if you were to add up the power cost over the course of a season of a TV show, for example, the cost of tolerating line loss easily exceeds the cost of using larger cables initially. In a different context, like ongoing operations at a factory or industrial facility, engineers devote significant effort to designing systems to avoid waste such as excess line loss. Maybe it's because the term of a production is short, and our systems are portable, that people don't think about efficiency as they would in a long-term, permanent context, but really, production of screen entertainment is every bit as much a continuous, long-term process as any other industry.

The severity of voltage drop and line loss increase with the amount of current carried by a particular conductor, but generally voltage drop starts to become significant in feeder cables longer than 100 ft. for 120 V loads, 200 ft. for 208 to 240 V loads, and 400 ft. for 480 V loads. As a rule of thumb, lighting technicians assume that 4/0 feeder cable loses about 4 V per 100 ft. when running at 80 percent capacity. So, you can anticipate a significant line loss any time there is a fairly long run of cable and the cable is loaded near its maximum ampacity rating.

Causes of voltage drop

The three major variables that affect the amount of voltage drop are length, wire gauge (cross-sectional area), and load current (amps).

1. The resistance of a conductor increases directly with its length. The longer the run, the greater the voltage drop.
2. The resistance of a conductor decreases in proportion to its cross-sectional area. The larger the conductor, the less the voltage drop.
3. Voltage drop varies directly with the load. The larger the amperage load, the larger the voltage drop.

Figure 17.1 the shows effect on voltage drop of increasing the number of parallel conductors. You might think that doubling the cable also allows you to pull more amperage. The doubled cable gives you a longer run without problems from line loss, but you cannot then add amperage without the problem of line loss returning.

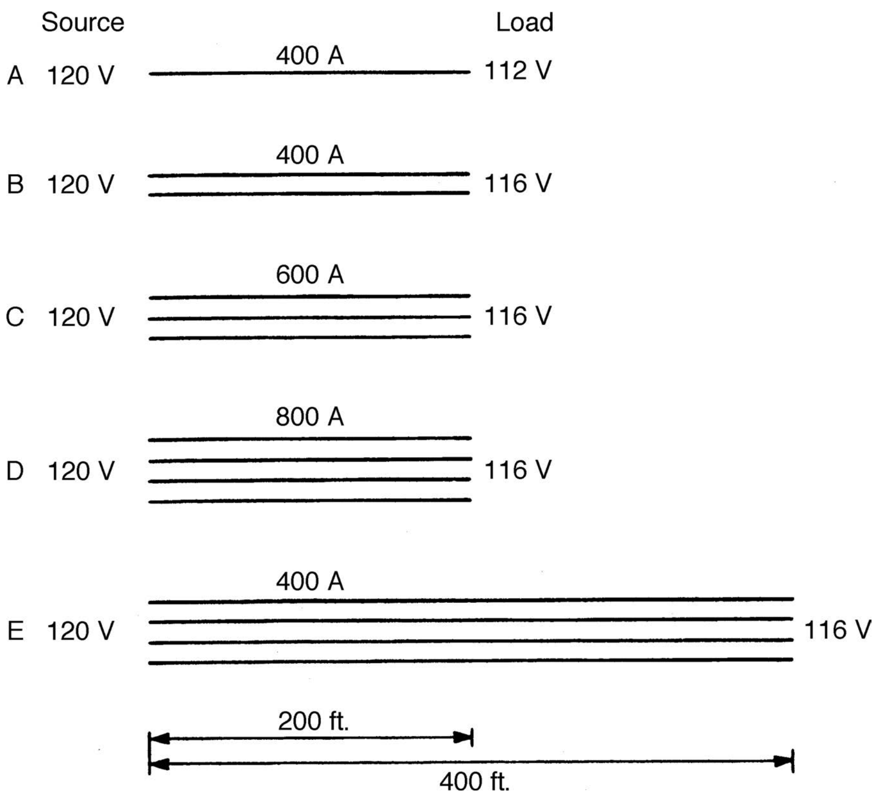


FIGURE 17.1

Voltage drop versus length versus cable size.

Heat increases resistance, which adds to voltage drop. Some circumstances that cause heat include:

- A weak or loose connection.
- Conductor or connector that is loaded beyond its capacity.
- Cables stacked on top of one another or grouped closely together.
- Severe bends in the cable.
- Circular coils in a single conductor.
- Harmonic current caused by non-linear loads.

Good set practices, such as checking for good contact between connectors, locking connectors tightly, avoiding circular coils, and replacing overheating parts, help rid the system of inexplicable line loss and melted connectors.

Allowable voltage drop

Voltage drop is not a safety issue, it is an efficiency/function issue. If the voltage is lower than the load equipment is designed for, the equipment won't function properly and, for certain equipment like electric motors, it can shorten the equipment's service life. Allowable voltage drop is the amount of voltage drop that still allows acceptable performance from the equipment and does not cause harm to the equipment.

The NEC does not regulate allowable voltage drop. In an informational note in Section 215.2(A)(1), the code reads:

> *Informational Note No. 2: Conductors for feeders as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, will provide reasonable efficiency of operation.*

Informational notes as defined in Section 90.5(C) are not enforceable as requirements of the code. This note is saying that if a voltage drop in the feeders does not exceed 3 percent, and does not exceed 5 percent total (both feeders and branch circuits), the voltage will provide "reasonable efficiency of operation." Table 17.1 shows how these percentages translate into volts.

You can see that a 120 V circuit with a 5 percent total voltage drop loses 6 V. It will be left with 114 V powering the load. This assumes you start with 120 V at the power source. In practice, utility voltage can vary from place to place and time of day, depending on demand. The effect of voltage drop

Table 17.1 Acceptable voltage drop as percentage of the rated voltage of the system

Voltage of load	3 percent (Feeders)	5 percent (Overall)
120 V	3.6 V	6 V
208 V	6.24 V	10.4 V
240 V	7.2 V	12 V
480 V	14.4 V	24 V

on tungsten lights is dramatic. An incandescent light running on 95 percent of rated voltage (114 V) produces only 83 percent of its full output. Light output falls off geometrically as the voltage decreases.

Electronic ballasts and electronic power supplies for fluorescents and LEDs usually have a range of acceptable voltage. The acceptable voltage range for electronic equipment is available from the manufacturer if it isn't written right on the power supply. Electronic HMI ballasts typically perform well in a range from 90 to 130 V or 190 to 250 V. If the line voltage decreases, a constant-power electronic ballast will maintain constant power to the lamp by drawing more current. For example, at 240 V, the amperage of an 18 kW ballast is around 82 A per phase; at 208 V, it draws 94 A. The light will continue to operate all the way down to 190 V, but by then the amperage has climbed to 103 A (see Chapter 9 for information on how this is calculated). If the ballast is fitted with a 100 A/240 V Stage pin connector, a sustained amperage approaching 100 amps is likely to cause the connector to overheat. This is why most rental houses fit their 18 kW HMIs with Camlock connectors and give you the option to use a cam-to-stage pin adaptor, or plug directly into a spider box with Camlock. Using the adaptor for voltages of 208 and lower could be courting problems.

As these examples show, we increase the risk of problems by making calculations based on what we can "get away with." Every electrical device is going to be healthier and run more reliably with proper voltage and that's what we should plan to deliver.

Mitigating voltage drop

It is permissible to mitigate line loss somewhat by increasing the voltage at the power source. If the power is from a portable transformer that has a tap switch, this can be done using different taps on a transformer. A transformer typically provides plus and minus 5 percent output in 2.5 percent increments. On a generator, a 5 percent adjustment is usually possible by increasing the field strength of the alternator. Any larger adjustment is inadvisable, as it can destabilize the frequency control of the generator, and according to some suppliers it can harm the generator.

When increasing the voltage at the source, keep two things in mind. First, if equipment is being powered at the upstream end of the cable run (such as the producer's trailer at base camp), the upstream equipment will be over voltage (the producer's computer is toast). Second, voltage drop is proportional to amperage load. If a lot of big lights are suddenly turned off, the voltage jumps up and the remaining load is over voltage (the sound cart is toast). I'm exaggerating a little to make the point here, but this is something to keep in mind and perhaps test for.

Increasing the voltage at the source does not get rid of voltage drop, it merely leaves you with a workable voltage after the voltage drop occurs. The only ways to truly reduce voltage drop is to reduce resistance by adding copper, shortening the distance, or using a higher voltage such as a 480 V for the feeders and stepping the voltage back down at the set with a transformer.

Simple line loss calculations

In the next section we will look at formulas for making voltage drop calculations, but let's just cut to the chase. If we can make certain assumptions the formulas can be boiled down to a simple rule of thumb. Table 17.2 lists the voltage drop per 100 ft. of cable, per 100 A of current for common feeder sizes. Since we use mostly 100-ft. cables, this gets the calculation down to easy numbers.

Table 17.2 Voltage drop for common feeders

	Three-phase system (Voltage drop per 100 A per 100 A)	**Single-phase system** (Voltage drop per 100 A per 100 A)
4/0 cable	1.06 V	1.2 V
2/0 cable	1.7 V	1.9 V
#2 AWG banded	3.4 V	3.9 V

Simplified voltage drop calculation for common feeder sizes

Example 1

For example, say you have a 200-ft. run of feeder from the power source to the set. You are using 4/0 cable and the maximum load on any leg is expected to be 300 A.

$$V_D = 1.06 \times 3 \times 2 = 6.36\,\text{V}$$

Notice that the system voltage has no part in this calculation. The voltage drops the same amount regardless of whether the voltage is 120, 208, or some other voltage.

To find the percentage voltage drop, divide the V_D by the applied voltage for the load.

$$\frac{6.36V}{120V} = 5.3\% \qquad \frac{6.36V}{208V} = 3.1\%$$

Five percent is the recommended maximum overall voltage drop. In this case, a 120 V load exceeds that, but a 208 V load does not.

To reduce the voltage drop we will need to run parallel 4/0 feeders. To calculate how many parallel feeders are needed, divide the voltage drop by 5 percent of the line voltage.

$$\frac{V_D}{5\% \times \text{line voltage}} = \text{number of conductors}$$

$$\frac{7.2V}{.05 \times 120V} = 1.2 \text{ conductors}$$

Rounding up, we need two 4/0 conductors per phase to bring V_D under 5 percent for all loads.

Example 2

On a 208/120 V system, the load is 220 A, the run is 350 ft., and the cable is 2/0.

$$V_D = 1.7 \times 2.2 \times 3.5 = 13\,\text{V}$$

$$\frac{13V}{120V} = 10.8\% \qquad \frac{13V}{208V} = 6.3\%$$

It would actually require a parallel run of 4/0 to bring the voltage drop under 5 percent for the 120 V circuits.

Example 3

Let's try one more using #2 AWG banded cable. Let's say you are powering an 18k at the end of a 250-ft. run. The 18k pulls about 93 A per phase at 208 V.

$$3.4 \times 0.93 \times 2.5 = 8\text{V}$$

The 18k ballast will receive around 200 V (208 − 8 = 200 V), and would be expected to run just fine (most electronic ballasts are designed to operate down to about 190 V). Note that 8 V is just under 4 percent voltage drop for a 208 V load.

$$\frac{8V}{208V} = 3.8\%$$

SINGLE-PHASE VOLTAGE DROP CALCULATIONS

Figure 17.2 shows voltage drop formulas for single-phase calculations. Use the single-phase formulas for the following situations:

- To make calculations for feeders on a 240/120 V three-wire or 120 V two-wire system.
- To make calculations for a two-wire, 120 V extension connected to any system.

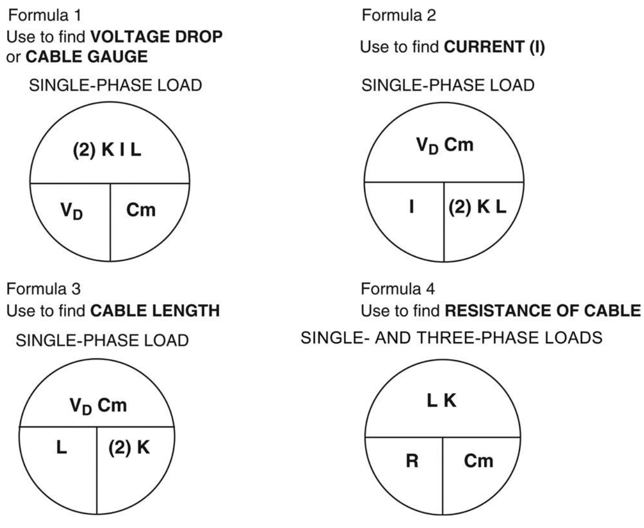


FIGURE 17.2

Voltage drop equations for single-phase loads.

We can use the equations in Figure 17.2 to calculate:

- *Thickness* of cable needed to limit the voltage drop to a selected value
- *Distance* a particular cable can carry a given amperage and voltage drop
- *Voltage drop* for a particular cable at a given amperage
- Maximum *current* we can send through a given length of cable and not exceed a chosen voltage drop

V_D	The voltage drop from source to load (in volts).
L	The length of the wire in feet. This is the one-way distance from source to load. (You'll notice in the formulas that follow, this number is multiplied by 2, giving the two-way length of wire to complete the circuit.)
I	The current carried by the cable (in amps).
Cm	The cross-sectional area of a wire measured in circular mils (cmil). For example, 4/0 cable has a cross-sectional area of 211,600 cmil. Table 17.3 gives the area in cmils, ampacity, and resistance of common gauges of copper wire. See also Appendix D. 1 mil = 1/1000 in.; cmil = (diameter in mils)^2
K	The specific resistance of the material composing a conductor. For copper cable, K = 12.9 at 75 °C.[1] (As resistance depends on the thickness and length of cable, this value represents cmil-ohms per foot, $12.9 \frac{cmil\ ohms}{ft.}$.) Single-phase circuit calculations involve 2 times K. 2K = 25.8.

Finding the voltage drop

The single-phase voltage drop equation (Figure 17.2, Formula 1) is used to find the voltage drop when the length, gauge, and current are known:

$$V_D = \frac{(2)KIL}{Cm}$$

2 K is 25.8, so

$$V_D = \frac{(25.8)IL}{Cm}$$

Example 1—Voltage drop for a given length and size cable at a given current

For example, what would be the voltage drop if a 1k is plugged into 150 ft. of stingers (#12 AWG)? We know a 1k draws 8.3 A and Table 17.3 tells us that #12 cable has a cross-sectional area of 6530 cmil, so,

[1] The resistance of copper varies with temperature. At one time the constant K = 10.8 at 25 °C was used for voltage drop calculations. Some time ago the NEC updated its tables to reflect the maximum operating temperature of cables, rather than room temperature, K = 12.9 at 75 °C. This represents a worst-case scenario. Electrical references and working professions vary in what they choose to use. *Practical Electrical Wiring* (Park Publishing, Inc.) recommends using the round figure K = 12 for intensively loaded conductors, and 11 for lightly loaded ones. Nonetheless, for consistency, we will use K = 12.9 in this text.

Table 17.3 Cross-sectional area and ampacity of cables				
AWG (wire gauge)	**Cross-sectional area (cmil)**	**Maximum ampacity (90 °C cable)[a]**	**Maximum ampacity (75 °C cable)[a]**	**DC Resistance Ω per 1000 ft. (75 °C)[b]**
4 × 4/0	846,400	1620	1440	0.0152
3 × 4/0	634,800	1215	1080	0.0202
2 × 4/0	423,200	810	720	0.0304
4/0	211,600	405	360	0.0608
2/0	133,100	300	265	0.0967
#2	66,360	190	170	0.194
#4	41,740	140	125	0.308
#6	26,240	105	95	0.491
#12	6530	20	20	1.98

[a] Noncontinuous loads, single-core cable in in free air, type W and IESL Entertainment Cable.
[b] NEC Chapter 9, Table 8, uncoated copper conductors.

$$V_D = \frac{(25.8)\,(8.3\,\text{A})\,(150\,\text{ft.})}{6530\,\text{cmil}} = 4.9\text{V} = \ (4\%\ \text{drop})$$

We would be reading about 115 V after 150 ft. What would happen if we put on a 2k instead?

$$V_D = \frac{(25.8)\,(16.67\,\text{A})\,(150\,\text{ft.})}{6530\,\text{cmil}} = 10\text{V} = (8\%\ \text{drop})$$

We would end up with 110 V after 150 ft. For a tungsten light, this will cause a fairly significant decrease in output and color temperature. Depending on the circumstances, this may or may not be acceptable. Let's look at what would happen if we ran a 100 A Bates extension instead. 100 A Bates is #2 AWG. Table 17.3 tells us that *Cm* for #2 cable is 66,360 cmil, so,

$$V_D = \frac{(25.8)\,(16.67\,\text{A})\,(150\,\text{ft.})}{66,360\,\text{cmil}} = 1\text{V}$$

Finding cable gauge

We can revise the equation slightly (Figure 17.2, Formula 1) to find the cross-sectional area (and thus cable gauge) necessary to keep within a given V_D for a given length and current:

$$Cm = \frac{2\,KIL}{V_D},\ \ Cm = \frac{(25.8)\,IL}{V_D}$$

Example 2—Size cable to limit voltage drop to a given amount at a given amperage

For example, we are running eight 10ks (four 10ks per leg) on a 240/120 V system. We are using 4/0 cable and the run is 350 ft. from the can to the load. If we allow no more than a 6 V drop, how many pieces of 4/0 do we need per leg?

$$Cm = \frac{(25.8)\,IL}{V_D} = \frac{(25.8)\,(4 \times 83.33\,\text{A})\,(350\,\text{ft.})}{6\,\text{V}} = 501,647 \text{ cmil}$$

Each piece of 4/0 is 211,600 cm. To find the number of pieces we need, we divide 501,647 cmil by 211,600 cmil and round up (or just check Table 17.3):

$$\frac{501,646 \text{ cmil}}{211,600 \text{ cmil}} = 2.4 \text{ pieces of } 4/0 \text{ per leg}$$

To go 350 ft., we need three pieces of 4/0 per phase.

Finding the maximum current

To calculate the maximum amount of current you can put through a given length and gauge of cable and remain within a specified voltage drop, use the equation in Figure 17.2, Formula 2:

$$I = \frac{V_D Cm}{(2)KL}, \quad I = \frac{V_D Cm}{(25.8)L}$$

Example 3—Amperage for given length and size cable

For example, how many amps can we draw per leg on a 240/120 system if we run four-wire banded (#2 AWG) that is 250 ft. long, if we allow no more than a 6 V drop?

$$I = \frac{V_D Cm}{(25.8)L}$$

$$I = \frac{(6\text{ V})\,(66,630 \text{ cmil})}{(25.8)\,(250 \text{ ft.})} = 62\,\text{A}$$

We can put only 62 A per leg.

Finding the maximum length

Finally, we can calculate the maximum length that a given cable may be expected to carry a given amperage and remain within a specified voltage drop using the equation in Figure 17.2, Formula 3:

$$L = \frac{V_D Cm}{(2)\,KI}, \quad L = \frac{V_D Cm}{(25.8)\,I}$$

Example 4—Length of cable for given V_D

For example, what is the longest length of head feeder extension we can have on a 10k and have only a 2.4 V drop? The power cable for a 10k is #4 AWG cable.

$$L = \frac{V_D Cm}{(25.8)\, I}$$

$$L = \frac{(2.4\text{ V})\,(41{,}740\text{ cmil})}{(25.8)\,(83.3\text{ A})} = 47\text{ ft.}$$

Using a 25-ft. extension and a 25-ft. head feeder the branch circuit has reached 2 percent voltage drop.

THREE-PHASE VOLTAGE DROP CALCULATIONS

Single-phase loads

Most lighting loads are connected to 120 V between a phase wire and the neutral. In theory, if the loads are balanced between phases and there are no reactive or harmonic currents, the neutral carries almost no current. According to one reference,[2] under these best case conditions the voltage drop is equal to only the voltage drop in the phase wire. The drop in one phase wire is equal to:

$$V_D = \frac{KIL}{Cm}$$

However, for our application we can't count on best-case conditions. We have constantly changing load balances and various kinds of reactive current. For 208Y/120 V systems it is more accurate to use the following equation, which is the voltage drop equation for three-phase systems.[3]

For voltage drop

$$V_D = \frac{(1.732)\, KIL}{Cm}$$

For cable area

$$Cm = \frac{(1.732)\, KIL}{V_D}$$

The final voltage provided to the loads will be:

208 V loads (phase to phase)

$$E = 208 - V_D$$

120 V loads (phase to neutral)

$$E = 120 - V_D$$

[2] *American Electrician's Handbook*, Sixteenth Edition. Division 3, Section 71. Calculation of voltage drop in four-wire three-phase circuits when effect of inductance can be neglected. McGraw-Hill Education, 2013.

[3] You'll notice that 2 does not appear anywhere in this equation, but the equation still accounts for the two-way length of cable. The 2 drops out. This is actually the single-phase equation times $\sqrt{3}/2$.

Example 5—Single-phase loads on a three-phase system

Say we are using a 208Y/120 system to power the set. The feeder run is a single run of 4/0 cable and the load is 320 A per phase. If the feeder run is 400 ft., what is the voltage drop to the 120 V loads? We use this equation:

$$V_D = \frac{1.732 \times 12.9 \times 320 \times 400}{211,600}$$

$$V_D = 13.5 \text{ V (phase to phase)}$$

So, assuming the system provides 208 V as the power source, the final voltage is:

$$E_{phase\ to\ phase} = 208\,V - 13.5\,V = 194.5\ V\ (6.5\%\ drop)$$

$$E_{phase\ to\ neutral} = 120\,V - 13.5\,V = 106.5\,V\ (11\%\ drop)$$

To ensure no more than 5% voltage drop at all voltages we will need to parallel the 4/0.

$$\frac{V_D}{5\% \times line\ voltage} = number\ of \text{ conductors}$$

$$\frac{13.5\,V}{.05 \times 120\,V} = 2.25 \text{ conductors per phase}$$

Rounding up, we'll need to triple the phase conductors, making this a 16-piece run (nine phase conductors, six neutral conductors,[4] and one ground), going 400 ft. (64 pieces of 4/0 all together).

Three-phase loads

There are only a few lighting loads that are truly three-phase loads: a portable step-down transformer (typically a delta/Y 480 V to 208Y/120 V), Luminys 480 V power supplies for SoftSun units of 50,000 W and greater, some xenon power supplies, and some chain motors. You can tell if a load is three-phase because the load itself relies on all three phases, and no neutral, to operate.

The voltage drop equation for true three-phase loads is as follows:

$$V_D = \frac{(1.732)\,KIL}{Cm}$$

Example 6—Three-phase load on a three-phase system

A 480 V step-down transformer is to be placed 400 feet from the generator. The load on the secondary is 115.2 kVA (320 A/phase at 120 V). Using 4/0 feeders, what is the voltage drop in the feeders to the transformer?

---

[4] This assumes double neutral for non-linear loads.

To determine the current in a three-phase circuit, divide the apparent power by 1.732 times the voltage.[5]

$$I = \frac{P}{1.732 \times E}$$

So, to find the current in the primary feeders:

$$I = \frac{115,200\ VA}{1.732 \times 480\ V} = 138\ A$$

Now, plugging 138 A into our voltage drop equation:

$$V_D = \frac{1.732 \times 12.8 \times 138\ A \times 400\ ft.}{211,600\ cmil} = 5.8\ V$$

So, the final voltage at the transformer primary will be:

$$480\ V - 5.8\ V = 474.2\ V$$

As a percentage of 480, that's a 1.2 percent drop. The voltage on the secondary will also have a 1.2 percent drop, 205.5 V phase to phase, and 118.6 V phase to neutral (assuming no losses in the transformer).

By comparison, recall from example 5 that, at 208/120 V, the same 400-ft. run carrying the same amount of power had an 11 percent drop, requiring us to triple to 4/0 run. At 480 V, we will have a four-piece run (three phases plus ground), 16-pieces of cable all together, one-quarter of the cable as before, and a quarter of the labor and time.

Cable resistance

The final equation (Figure 17.2, Formula 4) allows you to calculate the actual resistance of a cable.

$$R = \frac{KL}{Cm}$$

Example—Resistance in ohms, given cable size and length

Let's calculate to resistance of a 100 ft. for 4/0 cable (211,600 cmil). (To avoid a rounding error, we will use K = 12.87 in this case.)

$$R = \frac{12.87 \times 100\ ft.}{211,600\ cmils} = 0.00608\ \Omega$$

This result is consistent with the value given in Table 17.3.

[5] 1.732 is the square root of three. It comes up a lot with three-phase circuits because of the 120° difference in time between the three phases.

Knowing the resistance of the cable, you can actually use Ohm's law (E = I × R) to calculate voltage drop. Where E is the one-way voltage drop, I is the current in the circuit, and R is the resistance of the cable.

So, if the cable carries 330 A, the two-way voltage drop is:

$$V_D = 2 \times 330\ A \times 0.00608\ \Omega = 4\ V$$

This brings us full circle back to the simple rule of thumb that we started with: voltage drop is roughly 4 volts per 100 ft. of 4/0 near full load.

You might find the results of these voltage drop calculations surprising. We routinely load cables to near their maximum ampacity and run them out a couple of hundred feet. However, to avoid serious voltage drop, when long lengths of cable are needed, we need to increase the cable size. Instead of running 200 ft. of stingers, use a 100 A Bates. Instead of running a city block with banded, put in a 4/0 run.

Power factor

An incandescent fixture is a *purely resistive load*. When voltage is applied to a resistive load, current flows in lockstep with the voltage. Think of the sine wave of alternating current: voltage and current increase and decrease together at 60 Hz (Figure 17.3A). In contrast, when an AC load involves coils, such as those in a transformer, motor, or magnetic ballast, it creates resistance and *inductive reactance*. The nature of induction is that current lags behind voltage (Figure 17.3B). As the current increases and decreases 120 times/second in a coil, a magnetic field expands outward from the center and then collapses back inward again. When the lines of flux of the magnetic field grow and collapse, they briefly induce a *counter-electromotive force* (counter EMF). The counter EMF has the opposite polarity of the applied voltage. As a result, the applied voltage must overcome the induced voltage before current can flow through the circuit. This delays the flow of current, causing the current sine wave to lag behind the voltage. This opposition to the flow of current is called *inductive reactance*.

On the other hand, a load like an electronic power supply has capacitors as part of the front-end power conversion circuitry. Capacitors draw current ahead of the voltage waveform. Such a load has resistance and *capacitive reactance* (Figure 17.3C). Either kind of reactance, inductive or capacitive, throws the voltage and current out of phase with one another, which has two important consequences.

First, it means that the *true power*—the power (watts) that is actually being produced by the device—is less than the *apparent power* (volts × amps) traveling in the cables. This reduction from 100 percent efficiency is termed the *power factor* (*pf*). The power factor is typically expressed as a decimal less than one or as a percentage. For example, a power supply with a power factor of 0.7 uses only 70 percent of the power it draws. The rest is current cycling back and forth between the power source and the ballast, creating amperage in the cables, without doing any actual work. It means the generator has to work 30 percent harder, burn 30 percent more fuel, and have 30 percent less capacity available for lighting. Electrical utilities charge an additional fee to installations that have poor power factor because the transformer and cables have to be sized for volt-amperes, and the facility ties up transformer capacity, but only pays for the watt-hours it uses. A purely resistive circuit is said to have a power factor of 1.0 or *unity* power factor or 100 percent power factor. With unity power factor, the equation watts = volts × amps is correct. When the power factor is less than one, the equation becomes, watts = volts × amps × *pf*.

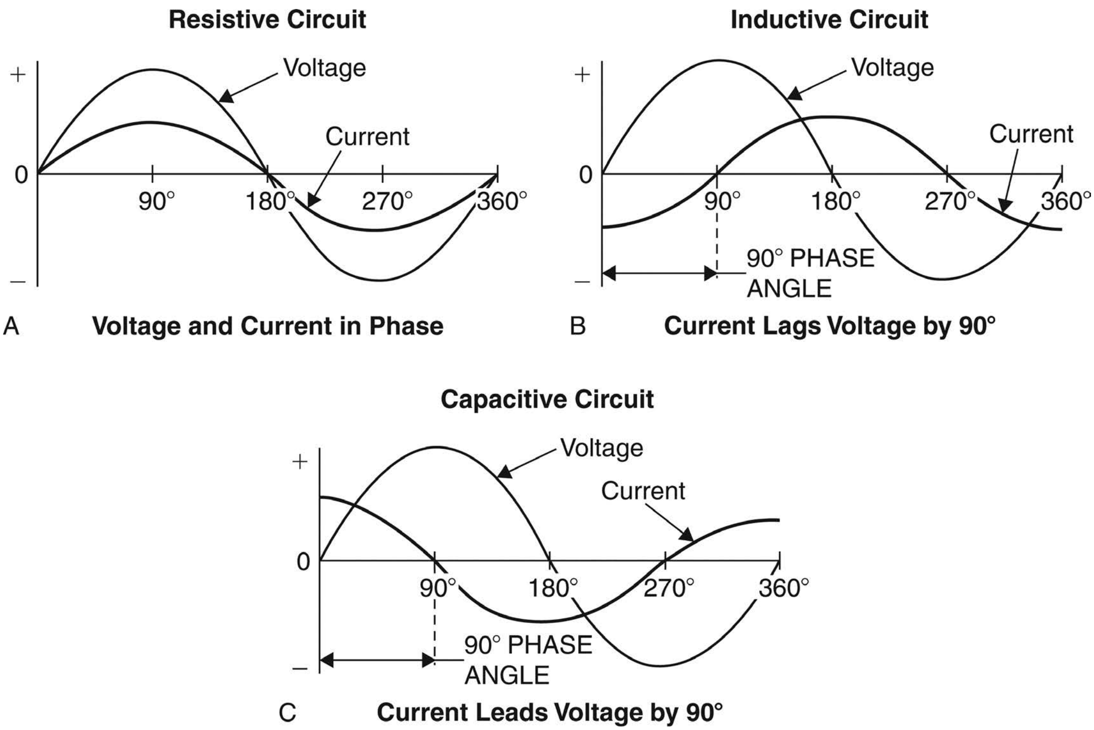


FIGURE 17.3

The effect of (A) resistance, (B) inductance, and (C) capacitance on the voltage/current phase relationship.

Second, because reactance puts the current out of phase with the voltage, the currents recombining on the neutral do not cancel completely even when the phases are evenly loaded. With resistive loads, the neutral only carries the difference in current between the phases, but when loads do not have unity power factor, the neutral carries some percentage of the current, even when the phases are balanced. When imbalanced, the neutral could carry more than the phase wires. As a result, the neutral wire must be oversized, typically doubled.

The degree to which the voltage and current waveforms are put out of phase is expressed by the cosine of the *phase angle* between them. The phase angle depends on the relative amount of resistance and reactance offered by the load. The more they are out of phase, the lower (poorer) the power factor. Power factor is equal to the cosine of the phase angle between current and voltage. For a purely resistive load, voltage and current are in phase and the power factor is 1.0 (pf = Cos 0° = 1.0), *unity power factor*. For a phase angle of 45° with voltage leading current, pf = Cos 45° = 0.7.

Power factor correction

The manufacturer may build in circuitry that counteract it and restore nearly unity power factor. Large electronic HMI ballasts all contain active line filtering and power factor correction. However, these circuits add to cost, so you will find many manufacturers that do not see the necessity, especially for low-wattage LEDs. Uncorrected LEDs often have power factors between 0.6 and 0.7. The power factor is usually written on the equipment.

The power factor equation

The power factor (*pf*) is the ratio of *true power* to *apparent power*:

$$\frac{\text{true power (W)}}{\text{apparent power (VA)}} = \text{power factor}$$

If you were to measure the current and the voltage, then multiply the two together, you get what's called the *apparent power* (expressed in volt-amperes).[6] This is the amount of power traveling back and forth in the cables.

For single-phase loads, volt-amperes = volts × amps:

$$\mathrm{E_{RMS}} \times I_{\mathrm{RMS}} = VA \text{ (apparent power in volt-amperes)}$$

True power is the actual amount of energy being converted into real work by the load, in watts. You can read true power and apparent power with a *wattmeter* or *power quality meter* (see "Measuring electricity" later in this chapter).

$$E_{RMS} \times I_{RMS} \times pf = \text{true power (W)}$$

As one electrician put it, if apparent power is a glass of beer, power factor is the foam that prevents you from filling it up all the way. The size of the feeder cables and the rating of the power source must be sufficient to supply the *apparent power* (beer plus foam), even though only the beer (true power) counts as far as how much actual drinking is possible. Load calculations must therefore include the power factor.

Power factor calculations

To calculate the actual amperage needed to power equipment when the power factor is known, use the following equation:

$$\frac{\text{true power}}{E \times pf} = I$$

Suppose that we are powering four 4k HMIs. If we made the mistake of discounting the power factor, we would incorrectly calculate the amperage as follows:

$$\frac{4 \times 4000\ \text{W}}{120\ \text{V}} = 133\ \text{A}$$

[6] Measurements should be made with a true RMS voltmeter.

Remember 4,000 is the wattage of the lamp, not the power supply. If the ballasts have a power factor of 0.70, the actual amperage required is

$$\frac{4 \times 4000\,\text{W}}{120\,\text{V} \times 0.70} = 190\ \text{A}$$

From this, we see the importance of taking the power factor into account. The amperage is significantly higher than thought—57 A higher.

NON-LINEAR LOADS AND HARMONICS

A *non-linear load* is one in which the wave shape of the steady-state current does not match the applied voltage. Non-linear loads include various kinds of power conversion devices such as switch mode power supplies, electronic ballasts, and phase control dimmers. One of the consequences of the LED revolution is a fundamental change in the nature of lighting loads. In lighting large sets, it has become common practice to build large, powerful soft lights by assembling 20, 40, 60, or more LEDs onto a frame structure, for example. With several of these ringing the set, the number of lights is quickly in the hundreds, and despite the modest wattage of the individual LEDs, the total power becomes significant.

The vast majority of lights now on set use switch mode power supplies (SMPSs). Many LED manufacturers immediately recognized the need for power factor correction and line filtering in their power supplies; however, at this writing, about half the LEDs on the market are unfiltered and not power-factor corrected. Non-linear loads are characterized by high spike currents. They have rich harmonic content that causes a large amount of harmonic current on the neutral, which is high frequency and especially good at heating conductors.

As yet, the industry has not seen any large-scale infrastructure issues associated with the increase in SMPS, but there is no question that heat issues will manifest in the electrical distribution system, and transformer or generator. This has the potential to overheat neutral cables in studio facilities and burn out transformers and generators. Associated ill effects may include degraded cable insulation, equipment electronics failures, circuit breaker trips, excessive current on the neutral wire, instability of generators, noisy or overheating transformers and service equipment, loosened electrical connections, and efficiency losses. Unfortunately, these effects do not come with a note that explains where they come from. Without a clear cause and effect, there is reason to fear the root of the issue will never be properly addressed.

It becomes incumbent on the lighting crew to be aware of these effects and know how to monitor the system for signs of stress, and amend the way we design systems, derating the distribution system appropriately. Let's begin by understanding how SMPSs can create heating issues.

Switch mode power supplies

Compare the current waveforms of Figures 17.4 A and B. Figure 17.4 B shows the input voltage waveform (top) and a characteristic current waveform of non-power factor corrected SMPS (bottom). The LED in 17.4 B has a 470 W output. However, this highly capacitive load exhibits an apparent power of 670 VA with a measured power factor of 0.71. The RMS current is 5.38 A and the peak current is almost 10 A.

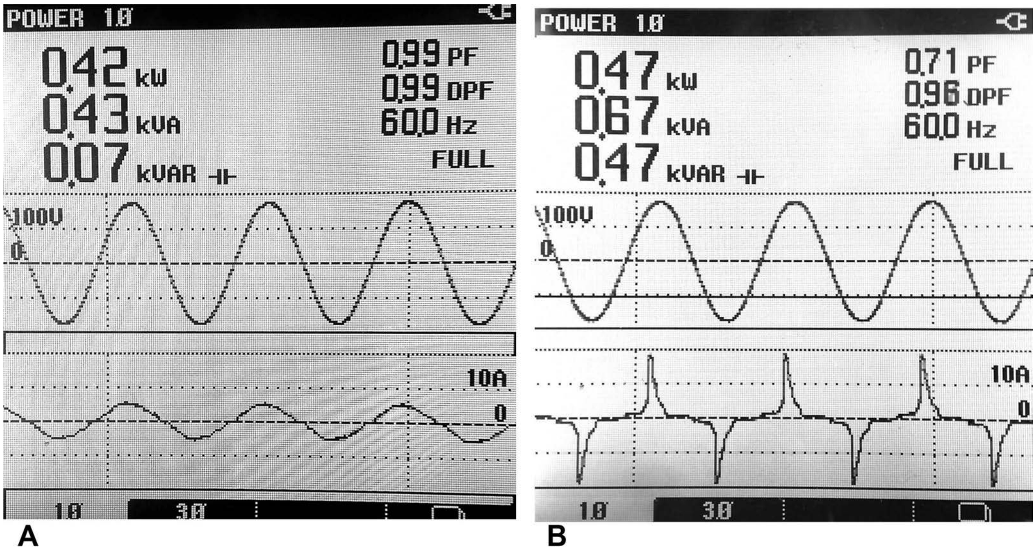


FIGURE 17.4

Voltage (top) and current (bottom) waveforms for (A) ARRI SkyPanels, which have power factor correction to 99 percent power factor. (B) Another LED light with non-power factor corrected switch mode power supply.

(*Courtesy Guy Holt, ScreenLight & Grip*)

The shape of the current waveform is explained by the way the power supply works. Power supplies vary, but all SMPSs begin by converting AC voltage to DC. (After that, the DC is converted into high-frequency, square wave which will allow flicker free filming and enable dimming.) To make DC, an SMPS uses a rectifier and smoothing capacitor. In simple terms, the rectifier bridge inverts the negative half of the AC sinewave, and the capacitor smooths out the resulting line of bumps. The problematic current waveform is a result of the way the capacitor gulps current. The capacitor charges very rapidly during a short time as the voltage is approaching peak. It then abruptly stops for the rest of the cycle (it reverses bias, discharging current, filling in the valleys between the bumps until the input voltage starts rising again). It is like a ravenous teenager who raids the refrigerator before meals and refuses to eat at dinnertime. This explains the high peak current and the leading current (capacitive reactance).

Harmonics

Despite the irregular appearance of the current waveform, science has figured out a way to represent the irregular shape in a way that makes the effects easier to understand and allows them to be measured and displayed on a power quality meter (PQM). An irregular but repeating waveform can be represented as a particular mix of waves that are multiples of the fundamental 60 Hz cycle. The 3rd order harmonic is 180 Hz, 5th order is 300 Hz, 7th order is 420 Hz, and so on. Figure 17.5 shows how the harmonics combine to describe any irregular wave shape. An unfiltered, non-power factor corrected power supply displays a current waveform that is harmonically rich. Compare the line graphs

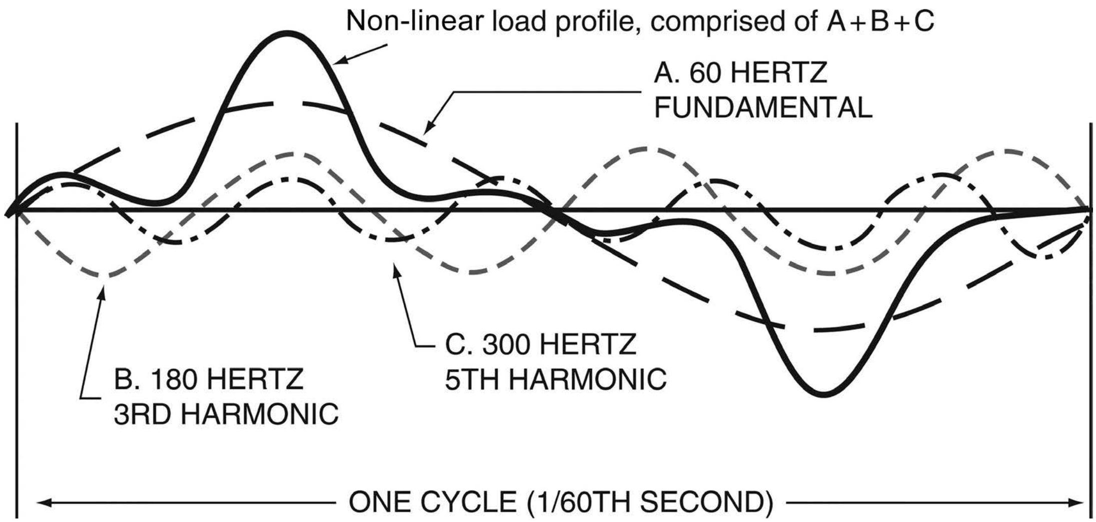


FIGURE 17.5

Non-linear loads produce distortions on the current waveform that are the summation of first-, third-, and fifth-order (and higher) harmonics.

in Figures 17.6A and B. Compare also the *total harmonic distortion* (THD), which is the relationship of all present harmonics to the fundamental frequency. There are LEDs with total harmonic distortion approaching 70 percent, with large third-, fifth-, seventh-, and ninth-order harmonic components.

Additive neutral current

Harmonics that are odd multiples of three—the 3rd, 9th, 15th, 21st, etc.—are referred to as *triplen harmonics*. Triplens can create unexpectedly high harmonic currents on the neutral. The reason for this has to do with the nature of a three-phase power system—three phases that are 120 degrees apart in the cycle. At the fundamental 60 Hz frequency these currents cancel each other out and the neutral carries only the vector difference in current between the phases (see Chapter 13). However, this is not true of the triplen harmonics. The 180 Hz wave, for example, makes three complete cycles in the span of one 60 Hz cycle, so it begins a new cycle every 120 degrees. This means the 180 Hz harmonics of the three phases are always in phase with one another and that's why these currents add together on the neutral.

Understand, it is not that all the phase current adds together, just the component of that current that are triplen harmonics. The extent to which additive currents occur depends on whether the loads have a large harmonic component. Many LEDs produce enough triplen harmonics that, with the loads completely in balance, you can easily end up with the neutral carrying 145 percent of any one of the phase loads, almost all of it harmonic. That's almost 50 percent of the current from each phase adding to the neutral.

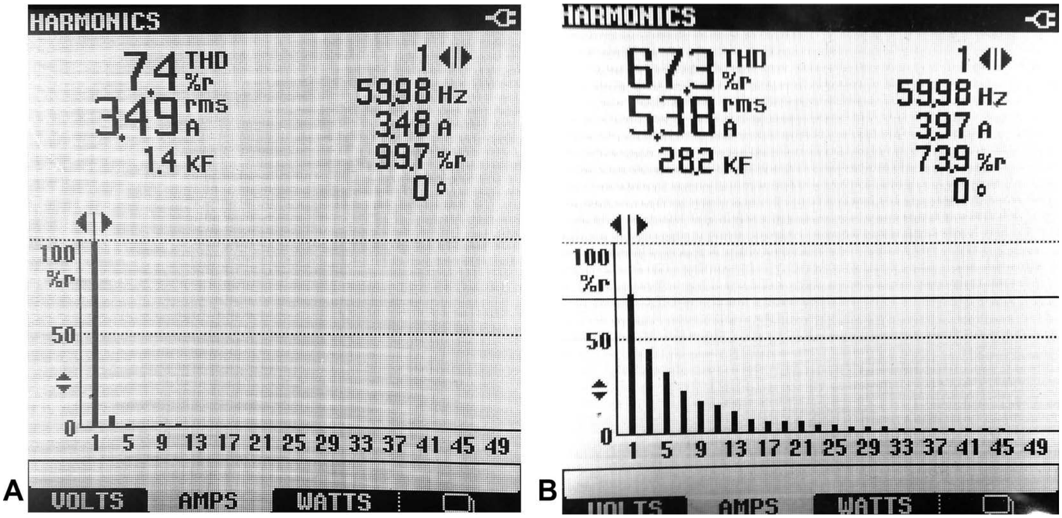


FIGURE 17.6

A power quality meter breaks down the harmonic content of the current. (A) A power factor corrected LED (ARRI SkyPanel). Almost all of the current is the fundamental. (B) An LED that does not have power factor correction or line filtering has 3rd, 5th, 7th, 9th order harmonics and beyond. The THD is 67.3 percent.

(*Courtesy Guy Holt, ScreenLight & Grip*)

Skin effect and proximity effect

The inevitability of overheating only becomes more certain when you consider other characteristics of harmonic currents like *skin effect* and *proximity effect*. Skin effect is the tendency of higher frequency current to flow near the surface of the conductor. As a consequence, the effective amount of copper is reduced, increasing the resistance of the conductor, and thereby increasing heat, voltage drop, and (I^2R) power losses. Skin effect occurs on all AC circuits to some extent, and they are taken into account in the NEC's ampacity tables. However, higher frequencies have a more pronounced skin effect, not contemplated in the rating of the cable. The NEC does require that the temperature of cables never exceeds their temperature rating, however.

Proximity effect is another way that current is displaced within the conductor, forcing it to travel within a smaller volume of copper. It occurs when conductors are closely spaced and is caused by the overlapping magnetic fields of the conductors. This is especially a problem for conductors traveling in conduit, like the cables that feed lighting supply panels on a sound stage.

Skin effect and proximity effect are not confined to feeder cables. When Socapex cable is used to power LEDs that have significant harmonics, these effects increase heat in the cable significantly.

The combination of effects makes it possible to exceed the temperature rating of a cable, even *without* exceeding its ampacity. Keep in mind, there is no circuit breaker on a neutral, so if it were overloaded, there would be no warning of it from a tripped breaker.

We have been talking about the effect on cables, but these same effects are propagated into generators and transformers, expensive pieces of infrastructure, that can be destroyed by heat.

Strategies for coping with large non-linear loads

At this writing, the lighting technician's only tools for avoiding ill effects from large numbers of non-linear loads is to derate and monitor the cables and the system.

Derate

When you have large loads with apparent power that is nearly double to true power and neutral currents that are 145 percent of the phase currents, the maximum load you can put on the system has to be significantly decreased or the system will overheat. To a rigging gaffer who has always built their system on a traditional way and never had a problem, it may seem absurd to cut the capacity of the generator and cables in half. But, this is our current reality. So, how do we rerate the system?

We are not alone in having issues with non-linear loads and harmonics. All kinds of modern devices create harmonics including, most notably, computers, monitors, and printers. The computer industry has long used a fairly simple ratio to determine a derating factor (*dF*) for service equipment serving large numbers of non-linear loads.[7] All that's needed are a couple of measurements from a light of the kind you will be using. Use a *true RMS-reading* meter. With no other loads on the system, connect a light (or bank of lights) to one phase of the distribution box. Place the current clamp on the distribution cable feeding the box. Read the RMS phase current and the instantaneous peak current (or just the crest factor, whichever one your meter reads).

The derating factor is calculated as shown.

$$dF = \frac{1.414 \times (true\ RMS\ \ phase\ current)}{instantaneous\ \ peak\ \ phase\ current} \quad or \quad dF = \frac{1.414}{crest\ \ factor}$$

In a system with no non-linear loads, the peak current is equal to 1.414 × the RMS current,[8] so *dF* would equal one in that case. When non-linear loads are present, the peak current will be greater than 1.414 × the RMS current, making the derating factor less than one, typically somewhere between 0.5 and 0.9.

Gaffer, educator, and equipment owner, Guy Holt, has made a study of generators, transformers, and power quality issues and has written and developed training on these subjects. In his writing, he makes calculations based on readings taken from a set that was using 250 LED tubes and found it had a derating factor of 0.43. This means, in order to avoid overheating, the power supply must be derated to 43 percent of the nameplate rating.[9]

---

[7] Fluke, a manufacturer of electrical meters, has a wealth of helpful information in relation to metering and troubleshooting. One such document, titled *Troubleshooting Power Harmonics,* sites this formula developed by the CBEMA (Computer and Business Equipment Manufacturers' Association, now called the ITI, Information Technology Industry Council).

[8] Just as the peak voltage is equal to 1.414 × the RMS voltage.

[9] "Power Quality in the Age of LEDs," *Protocol*, Spring Issue, 2018, by Guy Holt. Holt compared this result to another source of guidance on this issue, tables published by the International Electrotechnical Commission (IEC BS 7671 Appendix 11). He found the results were very similar.

Monitor

You can see and measure harmonic distortion with a power quality meter (as shown in Figures 17.4 and 17.6). It calculates power factor and total harmonic distortion and displays the harmonics present and their relative strengths.

If you don't have a power quality meter ($$$), you can use any true RMS meter to read the peak current and compare them to the RMS current. If peak current is more than 1.4 times the RMS current, there are non-linear loads. A true RMS current clamp meter will show the actual current on the neutral.

You can also monitor the temperature of the cable by touching it or measuring and viewing it with an infrared camera. There are a variety of IR accessories and phone apps available that display and record infrared images that can identify overheating such as FLIR. If the cable jacket exceeds the maximum cable temperature, it is overheating (75 °C = 167 °F, 90 °C = 194 °F). It is advisable to involve the facilities electrician. They will have a thermal imaging instrument to identify and dangerous hot spots in the feeders, panel, and transformer.

MEASURING ELECTRICITY

A variety of testers and metering instruments are commonly used by set lighting technicians and rigging crews. These range from inexpensive voltage testers, to full-featured digital multimeters, to full-featured power quality meters.

A word of warning. Taking readings from exposed parts is both a shock and arc-flash hazard. It is generally not within the job description or training of lighting technicians to perform tasks that require opening up an electrical panel or metering *exposed* live conductors. There is an important distinction between voltage testing branch circuits at the load-end of the distribution system, and voltage testing of the power source (especially inside an electrical panel in proximity to live exposed conductors). In both cases, the person doing the metering must be properly qualified, but their qualifications in one location are quite different from those in the other location.

If someone ever asks you to perform work for which you have not been trained, do not do so. Inform them that the work involves hazards that you are neither equipped nor trained to take on. When tasks involve risk of injury, the knowledge and experience of the person performing the work is an essential part of reducing the risk to an acceptable level. Proper training and protective measures are required by OSHA regulation.

Lighting technicians should be able to safely perform metering tasks such as the following:

- Check for short circuits before connecting the portable distribution system.
- Check for ground and neutral continuity before the phase connections are made to the power source.
- Check whether a circuit is live (e.g., troubleshooting a light that is not working).
- Verify a circuit is de-energized (e.g., when a task requires hands or tools close to conductive parts where they could make contact).
- Check for continuity, proper polarity, and ground when wiring outlets, practical lamps, and hand dimmers.
- Measure the operating voltage (to ensure that feeders are connected properly, voltage is as expected, and the system does not have excessive voltage drop once under load).

- Measure current on phase and neutral feeders. Check current balance between loads. No loads exceed the ampacity of the cable. Neutral is not overloaded.
- Measure harmonic characteristics of loads, either on a proactive basis, or when monitoring the system during production to ensure the system is not overloaded or overheated.
- Measure line frequency (check the generator, especially when using generators that are not crystal controlled like construction generators and putt-putt).
- When using house circuits on location, determine which circuit breakers control the receptacles being utilized.

Be sure to read the instructions for the meter you are using. Meters have peculiarities like odd ways of scaling, and may use abbreviations and symbols that you are not familiar with. Follow the manufacturer's instructions for inspecting and testing the meter and teat leads.

AC Circuit Load Tester

An AC Circuit Load Tester is a useful piece of test equipment for checking the rig (such as the EXTECH CT70 and others). The meter plugs into a live 120 V Edison outlet and is capable of testing the health-of-system with metrics that include the following:

- Line voltage (V).
- Voltage drop (V_D). The screen turns red if the existing V_D exceeds the NEC recommended maximum of 5 percent. (Note: it runs a relatively small test current through the wires, 12, 15 or 20 A. This test does not give you the line loss that will be present when the system is loaded.)
- Impedance (Z) on the phase, neutral, and ground. Ground impedance should be less than 1 Ω, preferably around 0.25 Ω. Comparing the impedances at different points along the distribution system can tell you if there is a cable or connection that is creating an unusually high amount of impedance.
- Line frequency (Hz).
- Correct wiring of phase, neutral, and ground (detects if ground and neutral are miswired, for example).
- GFCI trip-time test (using a 6.0 or 9.0 mA trip current).
- Ground to neutral voltage. (Screen turns red if voltage exceeds 2 V.)

Circuit testers

A circuit tester (Figure 17.7B) is used to test Edison outlets. It tells you whether (1) the circuit is hot, (2) the polarity is correct, and (3) the grounding wire is present. A similar device is available for Socapex cable. A plug-in voltmeter (Figure 17.8) gives a constant readout of system voltage.

A voltage sensor (Figure 17.7G) is useful for checking whether a wire is live. Simply hold the sensor against an insulated cable. The sensor beeps or lights up to indicate it senses the magnetic field of electricity. It is also called a non-contact voltage tester, penlight tester or voltage tic. Tools are available with a voltage sensor built in, such as a screwdriver, lineman's pliers, or crimper/stripper tool.

A voltage sensor can give false positive and false negative readings. One can get a positive reading from a wire that is connected to nothing at both ends. Do not use a voltage sensor to verify the *absence*

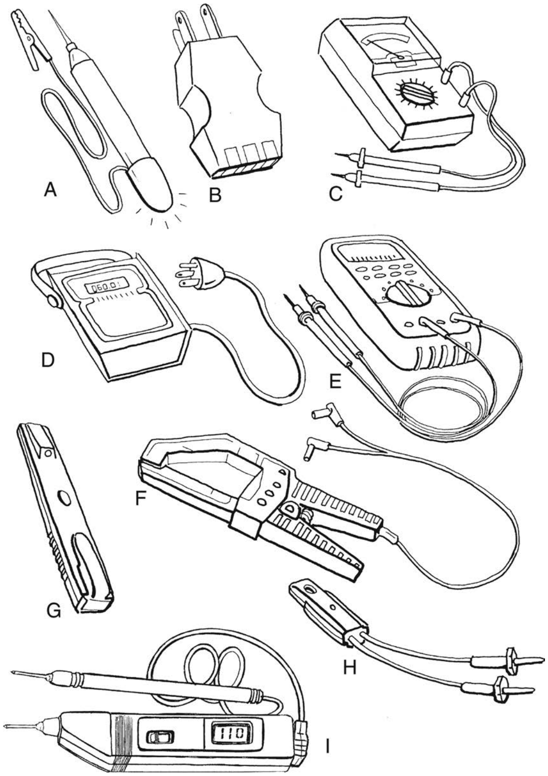


FIGURE 17.7

Meters for measuring electricity: (A) continuity tester, (B) circuit tester, (C) voltmeter, (D) line frequency meter, (E) digital multimeter, (F) amp probe attachment for multimeter, (G) voltage sensor, (H) voltage tester, (I) small portable digital multimeter.

of voltage when it is a matter of personal safety. Use a contact-making voltage meter to verify the absence of voltage before touching any part that might pose a shock hazard.

Testing continuity and testing for shorts

Unlike most other tests discussed in this section, a continuity test must be performed with the circuit disconnected from power. The test checks for a break in the line. If the line is continuous, the tester will beep or light up. There are stand-alone testers (Figure 17.7A), but a continuity function is built into most multimeters like those in Figures 17.7 E and I.

A continuity tester is handy to check whether a bulb or fuse has blown or whether there is a broken wire somewhere in a cable. If the filament of the bulb is intact, the tester will show continuity across the terminals of the bulb.

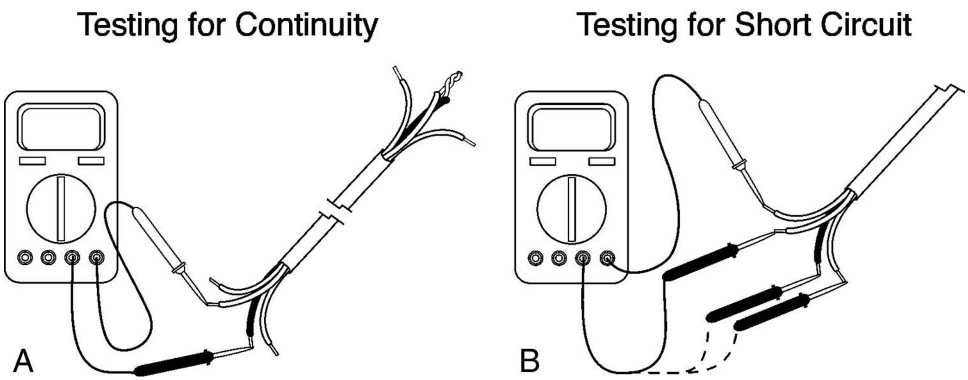


FIGURE 17.8

An easy way to shop-test continuity in a cable is to twist the wires together at one end and read continuity at the other end, as shown (A). If you get a beep, both wires are good. (Use a jumper wire or make a testing plug to short out the conductors when the cable has connectors attached.) You can also use the continuity meter to check for shorts between wires (B) by touching a meter probe to one wire, then checking each of the other wires. If you get a beep, there is a short between those two wires.

If you are checking continuity on a piece of cable, it is often easier to do it from one end, rather than having to touch one probe to both ends. If the cable has bare wire ends, you can do this by simply twisting the wires together on one end, and then reading continuity (up and back) from the other end (Figure 17.9A). If the cable has connectors on the ends, make a testing aid—a male connector with a jumper wire connecting all the contacts. This makes it a simple process to plug the connector onto the female end of the cable and read continuity between each of the male contacts at the other end. (Note: You might want to label your device with a warning like “Testing Aid. WARNING DEAD SHORT.”)

If you suspect a short in a piece of cable or equipment, you can use a continuity tester to check for continuity between wires (Figure 17.9B). If you find continuity, there is a short. Check each combination of wires (neutral and phase, neutral and ground, phase and ground). You can check a whole cable run this way. If you find a short, just be sure that you haven’t overlooked a path for continuity before you jump to conclusions (remove the bulb before testing for shorts on a light fixture).

Voltage meters

Lighting technicians usually carry some kind of voltage meter with them. Meters and testers come in many shapes and sizes.

Most lighting technicians may invest in a small digital multimeter (Figure 17.7I) that measures AC and DC voltage, detects continuity, and measures resistance. An “average-responding” or “RMS-calibrated” meter assumes the waveform being measured is close to a pure sine wave and works accurately for incandescent and power factor corrected loads; however, they read 30–70 percent low when harmonic distortion is present. A true RMS meter is necessary to make accurate readings of non-linear loads (Figure 17.10).

FIGURE 17.9

Plug-in voltage meter.

Here are some general precautions when you are setting up to take readings:

- Be sure that your hands, shoes, and work areas are dry.
- Set the meter on a stable surface or hook it over a stable vertical surface. If one of the probes is attached to the meter, place your body so you will not have to strain, twist, or get off balance to see the readout.
- Avoid taking readings in extremely humid or damp conditions or where there is dust or sawdust in the air. These conditions increase the risk of an arc.
- Carefully inspect the full length of the test leads and the test probes for worn insulation, exposed wire, gaps between the wire insulation and the connector shrouds, broken tips.
- Select the type of service being read (AC or DC) and select the voltage range (if applicable). If metering unknown values start with the highest range, then change to a more accurate setting once you know the correct range.
- For voltage readings, double check that AC voltage mode is selected. Metering accidents have occurred because the meter was set for amperage, resistance, or continuity mode. Double check that the test leads are connected to the voltage jack, not amperage or resistance jacks.
- Meter readings should be taken from test jacks in the distribution box or by inserting the probe into a receptacle or single-conductor connector. Place fingers behind the flared finger guards. Do not place fingers close to the probe tips or any live parts. Apply one probe at a time. Take care not to let the probe tips touch one another.

FIGURE 17.10

True RMS multimeter.

(*Courtesy Fluke*)

Measuring amperage

A clamp-on ammeter (Figure 17.7F) is used to measure amperage traveling through a single conductor. The amp clamp has two curved fingers that close around an insulated single-conductor cable. When reading non-linear loads, a true RMS ammeter must be used for accurate results.

Wattmeter or power meter

A wattmeter or power meter has a clamp-on device like an ammeter, and probes like a voltmeter. It reads true power (W) in a circuit. This meter can account for the phase difference between current and voltage when there is inductive or capacitive reactance in the circuit. Some power meters require you to turn off power to the circuit when connecting and disconnecting the meter, then turn on power to take readings. A wattmeter also reads amperage and voltage separately, which together give you the apparent power and power factor.

Power quality meter

A power quality meter looks like a multimeter on steroids (Figure 17.11). It typically has a large screen. The current clamp and voltage leads plug into the meter. (There are also amp clamp-style power quality meters.) The meter provides detailed analysis of the power, including true RMS and peak voltage and

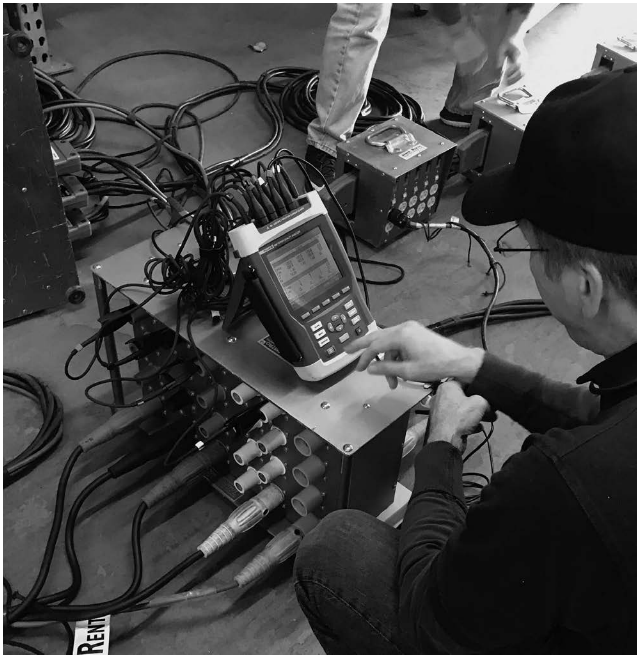


FIGURE 17.11

Power quality meter.

(*Courtesy Alan Rowe*)

current readings with a visual display of the waveform, displays current harmonic bar graph, total harmonic distortion, frequency (Hz), power factor, and load imbalance. It can be set up to monitor and log the system. These are professional instruments capable of performing analysis that is way beyond what a lighting technician would ever need to do. Nonetheless, they are especially useful for investigating issues associated with non-linear loads.

Measuring frequency (Hz rate)

A frequency meter measures the frequency of an AC circuit in cycles per second (Hz). A stand-alone, plug-in unit like the one in Figure 17.7D is useful for monitoring frequency. Many meters have the capability to measure frequency including some multimeters and amps clamps, and almost any watt meters or PQMs. Knowing that the generator is providing a frequency of exactly 60 Hz is necessary when powering HMIs from magnetic ballasts.

Circuit breaker finder

This is a helpful device for determining which circuit breaker controls which outlets when powering from house circuits on location. A circuit breaker finder is a two-part system. First, you plug the transmitter into an outlet. Next you go to the circuit breaker panel and run the trace over the circuit breakers.

The trace will flash or beep when it identifies the circuit breaker associated with the outlet. The transmitter injects a signal into the wiring which the receiver detects. See Chapter 18.

Meter categories

Any kind of electrical test equipment must meet product safety standards and should bear the mark of a recognized testing lab like UL or the Canadian Standards Agency (CSA). Voltmeters, amp clamps, power meters, and power quality meters must also be category rated. The location in which an electrical meter is used determines the rating required for that measuring instrument.

Cat I	Electronics within an appliance or device. Do not use for power circuits.
Cat II	Long branch circuit receptacles (< 30 ft.).
Cat III	AC distribution panels and distribution boxes. Receptacles on short branch circuits.
Cat IV	Power sources, generators, service entrance, main panel, panels immediately downstream of transformers or generators including light supply panels on a sound stage.

The category rating is protection from transient voltage spikes created by lightning striking distant power lines, loads switching, or malfunction in the utility. A voltage spike can cause arc-over inside the meter, and possibly lead to an arc flash event which can be very dangerous, blowing up the meter and burning the hands of the user. Energy levels are highest the further upstream in the system you are metering. As you move further downstream, impedance of the cables and circuit parts reduces the arc risk. A meter rated for Cat IV has thicker insulation on the test probes, bigger internal distances between electrical points, a fuse to protect the meter and the user, and a fuse to help protect against high-energy transient voltages. Generally, a Cat III or IV meter should be used to meter portable distribution equipment. A Cat IV meter should be used for readings taken at a power source or directly downstream from it. Be sure to use a meter that's correctly category-rated for the work you are doing.

ELECTRICAL SHOCKS AND MUSCLE FREEZE

Some important rules to live by when working with electricity:

- Never expose conductive parts unless the system is de-energized and the absence of voltage has been verified with a meter. When working on portable equipment, ensure the power cord or cables are disconnected from power and that the cord remains under your sole control so that no one else can restore power while you are still working on it.
- Do not open up the casings of ballasts or power supplies that have capacitors unless you have been trained and know how to safely discharge them.
- Use well-maintained, properly rated tools and test equipment. Store your test instruments in a dedicated case to protect them from damage.

- Use appropriate personal protection equipment. If there is a chance that you could contact an energized part, the system should not be energized. If it has to be energized to accomplish the task (because voltage is necessary), you should be a qualified person—someone with some serious electrical training. If you are that person (why are you reading this chapter?), you must be wearing voltage-rated class 00 rubber gloves with leather protectors for shock protection. If there is a risk of arc flash, there is a ton of arc-flash protective equipment that is required to be worn as well. None of this would normally fall within the job description of a lighting technician.
- Don't work alone.

If a person comes into contact with a live wire and completes a circuit, the biggest danger is that their muscles will contract and freeze, and they will not be able to pull away from it. If this happens, the most important thing is to *turn off the electricity* as quickly as possible. The severity of an electrical injury and the likelihood of cardiac arrest and death is directly proportional to the length of time a person is shocked. *Do not touch someone who is being shocked*. Unless you can move faster than 186,000 miles/second (the speed of light), you will become part of the circuit. *Turn off the power first*.

Once the victim is away from the circuit, check for pulse and breathing. Begin CPR immediately if there is no pulse. Call for professional medical assistance. It is important that a person who has received a shock go to the hospital, have their heart monitored and bloodwork done, and be looked over by a doctor. Even without any outward signs, shock can cause serious injury to internal muscles and organs. It has happened that a person walked away from a shock accident only to have a heart attack two days later when the injured heart muscle seized up. A doctor can check the electrolytes in the patient's blood and prescribe muscle relaxants and other therapy if he or she sees a potential risk.

The technician who has been shocked may not even want to go to the hospital. He or she may feel embarrassed and want to play down the accident. He or she may feel fine and not want to be taken out of work. Keep in mind that this person is probably not thinking very clearly. Always report any kind of injury. It could seem like nothing at the time, yet turn out to be something serious. If you report it to the medic, you have started a paper trail, which will be necessary later to establish that the injury was work-related.

In addition to the duration of contact, the severity of damage from a shock is determined by the number of vital organs traversed, especially the heart. The most lethal path electricity can take is into one arm and out of the other. As electricity travels across the chest and through the heart and lungs, it can very easily cause ventricular fibrillation or stop the heart entirely. This is the reason that electricians put one hand in their back pocket or behind their back when dealing with live parts.

The amperage of a shock is a combination of the current in the circuit and the resistance present (Table 17.4). The resistance of dry skin, for example, is about 100,000 Ω. This resistance is enough for brief contact with a 100 V circuit to allow about 1 mA, or 0.001 A, to flow through the body, which is enough to bite, but not enough to cause damage (Table 17.5). In contrast, the resistance of wet skin is about 1000 Ω, which allows about 100 mA to flow through the body. This is enough to cause ventricular fibrillation, impede breathing, and cause unconsciousness and possibly death.

Every lighting technician must have a healthy respect for electricity if he or she aims to have a long and successful career. People are killed every year by accidental electrocution. Pressure, stress, long hours, and physical exhaustion can cloud good judgment and clear thinking. Be aware of your

Table 17.4 Effect of resistance on amperage of shock

Condition	Resistance (Ω)	Milliamps (mA)
Dry skin at 100 V	100,000	1
Wet skin at 100 V	1000	100
Through an open cut at 100 V	500	200
Dry skin at 10,000 V	100,000	100

Table 17.5 Effect of ampacity on shock victims

Current	Effect on body
1 mA or less	No sensation (not felt)
More than 5 mA	Painful shock
More than 10 mA	Muscle contractions, could “freeze” some people to the electrical circuit
More than 15 mA	Muscle contractions, can cause most people to become frozen to the electrical circuit
More than 30 mA	Breathing difficult, could cause unconsciousness
50–100 mA	Ventricular fibrillation of the heart possible
100–200 mA	Ventricular fibrillation of the heart certain. Death is possible
Over 200 mA	Severe burns and muscular contractions; the heart is more apt to stop beating than to fibrillate. Death is likely
1 A or more	Permanent damage to body tissues, cardiac arrest, severe burns, and probable death

physical and mental state. As a professional, your judgment of a situation has weight; don’t discount it. No matter how frantic things get, when it comes to dealing with electricity, remember to slow down, think about what you are doing, and don’t let anyone distract you. No situation in filmmaking is worth the risk to your life and health.

CHAPTER

Power sources 18

For high-demand productions like episodic television or feature films, power is generally from the lighting supply panels installed on sound stages and from a large trailer-mounted or tractor-mounted generator when working on location. However, power for a production's lighting can come from a wide variety of sources.

- Battery
- Battery-powered generators
- Small portable generator (1–9 kW)
- Wall receptacles on location
- A tie-in to a distribution panel on location

In each case, the lighting technician needs to know how the system operates, its potential, its limits, and problems to watch out for. We'll start small and work our way up.

RECHARGEABLE BATTERIES

Battery-powered lighting is indispensable in situations where no other power source is practical, such as when shooting in a moving car, a boat, on the street, a remote location, or when a light has to move with the action in a long tracking shot. Even when there's plenty of available power, battery power can provide a faster, more efficient way to work. Being cordless, a battery-powered light is easy to fly-in at a moment's notice. There are no cables to dress and hide from camera.

Battery types and mounts

With the advent of very capable low-wattage LED lights, there has been a corresponding increase in the use of battery-power in the lighting department, especially on-board *brick* batteries (Figure 18.1), but also high-capacity *block* batteries (Figure 18.2), and *belt* batteries (Figure 18.3).

Brick batteries of the 14 V and 28 V variety are generally available in capacities between 90 and 290 watt-hours (Wh). There are three standard systems used to mount and lock brick batteries to plates on cameras and lights (Figure 18.4):

- V-Mount, developed by Sony, now open to all manufacturers.
- Gold Mount, developed by Anton Bauer (also known as an *A/B mount* or generically as *3-stud*), now open to all manufacturers.
- B-Mount developed jointly by ARRI and Bebob, open to all manufacturers.

FIGURE 18.1

Brick batteries are on-board batteries, meaning they are mounted to a mating plate on the light or power supply. These Helix 90 and 150 Wh Li-ion batteries from CORE SWX display predicted run time, based on rate of consumption.

(*Courtesy CORE SWX*)

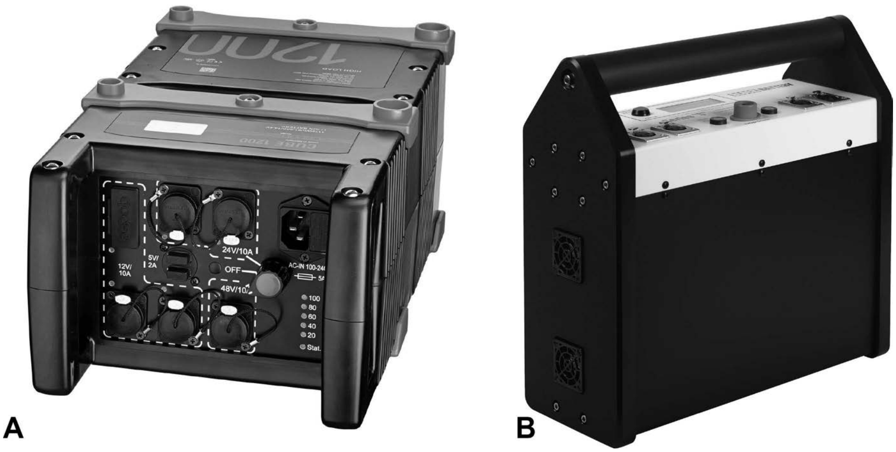


FIGURE 18.2

For larger, more powerful lights, a block battery may be necessary to achieve a reasonable run time. (A) Bebob's CUBE 1200 is a Li-ion battery with a capacity of nearly 1,200 Wh. In addition to 12 V and 24 V, it can provide 48 V, which can run a SkyPanel S120 at full power (when operated on 28.8 V the S60 and S120 operate at 50 percent output). (B) Block Battery™ makes a variety of NiMH, 14.4 V and 28.8 V block batteries including this S800, which has an 800 Wh capacity.

(*A Courtesy Bebob. B Courtesy Block Battery*)

FIGURE 18.3

Belt battery. With the cells distributed around the belt, a belt can be worn by the user.

(*Courtesy LibertyPak*)

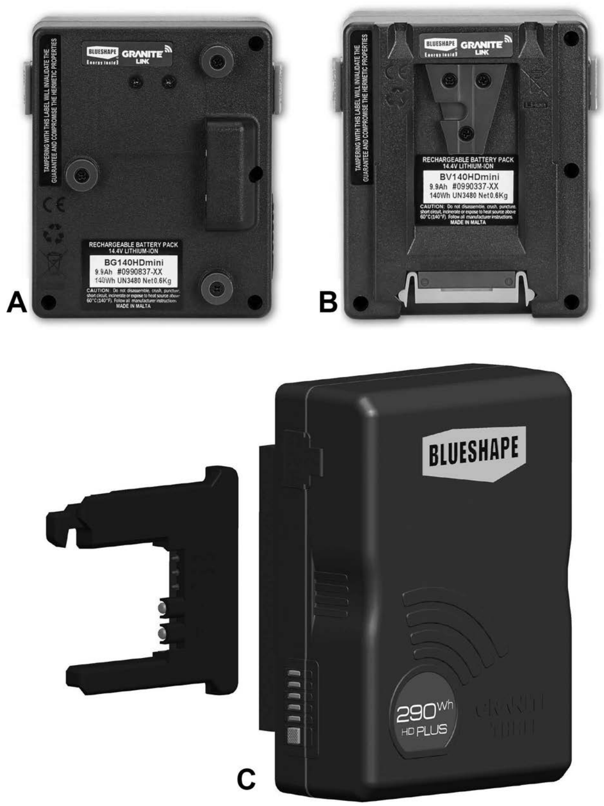


FIGURE 18.4

Brick battery mounts: (A) Gold Mount (three-stud), (B) V-Mount, (C) B-Mount.

(*Courtesy Blueshape*)

These mounting systems provide physical capture and the electrical connection automatically as the battery is mounted. Currently, for feature film and large production lighting, rental companies in the US tend to use Gold Mount. Gold Mount has less of a chance of being inadvertently unmounted whereas V-Mount can easily unmount if the release lever is bumped. On independent productions, you see more V-Mount as there are more low-cost alternatives. V-Mount and Gold Mount are widely adopted, so batteries and accessories are almost universally available in either style.

B-Mount was introduced in 2019. It is a duel-voltage system, 12/24 V (or 14.4/28.8 V), with a very stable mount capable of handling heavier batteries. It uses higher-capacity electrical connections than the previous mounts. It was designed to address the increasing power needs of large cameras and LED lights. ARRI and Bebob have made the protocol and interface open to all manufacturers and are working to make B-Mount the new, universal standard.

Brick batteries are available in a variety of chemistries, most commonly lithium-ion (Li-ion) and nickel metal-hydride (NiMH). For comparison, a typical 14 V, 150 Wh Li-ion battery weighs roughly 2.5 pounds, while a comparable NiMH battery weighs about 5.6 pounds. We'll discuss other differences between chemistries later in this section.

Block batteries are available with capacities ranging from 300 to 1200 Wh. They can weigh 15 to 35 pounds and are connected with a cable. Generally, block batteries are NiMH, but Li-ion and lithium iron phosphate ($LiFePO_4$), "safe lithium," versions are also available. There are important differences in capability between different battery chemistries.

Cables for 12- to 28-volt DC systems generally use 3-pin or 4-pin XLR connectors. (Some block batteries use other connectors. See Table 18.2.) Many battery mounting plates and block batteries supply 14.4 V using a 4-pin XLR connector and 28 V using a 3-pin XLR connector; however, there are notable exceptions. The ARRI SkyPanel accepts 28 V using a 4-pin connector. Many lights can accept either voltage, and some equipment can be ordered with either connector at the customer's discretion. So, it is up to the rental houses and lighting technicians to ensure that they have the cables and adapters to make the parts work together. In all cases, only two of the pins are actually used.[1]

Voltage

A battery pack is made up of cells that have a certain nominal voltage. For example, a 14.4 V Li-ion pack has four 3.6 V cells. A 12 V NiMH battery has ten 1.2 V cells. The most commonly used nominal battery voltages for lighting applications include the following:

Li-ion	7.2 V, 14.4 V, 28.8 V
NiMH or NiCd	12 V, 24 V, 30 V

These are nominal values. The voltage is actually a range from fully charged to the low-voltage cut-off point. For example, a 14.4 V Li-ion battery typically has an operating range of 16.8–11.2 V. The

[1] Creamsource pinout for 350 W Doppio uses all four 15 AWG conductors to handle the 14 A current. Two are wired as plus, the other two as minus. Exceptions like this make it crucial to use the appropriate cable when using the higher wattage LEDs.

charger will stop charging when the battery reaches 16.8 V and the battery will cut out when discharged to 11.2 V. This is because each Li-ion cell has a range from between 2.8 to 4.2 V.[2]

Lights that accept DC battery power are therefore designed to tolerate a range of voltage, such as 12–35 V or 24–36 V, for example. The following protections are standard and required for safety and for the health of the battery: over-current, over-charge, and over-discharge. Some batteries also have thermal protection to disable the battery if it starts overheating. These safeguards protect the battery from states that would permanently damage the battery or could pose a safety hazard. You may run into cheaper, imported batteries that do not provide undervoltage protection, for example. This could allow a light that is capable of operating at low voltages to discharge the battery down to a level that is permanently damaging the battery. More about battery protections later.

There are a couple of ways a battery can provide multiple voltages: A battery can provide 14.4 or 28.8 V, for example, by running two 14.4 V cell groups in series (28.8 V) or in parallel (14.4 V). A second way is to buck (reduce) or boost the voltage using electronics. This is called a regulated battery. See "Options for powering lights with batteries" later in this chapter for examples of voltage regulation being employed to power larger LEDs.

Many lighting devices are designed with 14.4 and 28.8 V batteries in mind. For example, an LED that accepts 24–36 V DC can be powered from a 28 V brick battery or block battery, or from two 14.4 V brick batteries connected in series (via a duel-mounting bracket). The light could also be powered by a 30 V battery belt.

Belt and block batteries are most commonly NiMH, available in 12, 24, or 30 V. HMIs like the Pocket Pars and Joker-Bug require 30 V batteries. The ARRI AC/DC EB 575/1200 ballast can run off 24 V DC to power a 575 W HMI, or 48–60 V DC to power a 1200 W head.

Small lights (small LEDs, dedos, MR-16 track lights, and car kits) that can operate on a 12 V system have the added capability to be powered from a vehicle's cigarette lighter or auxiliary 12 V circuit. A lighter circuit is generally protected by a 10 A fuse, so 120 W is the maximum load.

Current

The critical factor for selecting an appropriate battery for a particular light is the battery's maximum current draw. The battery can only power lights that draw less than the battery's maximum designed current. Lights above a certain wattage use a 28.8 V system because the current at 14.4 volts could exceed many batteries' maximum current. Lights that are even larger may use a 48 V system. Using a higher voltage reduces the current, which is better for the light as well as battery longevity; there is less heat, less energy loss, and better battery run time.

As an example, many of the larger capacity brick batteries have a 10 or 12 A maximum current. At 12 A, a quick calculation tells you the biggest light that can be powered at 14.4 V is 173 W (12 A × 14.4 V = 173 W). By the same logic, for a 28.8 V battery the maximum wattage is 350 W. Some lights in the range from 300 to 575 W can be powered by a 48 V system. Brick batteries have a maximum discharge current between 6 and 12 A. Lighting technicians need to pay attention to this. There is nothing to prevent a battery with a 6 A max current draw being connected to the light that draws 12 A.

[2] Some Li-ion batteries are labeled as 14.8 V instead of 14.4 V. This is due to slightly lower internal resistance. It is a marketing advantage because it allows the manufacturer to post a higher Wh rating for the battery, but this does not affect the operation of portable devices nor the setting of the chargers. You'll also see batteries simply referred to as 14 and 28 V.

Excessive current will trip overcurrent protection circuitry in the battery. If the battery has a brain (microprocessor and management system), the battery management system triggers the shutdown based on temperature or current. Batteries typically also have an additional fail-safe fuse which may be either self-resetting polyfuse or one that is not user serviceable. If a battery cuts out due to over-current, it will typically reset itself automatically once it has had a chance to cool. Operating batteries regularly at or above their rated maximum current will damage the cells and shorten the life of the battery. There are batteries available that are designed to deliver 15 and even 25 A maximum draws (see Tables 18.1 and 18.2).

Another possible limiting factor if the system uses XLR connectors is the ampacity of the connector and wire gage. The capacity of XLR connectors varies by type and number of pins, but the beefiest ones intended for DC power (like Neutrik NC3MXX or RX series) are rated 16 A for 3-pin, and 10 A for 4-pin.

Table 18.1 Sample of brick batteries (V-Mount and Gold Mount®)

Make and type	Chem	Nom voltage (V)	Capacity (Wh)	Max discharge (A)	Weight (lb.)	Connectors	Notes
Anton Bauer							
Dionic XT90	Li-ion	14	99	12	1.76	A, B, D	2
Dionic XT150	Li-ion	14	156	12	2.4	A, B, D	2
Titon 90	Li-ion	14	92	10	1.76	A, B, D	2
Titon 150	Li-ion	14	156	10	2.4	A, B, D	2
HyTRON 140	NiMH	14	140	12	5.49	G	2
Digital G190	Li-ion	14	194	10	2.99	A, B	2
Block Battery™							
2F1–144	NiMH	14/28	144	125 W (200 W max)	3.75	E	
2F1–96HCU	$LiFePO_4$	14/28	96	200 W (300 W max)	2.5	E	
Blueshape							
BV095HDMini	Li-ion	14	95	7	1.48	A, B	
BV150HDMini	Li-ion	14	143	12	1.96	A, B	
BV090	Li-ion	14	90	7	1.69	A, B	
BV150	Li-ion	14	150	9	2.62	A, B	
BV180	Li-ion	14	180	9	2.62	A, B	
BV100HD	Li-ion	14	94	12	2.62	A, B	1
BV140HD	Li-ion	14	190	12	3.57	A, B	1
BV270HD	Li-ion	14	266	12	3.57	A, B	1

Table 18.1 Sample of brick batteries (V-Mount and Gold Mount®)

Make and type	Chem	Nom voltage (V)	Capacity (Wh)	Max discharge (A)	Weight (lb.)	Connectors	Notes
BV100HDplus	Li-ion	14	96	20	1.69	A, C	1
CORE SWX							
HV Slim 98	Li-ion	14	98	12	1.4	A, B, D	2, 3, 5
Hypercore 98	Li-ion	14	98	12	2	A, B, D	2, 3, 5
Hypercore 150	Li-ion	14	150	12	2.4	A, B, D	2, 3, 5
Hypercore PRIME	Li-ion	14	190, 95/half	10	2.6	A, B, D	2, 3, 5
Hypercore XL	Li-ion	14	293	15	3.4	A, B, D	1, 2, 3, 4, 5
HLX 9	Li-ion	14/28	98	12/6	1.4	A, B, D	1, 2, 3, 4, 5
HLX 150	Li-ion	14/28	147	12/6	1.8	A, B, D	1, 2, 3, 4, 5
HLX XL	Li-ion	14/28	293	15/7.5	3.4	A, B, D	1, 2, 3, 4, 5
HLX PRIME	Li-ion	14/28	190, 95/half	12/6	2.6	A, B, D	1, 2, 3, 4, 5

Note: The actual nominal voltage listed by the manufacturer may be 14.4 or 14.8.
A: Can be ordered in either V-Mount or Gold Mount®
B: P-tap, Power tap™, D-tap (which are all different names for the same auxiliary connection port)
C: P-tap charging option
D: USB
E: Uses proprietary mount. Adaptor plate for V, Gold Mount®, belt battery, or direct mount
G: Gold Mount only
1: Wi-fi to diagnostic app
2: LCD display (run time etc.)
3: LED lights indicate state of charge
4: Storage mode reduces loss during storage and provides 30 percent state of charge for travel
5: Sleep/hibernate modes. Battery accelerometer detects and times inactivity and activates sleep mode to preserve charge

Table 18.2 Sample of block batteries

Make and type	Chem	Nom voltage (V)	Capacity (Wh)	Max discharge (A)	Weight (lb.)	Connectors	
Anton Bauer							
Cine VCLX	NiMH	14/28	630	20/12	24.86	F	2
Bebob™							
CUBE 1200	Li-ion	12/24/48	1176	10	20	B, D, J, H,	3
Block Battery™							
S401-33044	NiMH	14/28	400	20/12	18	F, H, I	2

Continued

Table 18.2 Continued Sample of block batteries

Make and type	Chem	Nom voltage (V)	Capacity (Wh)	Max discharge (A)	Weight (lb.)	Connectors	
S600-33044 D600-33044	NiMH	14/28	560	15	27	F, H, I	2
S800-33044 D800-33044	NiHM	28/14	800	15	35	F, H, I	2
SLi-300	Li-ion	14	280*	15	9	J	2
Sli-600	Li-ion	14/28	550	12	17	F, H	
HC400	NiMH	28	400	25	15	K	3
HCL-435	$LiFePO_4$	24/48	435		15	K	2, 6

*SLi-series and HCL-435 have a modular cell design enables battery to travel in parts. See manufacturer's instructions.
B: P-tap, Power tap™, D-tap (which are all different names for the same auxiliary connection port)
D: USB
F: Normally 4-pin XLR @ 14.4 V (can also be custom ordered)
H: Normally 3-pin XLR @ 28.8 V (can also be custom ordered)
I: Optional 2-pin Amphenol @ 28 V
J: 4-pin XLR
K: 2-pole Neutrik Speakon (NL2FX) connector
2: LCD Display (run time etc.)
3: LED lights indicate state of charge
6: SkyPlate for mounting directly to ARRI SkyPanel

Battery capacity, run time, and charging

Battery capacity can be expressed in watt-hours (Wh) or amp-hours (Ah). Having the value in watt-hours tells you directly how long a battery will last when powering a particular wattage (Wh ÷ watts = hours). Theoretically, a 120 Wh battery can power a 120 W light for one hour (or a 60 W light for two hours, or a 40 W light for three hours, and so on). This is a handy way to think about capacity because it is independent of the voltage. Table 18.3 shows run time in minutes for different combinations of lights and batteries.

Run times calculated: Wh ÷ W × 60 = endurance in minutes. This assumes the battery is fully charged and its capacity is undiminished by age or abuse. Depending on battery voltage, some combinations may not be practical due to excessive current. Actual power consumption is less when dimmed. See Appendix H for maximum power consumption of LEDs.

The amp-hour rating tells you how long the battery will last at a given amperage draw (amps × hours = Ah). For example, a 120 W light operating at 14.4 V draws 8.3 A. If it is connected to a battery that has a nominal capacity of 9.9 Ah, it will power that light for 1.2 hours (9.9 Ah ÷ 8.3 A = 1.2 hours).

A *smart battery pack* is a battery pack that has a *battery management system* (BMS) and external communication bus. A smart battery pack must be charged by a *smart battery charger*. A BMS protects a battery from over-current, over-voltage during charging, under-voltage during discharging, over-temperature, and other states that could harm the battery. It also enables monitoring the voltage, current, state of charge, and other parameters. The charging protocol establishes how much voltage or current is

Table 18.3 Run time in minutes

Run time in minutes						
Battery apacity (Wh)	**Light power output (W)**					
	50	**100**	**150**	**200**	**250**	**300**
90	108	54	36	27	22	18
120	144	72	48	36	29	24
150	180	90	60	45	36	30
190	228	114	76	57	46	38
260	312	156	104	78	62	52
290	348	174	116	87	70	58
400	480	240	160	120	96	80
500	600	300	200	150	120	100
800	960	480	320	240	192	160
1200	1440	720	480	360	288	240
1600	1920	960	640	480	384	320

applied for how long, and what the charger does when charging is complete. A smart charger typically can charge a "dumb" battery. There are plenty of "dumb" batteries in the lower-end battery market, so you need to know what you have.

A charger for Li-ion batteries follows a specific charging sequence that is different than that of a NiMH or NiCd battery. The Li-ion charging cycle begins by the charger applying a constant current to the battery. As the battery charges, the charger steadily increases the voltage to maintain constant current until the voltage limit of the battery cells is reached (4.2 V/cell). At that point the battery is about 85 percent full. The charger then switches to phase two, finishing the charge at a constant voltage. Current slowly declines as the voltage in the battery equalizes to the voltage of the charger. At that point the charge is complete. Li-ion batteries cannot tolerate overcharging, so the charging protocol includes a way for the battery charger to sense the state of charge, and cut off when the charge is complete. Li-ion batteries do not tolerate trickle charging (charging at low current to continually top off the battery).

A smart charger's BMS can identify the battery type when the battery is connected. Some chargers are designed to adapt the charging method to the battery chemistry making the charger multi-chemistry compatible. Others are designed for use with a particular chemistry only. Battery protocols have evolved over the years, so the more up-to-date the equipment is, the smarter it is. Be careful that the charger being used is appropriate for the battery. If in doubt, check the manufacturer's documentation. In addition, for some manufacturers, using a charger by another manufacturer may void the battery warranty.

Important things everyone should know about charging batteries (this applies to your laptop, cell phone, and GoPro too):

- Do no leave batteries discharged for a long time. This can permanently damage and even disable the cells or may present a safety hazard when they are recharged.

- Do not over-discharge batteries. When your phone hits the redline, using it longer is shortening the useful life of your phone. Same goes for all batteries.
- Do not continually top-off batteries. This also can damage them.
- When batteries are in storage or out of use, store them at a 30–40 percent state of charge.

Charge time

Charge time depends on the charger current and the battery capacity (Ah). A charger has a maximum current; 2, 2.5, 3, 4.0, 4.8 A are common. For a rough estimate of charge time for Li-ion batteries use this formula:

$$\text{Charge time (hrs)} = \frac{Battery\ capacity\ (Ah) \times 0.85}{Charger\ \ current\ (A)} + 0.5$$

It is important to recognize that charging batteries at higher current may shorten the life expectancy of the battery. With current Li-ion technology, 3 A is the happy medium between charge time and battery longevity. For the equipment owner, it is not a good thing that there is market pressure to charge batteries faster. No matter what the marketing says, faster charge times cannot be achieved without permanently affecting the life of the battery. Many V-Mount and 3-stud batteries shut down if the charge current is 5 A or more, but there are 6 A, D-tap chargers that can get around this. The preferable solution is to have enough batteries to cover the required charge time and don't push charge times.

How many batteries do you need to run a light continuously? With a high-wattage light, it takes longer to charge than to discharge. To be safe, you need to have four or five batteries in circulation per light, provided the dead batteries can be put on the charger right away and four batteries can be charged simultaneously.

For example, if you are using 190 Wh, 14.4 V batteries (13.2 Ah) and the charger current is 3 A, the recharge time is 254 minutes. If the light's discharge current is 10 A, the first battery will be dead in 79 minutes. That means by the time the first battery is recharged, you will have discharged 3.2 more batteries, requiring at least five batteries to keep things going continuously.

On the other hand, if the charger current is 4.8 A, it will take only about 179 minutes to recharge the battery. By the time the first battery is charged, you will have discharged only 2.1 more batteries, so you could operate continuously with four batteries.

Of course, if you don't have access to power, you'll need enough batteries to last the full work day.

Combining batteries with plates and power stations

When using brick batteries, circumstances may require some additional capabilities, like the following.

- "Hot swap" (replace a battery without loss of power).
- Double battery capacity for large loads or long run times—increase the total capacity (Wh) of the power source by connecting several batteries in parallel.
- Power 28 V loads using two or four 14.4 V batteries (batteries in series or parallel pairs in series).
- Power 48 V loads using two or four 28 V batteries (batteries in series with voltage regulation to attain the correct voltage).
- Monitor state of charge, current draw, voltage, and wattage.

FIGURE 18.5

Power stations enable multiple batteries to run power-hungry devices. (A) PWS4 Blueshape power station. One to four hot swappable batteries power: two regulated 28 V (max 560 W) and simultaneously two regulated 14 V (max 280 W). (B) PWS4–48. Rugged power station from Blueshape use one to four hot swappable brick batteries to power two regulated 48 V (max 560 W) outs, two regulated 14 V outs (max 340 W) plus USB. Both stations have a backlit LCD display for monitoring.

Various power stations, adapter plates, and charger/dischargers are available from the major battery manufacturers like Anton Bauer, Bebob, Block Battery, Blueshape, Coemer, CORE SWX, and IDX. Power stations in various configurations are available to enable series connection or parallel combination of batteries and hot swapping (Figure 18.5).

Battery hot swapping and unregulated paralleling can also be accomplished with a shark fin (Figure 18.6) or similar battery plate. A shark fin is a double-sided plate that accepts a battery on each side and combines them into a single mount of the same type (V-Mount or Gold Mount).

Options for powering lights with batteries

It is instructive to look at some examples of how lights can be battery powered.

DMG Mini Switch is an 85 W light that accepts 12–35 V DC, so either a 14 or 28 V battery could be used. The backplates of DMG's lights are designed to accept various mounting plates so the controller and power supply or battery can be on-board. The DMG battery plate (either V- or Gold-Mount)

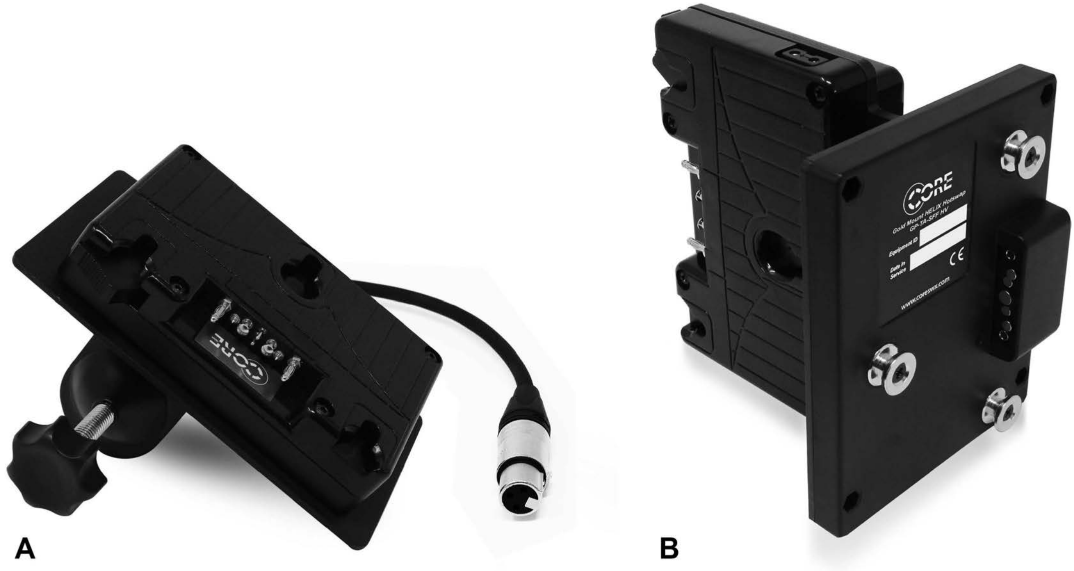


FIGURE 18.6

(A) 3-stud mounting plate with light stand clamp can be used with (B) a shark fin to accommodate hot swapping batteries. The shark fin enables two batteries to be mounted. These accessories by CORE SWX are specially designed to work with their duel-voltage, 14/28 V Helix (HLX) battery series. You can also use 14 V batteries on the HELIX plates and use HELIX batteries on non-helix plates at 14 V without any chance of transmitting higher voltage. Using the HELIX plate/battery combination gives access to 28 V, ideal for running LEDs most efficiently.

(*Courtesy CORE SWX*)

connects to the controller via DMG's special connector. A 190 Wh battery provides a theoretical run time of 134 minutes.

Litepanels's Gemini (1 × 1) specs say 13–28 V. It runs at 90 percent power from a 14.4 W battery and at its full 200 W from a 28 V battery. Even at 90 percent, the current draw at 14 V is high. For the sake of the light as well as the battery, it would be advisable to power this light with a 28.8 V battery. An accessory plate on the yoke of the light supports either a brick battery or AC power supply. A cable from the plate plugs into the side of the light.

Many LED lights that fall into the 100 to 200 W range operate on 28.8 V nominal. For example, Kino Flo's 140 LED DMX controller has a three-pin XLR input that accepts 18–36 V DC directly from a battery. Kino's 150 W lights can be powered by Kino Flo's own KF-21 NiMH battery for about 1 hour 10 minutes. The intention of the design of this light is that the power supply be separate, hung on the light stand where it is easy to reach. Accordingly, the battery plate has a mafer mount that can be attached to the light stand.

The Creamsource Mini, a 150 W, 1 × 1 LED panel, has its controller built into the light. It accepts DC via a 3-pin XLR input from either the AC power supply or from the 28.8 V battery plate. The battery plate mounts to the back of the light and its cable connects directly to the light. The plate accepts two 14.4 V batteries of at least 150 Wh. According to product literature, two 160 Wh, 14.4 V batteries can power the light for 50 minutes. Two 160 Wh, 14.4 V batteries in series are equivalent to one 160 Wh, 28.8 V battery.

A SkyPanel S30 (200W), S60 or S120 (both 420 W) accepts 23–36 V DC. Unlike most setups, ARRI uses a 4-pin XLR for its 28 V input. The S60 and S120 operate in battery mode, dropping to 50 percent of max output (about 200 W). This puts them in the range for use on 28 V brick and block batteries. Various plates (Figure 18.7) that mount to the light's back rail (or to an adaptor plate for ARRI's power supply) are available for onboard batteries, either two 14 V batteries in series or 28 V batteries in parallel. At 200 W, a 293 Wh battery provides a theoretical maximum run time of 87 minutes. Always be sure to shut off/unplug the battery before plugging the AC power supply into the light.

Third-party manufacturers have come up with other ways to power SkyPanel S30s, S60s, and S120s by using the light's 48 V power input instead of the 28 V battery input. When powered from this input, even the S60 and S120 can operate at full power. These solutions can also power other 48 V lights like the Filex Q1000 (300 W in battery mode). Here are some examples:

A large capacity battery like the Bebob CUBE (see Figure 18.2 and Table 18.2) has a 48 V outlet, in addition to 12 and 24 V. It can be used with 14.4, 28.8, and 48 V lights and is capable of powering up to a 480 W light.

The HCL-435 battery from Block Battery is a 435 Wh, duel-voltage (24/48 V) Lithium Iron Phosphate block battery that can mount to the back of the SkyPanel (see Table 18.2).

FIGURE 18.7

CORE SWX SkyPanel battery plate can accept two of CORE's 14/28 V Helix batteries and runs them in parallel which allows a lower battery current. Similar mounts are available as series-connected 14 V batteries. Be sure to use the correct three-pin XLR to four-pin XLR to connect to the light. The pin assignments must be compatible with the light.

(*Courtesy CORE SWX*)

The R-48-mini from Block Battery is a regulator that provides up to 500 W from one 48 V output. It is powered by two separate 28 V block batteries. Depending what batteries are connected, it can provide 400 to 1600 Wh capacity.

Shipping and flying with batteries

Li-ion batteries are unique in the amount of energy they can contain and how readily and quickly that energy can be discharged or feed into a short circuit. These characteristics make them great for powering lights and large format cameras, which tend to consume a fair amount of power. However, these characteristics can also contribute to thermal runaway if shorted and a possible battery fire. The Li-ion electrolyte is highly flammable, and battery rupture can cause physical injury and damage. This becomes an especially serious concern when batteries are put aboard aircraft. Even the halon fire suppression systems in the cargo bays of passenger and cargo aircraft cannot extinguish a Li-ion fire. As required by international regulation, Li-ion batteries have to be constructed with built-in physical and electrical protection and they must be rigorously tested, registered, and certified to meet UN requirements. You may see compliant batteries advertised as "safe to fly."

In addition, there are important restrictions on shipping and flying with Li-ion batteries. The Federal Aviation Authority (FAA, and its equivalents abroad) will confiscate equipment that does not comply. There have been instances where productions were brought to a halt when equipment was held up in transport due to noncompliance. Battery fires have occurred related to our industry, burning out a camera truck in one case, damaging a camera assistant's house in another, and smoldering in the cargo bay of a passenger jet liner in a third (only to be discovered just as the plane was about to be boarded). I hasten to point out that *none* of these events involved certified batteries like those listed in Table 18.2, which are drop tested and ruggedly built with all the necessary chemical, mechanical, and electrical protections.[3] Nevertheless, it is important to take travel regulations seriously. For safety, as well as for the reputation of our industry, it is important to respect the travel requirements and to plan accordingly.

You can find detailed shipping requirements online on the Web sites of the FAA, International Air Transport Association (IATA), and battery manufacturers, but briefly, the FAA does not allow any spare (uninstalled) Li-ion batteries in checked luggage, no matter the Wh rating. Certified batteries up to 100 Wh are permitted in carry-on bags (Figure 18.8). Up to two batteries from 100 to 160 Wh *may* be allowed in carry-on luggage, but only with the permission of the airlines. All batteries traveling must be protected from physical damage (by being firmly seated and separated in a hard shell case, for example) and contacts must be capped, so as to prevent short circuit. Batteries over 160 Wh are permitted to travel by air only if they are shipped as Class 9 Dangerous Goods, which means they have to be discharged to 30 percent or less, packed according to requirements for Class 9 Dangerous Goods by a certified shipper, and labeled with approved "Cargo Aircraft Only" and "Li-ion battery" labels. Otherwise they must travel by ground. Even if the travel by ground, Li-ion batteries over 300 Wh must ship via an authorized Class 9 Dangerous Goods shipper. NiMH and NiCd batteries are permitted to travel by air or ground without restriction.

---

[3] These incidents involved widely available, knock-off batteries that were not certified and were not constructed with required protections. Two of these incidents occurred while batteries overheated during charging. They were inexpensive knock-offs of Sony NP-F type or L-series, the type of battery widely used for camera remote focus accessories, field monitors, and some small LEDs. None of these incidents involved V-Mount or Gold Mount® battery types. When it comes to Li-ion, it is important to use batteries from reputable companies.

FIGURE 18.8

This 190 Wh battery separates neatly into two 95 Wh parts, so that it can travel in a carry-on. The battery is the HELIX Prime.

(*Courtesy CORE SWX*)

Common couriers (FedEx, UPS, etc.) have trained employees at specific offices who can ensure the package meets requirements regarding shipping Class 9 Hazardous Substances. Some battery manufacturers sell protective battery flight cases that are permanently labeled.

A block battery like the Sli-600 (made by Block Battery) is a 550 Wh Li-ion battery. It makes an instructive example. It can be shipped one of three ways. If it is shipped fully assembled, it must be shipped via an authorized Class 9 Dangerous Goods shipper, via ground shipping only. As an alternative, the design of this battery allows the cells to be unplugged from the case and removed and shipped separately. The product literature states that the 10–55 Wh cartridges can be shipped by ground without shipping as Class 9 Dangerous Goods by simply wrapping them individually in bubble wrap, which can all be placed in one box. Consult the shipper for proper packing, labeling, and paperwork. Ship the housing in a separate box. If it is urgent that the battery be shipped by air, there's a third and final option, which is to ship two cartridges per box in five separate boxes. Each cartridge is only 55 Wh at 3.2 V and will need to be discharged to a 30 percent state of charge prior to packing.

Battery chemistry and care

Differences between battery chemistries affect how we use them and what we use them for. Table 18.4 was prepared from data collected by batteryuniversity.com and actual field-testing. It gives a good idea of the advantages and disadvantages inherent in the various battery chemistries.

Table 18.4 Performance characteristics of various battery chemistries

Description	NiCd	NiMH	Lead-Acid	Li-Ion
Memory problems	Yes	Yes	Yes	None
Low maintenance	No	No	No	Yes—none
Holds its charge	No (–20%)	No (–50%)	Yes (–5%)	Yes (–1%)
High temperatures	Good	Good	Fair	Good
Cold-weather performance	Good	Good	Poor	Best (–20 °C)
Low internal resistance	Yes	Yes	No	Yes
High sustained voltage	Yes	No	No	Yes
Fast charge	Yes	No	No	Yes
Terminal voltage per cell (V)	1.2	1.2	2	4.2
Operational in any position	Yes	Yes	Not always	Yes
Cycle life expectancy	Up to 1000	Up to 500	Up to 300	Over 500
Weight per 100 Wh (lb.)	5	5	6	1.2
Environmentally safe	No	Somewhat	No	Yes

Lithium-ion

Li-ion batteries' advantages include more power, less weight, faster charging speed, no memory, and good cold-weather performance.

Especially if you own the batteries, you might consider using two packs connected in parallel when powering high-current loads, when possible, to reduce current and increase capacity. This improves battery longevity.

The two factors that most affect aging are temperature and state of charge. Li-ions age more quickly if kept at a high temperature for long periods (like when a laptop computer is used connected to mains power for long periods of time, or when a battery is left on the charger after it is fully charged). They will also last longer if stored with only a partial charge.

Achieving maximum performance from Li-ion batteries requires different operational techniques than those of NiCd and NiMH batteries. Batteryuniversity.com offers the following guidelines for operating Li-ion batteries:

LITHIUM-ION OPERATION

- Avoid frequent *full* discharges because this puts additional strain on the battery. Several partial discharges with frequent recharges are better for lithium-ion than one deep one. Recharging a partially charged lithium-ion does not cause harm because there is no memory. Short battery life in a laptop is mainly caused by heat rather than charge/discharge patterns.
- Keep the lithium-ion battery cool. Avoid a hot car. Don't leave them on the charger.
- For prolonged storage, keep the battery at a 40 percent charge level. When they are not going to be used for a while, do not recharge them fully.

- Avoid purchasing spare lithium-ion batteries for later use. Observe manufacturing dates. Do not buy old stock, even if sold at clearance prices.
- If you have a spare lithium-ion battery, use one to the fullest and keep the other cool by placing it in the refrigerator. Do not freeze the battery.[4]

4 Buchmann, Isidor. *Memory: Myth or Fact?* Batteryuniveristy.com. Copyright 2003–2005 Isidor Buchmann. Used by permission.

NiCd and NiMH

Performance under controlled conditions shows that NiCd actually has very little reduction in performance over 2000 cycles, unlike other types. This may come as a surprise to readers who have experience with rented NiCd battery packs, because we commonly run across NiCd packs with degraded performance. The difficulty is that NiCd are particularly susceptible to "memory" problems. Battery memory is reduction in the full charge voltage of a battery, which reduces the amount of time a battery can power a device with each charge cycle. This happens if a battery is repeatedly recharged before completing a full discharge and also when the battery is left on the charger for hours (or days) after being recharged. In normal use, we do not allow the battery to discharge fully, so memory is inevitable unless the battery is periodically "exercised."

Exercise is simply discharging the battery fully, down to 1 V/cell. It has been shown that exercising a NiCd battery once a month avoids the problem of memory. It is not necessary—in fact, it is counterproductive—to exercise a NiCd battery any more than once a month. It is also not necessary to go to any trouble to discharge the battery fully every cycle if the battery is given its once a month exercise. Exercise is best performed with a battery conditioner, a specialized battery charger, which automatically brings the state of charge down to a full discharge without harming the battery by over doing it.

When NiMH batteries first came out it was thought that they did not have memory; it has subsequently become clear that they do, but not to the same extent as Ni-Cads. No scientific research is available on the result of exercising NiMH, but experts estimate that exercising them once every 3 months will prevent the kind of crystalline buildup that causes the "memory" issue.

If the battery is left for a long time in a memory condition, the crystalline formations are much harder to break down. However, the battery can usually be completely restored using a combination of exercise and reconditioning. Reconditioning is regular exercise down to 1 V/cell followed by a very careful slow deep discharge to 0.6–0.4 V/cell. If a NiCd sits unused and unexercised for 3 months or more, it will require reconditioning. If the rental facility owns a battery analyzer, they can exercise and, if necessary, recondition all of your batteries before the prep. This will restore full performance in 9 out of 10 batteries that show degraded performance, and will weed out the ones that are beyond repair.

NiMH batteries will suffer damage if overcharged or over discharged, or overheated, so the charger must be a NiMH charger, matched to the battery. Once charged, NiMH batteries have a tendency to lose charge while waiting to be used and must be "topped off" before use. This is also true of NiCd batteries, but less so. It is often impossible to know the age of batteries when a rental house provides them. When you are relying on battery power for a shot, it is important to order more batteries than you need. It is safe to assume that some will not be able to give a full charge.

NICD AND NIMH OPERATION

- Exercise the battery with a full discharge at least once a month for NiCd; at least once every 3 months for NiMH.
- It is not necessary to discharge the battery before each recharge. This actually just puts more stress on the battery.
- Operation at high temperatures drastically reduces life cycle (reduced 20 percent at 86 °F, 40 percent at 104 °F). For better endurance, keep the battery out of direct sun.
- Avoid high temperature during charging. Charger should switch to trickle charge to cool the battery. Discontinue use of chargers that cook batteries.
- If not used immediately, remove the battery from the charger and apply a topping charge before use. Do not leave a nickel-based battery on the charger for prolonged periods, even if on a trickle charge.
- Nickel-based batteries prefer fast-charging. Lingering slow charges cause crystalline formation (memory).
- A NiMH battery charger can be used to charge NiCd, but not the other way around. A NiCd charger will overcharge and permanently damage a NiMH battery.
- Batteries age more quickly and can be damaged as a result of exposure to heat.
- For prolonged storage, store the battery at 40 percent charge level. And keep it cool. Lead acid batteries are the only type that should be stored at 100 percent charge.[5]

5 Taken from various articles by Isidor Buchmann on Batteryuniversity.com. Used by permission.

Inverters

An inverter is useful to power lights that operate on AC power, like fluorescents and HMIs. An inverter converts low voltage DC from a battery to 115 V, 60 Hz by generating a “pure sine wave” that has characteristics similar to the sine wave shape of utility power. This type of waveform is suitable for most AC loads, including linear and switching power supplies as well as transformers and small motors. Block Battery makes 600 and 1500 W inverters that are powered with between one and four block batteries. There are also battery-pack/inverter combinations, like the Little Genny (Figure 18.9).

FIGURE 18.9

The Little Genny Inverter System works as an uninterruptible power source (UPS); you can unplug the charger power supply and plug it into a different outlet without losing power to the light. It can be charged using a 24 V power supply or a special fold-up solar panel. The power is clean and can be used to power a laptop computer or charge a cell phone. It can also provide 24 V directly from the battery.

(*Courtesy LibertyPak*)

LARGE BATTERY PACKS

Combining powerful batteries with an AC inverter, large battery packs are capable of producing 120 V AC and even 208 V AC. There are a number of unique benefits to using such as system, the main one being the power source is completely silent and does not create exhaust, so it can be used on set or very close to set, and can be moved around fairly easily. In situations where you have limited ability to run cables (such as when a location imposes limitations) the power pack can just sit next to the light. When shooting on boats and vehicles, a gas-power generator can have fuel-flow problems because the fuel is sloshing around in the tank. A battery pack does not have that issue. It will not provoke noise complaints from the public, which diesel generators sometimes do. Fuel-powered generators involve fire prevention measures (especially in dry California), which can involve a fuel truck and fire-safety officers. A battery-powered source avoids these issues. They are ideal for shooting situations where vast quantities of power are not required, but a traditional generator is not practical or not desirable. Unlike gas-powered generators, these units only use up capacity when loads demand power; otherwise, the energy is just stored.

One example is the Electrix portable power pack from GripTrix. Mounted on a hand-dolly with oversize tiers, the system uses 24 V $LiFePO_4$ batteries. The AC inverter can output 1.8 kW or 2.56 kW at 120 V, or the pack can be used as a 24 V source (21.6–28.8 V). The unit has a 4-hour recharge time.

Another example is the VOLTstack series “electric generators” from Portable Electric. The units range from the size of a putt-putt generator, to a trailer-mounted unit (the size of a small U-Haul trailer). The line-up includes: 250 W (190 lb., 2.8 kWh, 120 V, 2.5-h recharge), 5 kW (330 lb., 5.6 kWh, 120 V, 2.5-h recharge), 20 kW (5000 lb., 107 kWh, 208/120 or 240/120 V, 5-h recharge from 208 V). The VOLTstack systems feature wireless, real-time energy management data.

USING AVAILABLE OUTLETS

When shooting on location with today’s efficient LED and HMI lighting and sensitive cameras, it has become more feasible to power the entire shoot using available wall outlets. This approach limits the DP in the type, size, and number of lights they can use; however, by using punchy, efficient lights like the ARRI M18 (17 A) for “sunlight” through windows for example, as well as LED softlights for key and fill, the lighting crew can address many lighting challenges even with the limitation of power. The two key questions are how to manage the brightness of daylight outside windows and doors, and how to manage the available power.

The first task is to appraise what lights you will be using, identify how many separate 20 A circuits you need for the “big” lights, identify enough additional circuits to accommodate all the smaller lights, and establish an organized system for ensuring that no circuit is overloaded. Remember, you are probably not the only department that needs to use house power. You have to count on hair-curling irons or blow dryers also needing power.

Getting organized

Organize the work to avoid the risk of tripping breakers. Not only does it slow production, there may be computers, hard drives, Wi-Fi routers, and other sensitive equipment connected. To the homeowner or location representative, circuit trips can feel like you are breaking stuff. It appears unprofessional and invasive. If one approaches it systematically, breaker trips are entirely avoidable.

Someone on the lighting crew should first find the circuit breaker box, check the number of available circuits, and verify the amperage rating of the circuit breakers or fuses. They are usually 15 or 20 A. Label all the outlets of the circuits you plan to use with the circuit breaker numbers. Run stingers from different sections of the house to have as many separate circuits as required plus a spare or two. Label the stingers with the circuit numbers as well.

Two lighting technicians working together using a circuit finder can determine which outlets are connected to which breakers in just a few (see Chapter 17). One person moves a plug-in transmitter from outlet to outlet, the other technician at the breaker panel identifies the circuit number and amperage (15 or 20 A) so the outlet can be labeled. For neatness in invisibility, a p-touch labeler is great to print a tiny label for each outlet.

Interior lighting circuits and wall outlets share circuits; however, you can usually count on certain circuits in houses and apartments to be separate. The circuit under the sink for the garbage disposal is usually a dedicated 20 A circuit. The electrical code specifies that in new houses there must be two designated 20 A circuits around the counter of the kitchen. The refrigerator is often on a separate circuit. Wall outlets, including the fused 20 A bathroom outlet, usually share circuit breakers with other outlets and overhead fixtures. Generally, the way circuits are distributed to areas of the house, you'll find upstairs circuits are typically separate from the downstairs ones. A garage is often separate. If the circuit breaker panel is well labeled, you'll have a general idea of separately circuited areas.

There are a couple of things lighting technicians may need to know about receptacles. Generally, if an outlet uses a NEMA 5–20 receptacle (the one with a T-slot) it is a 20 A circuit (see Chapter 14 for receptacle types). Old houses may have 2-prong, ungrounded outlets. Industry safety guidelines prohibit the use of ungrounded outlets for lighting. Usually you can find some parts of the house with newer grounded outlets. The use of ground lifters (3 to 2 prong adapters) is not good practice.

240 V receptacles

It is also possible to utilize the house's 240 V receptacles to power lights. The dryer receptacle in the laundry room is typically a 30 A, 240 V circuit. An electric range is typically a 30 A or 50 A circuit, enabling bigger lights to be powered including 2.5 kW and 4 kW HMIs.

There are three ways that a 240 V receptacle could be adapted for location power:

1) Use a 240-to-120 V break-out adapter that provides two 120 V circuits (e.g., a 30 A dryer circuit has a neutral and can provide two 30 A, 120 V circuits). Note: check the phase-to-neutral voltage during the scout to verify it has a neutral connected. Some receptacles may not have a connected neutral.
2) Use an adapter cable and power lights at 240 V.
3) Use a 240-to-120 V step-down transformer, which gives you all the available power from a single 120 V circuit (e.g., a 30 A, 240 V circuit becomes a 60 A, 120 V circuit). Step-down transformers are discussed later in this chapter.

If the receptacle was installed before 1996 it is likely to be a three-wire NEMA 10–30R (two phase wires and neutral, now disused because it lacks an equipment grounding conductor). After that date

4-prong, NEMA 14–30R receptacles were installed (two phase wires, neutral, and ground). If the house has an electric range, it may use a 30 A or 50 A, 240 V receptacle (NEMA 14–30 or NEMA 14–50 respectively). Using the circuit for an electric range may not be as convenient as using the dryer circuit depending on how hard it is to get to the outlet, which may be behind the range. Also, built-in ranges are typically hardwired, so there's no receptacle.

To use 240 V receptacles, a properly constructed adapter cable is needed. Lighting rental houses have the know-how and cable handy to build the adapter cable for you. The cable should be #10 AWG for 30 A, and #6 AWG for 50 A circuits. A note of caution: the following are legal and safe methods of utilizing house power; however, if you are building adaptor cables yourself, you should have the training and knowledge to do so properly and all the parts must be UL listed. Otherwise entrust the task to someone with the proper qualifications, tools and parts.

240-to-120 V break-out adapter

240 V household circuits are protected by a pair of tied circuit breakers in the electrical panel, so you cannot pull more than 30 A from either leg or it will trip both breakers. One way to configure the adaptor is the break-out into two 60 A Stage pin connectors, then connect gang boxes that have built-in overcurrent protection at 20 A. Do not exceed 30 A per leg.

240 V lights

A lot of newer solid-state lighting equipment is designed to be used internationally and use auto-sensing power supplies that accept a range of voltage (e.g., 100–265 V). Verify the equipment's voltage by checking the plate on the equipment. Using this equipment at 240 V is also a possibility; however, the power cord connector for the equipment should be rated for that voltage. Edison connectors are rated for 125 V maximum. A 250 V twistlock (L6–20 or L6–30) or PowerCON, TRUE1 connector can be used for either voltage (see Chapter 14).

PUTT-PUTTS (SMALL PORTABLE GENERATORS)

For small amounts of remote power (1 kW to 10 kW), a portable generator is a handy unit to carry on any show. When one light is needed to illuminate a building in the deep background a portable generator can save running hundreds of feet of cable. A small portable generator can power work lights during wrap, allowing the main plant to be shut down and the cable wrapped. For a small shoot, a couple of small portable generators may supply all the power that's needed.

There are two types of portable generators commonly used in film lighting: the newer solid-state inverter-type (such as the popular Honda EU models, Table 18.5), and the older generation, commonly called AVR or putt-putt because they employ an automatic voltage regulator (Figure 18.10).

Retrofits and alternative configurations

Before Honda introduced their quiet-running inverter generators (2007), small "putt-putt" generators required significant modification to be reliable and useful for lighting on a film set. The older generators use an automatic voltage regulator (AVR). AVR generators, like the Honda 5500EX, needed to be retrofitted with a precision speed control because the generator's motor speed is directly tied to the AC

FIGURE 18.10

(Left) Honda EU6500, (Right) Honda 5500EX.

(*Reproduced by permission of Guy Holt, ScreenLight and Grip*)

Table 18.5 Small portable generators

Model	AC output	Tank (gal)	Run time @ full load (hr.)	Receptacles (factory configuration)	Noise level @ full load (dB(A))	Dry weight (lb.)
Honda inverter generators						
EU1000i	1000 W, 8.3 A @ 120 V (2000 W in parallel)	0.6	3.2	15 A Duplex	50	28.7
EU2200i	1800 W, 15 A (3600 W, 30 A in parallel)	0.95	3.2	20 A Duplex	57	46.6
EU3000i	2600 W, 21.7 A (5200 W, 43.4 A in parallel)	1.6	3.5	20 A Duplex 30 A twistlock (L5–30)	58	78
EU6500i	5500 W, 54.1 A @ 120 V 27.1 A @ 240 V	4.5	4.7	20 A 125 V GFCI duplex (2) 30 A 125 V twistlock (L5–30) 30 A 125/250 V twist-lock (L14–30)	53–60	275
EU7000i	5500 W, 45.8 A @ 120 V 22.9 A @ 240 V (11000 W, 91.6 A in parallel)	5.1	6.5	20 A 125 V GFCI duplex (2) 30 A 125 V twistlock (L5–30) 30 A 125/250 V twist-lock (L14–30)	58	261

Table 18.5 Small portable generators

Model	AC output	Tank (gal)	Run time @ full load (hr.)	Receptacles (factory configuration)	Noise level @ full load (dB(A))	Dry weight (lb.)
Honda AVR generators						
EB6500	5500 W, 45.8 A @ 120 V 22.9 A @ 240 V	6.2	6.9	20 A 125 V GFCI duplex (2) 30 A 125 V twistlock 30 A 125/250 V twist-lock	66	243
EB10000	9000 W, 75 A @ 120 V 37.5 A @ 240 V	8.1	4.6	20 A 125 V GFCI duplex (2) 30 A 125 V twistlock 30 A 125/250 V twist-lock 50 A 125/250 V twist-lock	73	403

frequency.[6] The newer inverter style generators use an electronic inverter that generates a clean sine wave that is not dependent on engine speed (by use of pulse width modulation of IGBTs operating at high speeds). The inverter can reliably power any device, including sensitive electronics such as computers and video systems. This system is much better equipped to deal with current harmonics from nonlinear loads than AVR generators.

Another common retrofit on small generators, that has continued with the inverter-style generators, is to modify the generator's output circuits and provide a 60 A Bates connector (Figure 18.11). The way the generators are delivered from the factory, they have two 120 V circuits and a 240 V circuit. For example, the EU7000 generator has 45.8 A available at 120 V, but not all from one connector, which limits the lights that can be plugged into it. To use all 45 A available, a retrofit is needed to connect the electrical windings in parallel instead of in series, as shown in Figure 18.12. Suppliers of motion picture generators sometimes split the windings so that you can switch between parallel windings (one 45 A, 120 V circuit) or series (two 20 A, 120 V, or one 20 A, 240 V circuit).

To make the heavier generators rental-ready they are sometimes also built into a rugged roll-cage frame and fitted with four large foam-filled tires.

With many of today's lights using universal power supplies (that accept European 230–240 V) another possible solution to tap more of the generator's capacity is to power all loads at 240 V. A lighting rental house should be able to supply an adaptor from the generator's 4-pin, twist-lock (L14–30) plug to whatever type of connector is required by the loads (Figure 18.13).

[6] These generators would also sometimes be fitted with a beefier regulator, better battery charging system, a fuel pump to reduce fuel flow problems common with gravity feed systems, and a fuel solenoid to automatically shut off fuel on shutdown to eliminate dribbling and flooding.

FIGURE 18.11

EU7000 retrofit by Multiquip Generators with 60 A Stage pin connector. 45.8 A maximum. 22.9 A per duplex outlet.

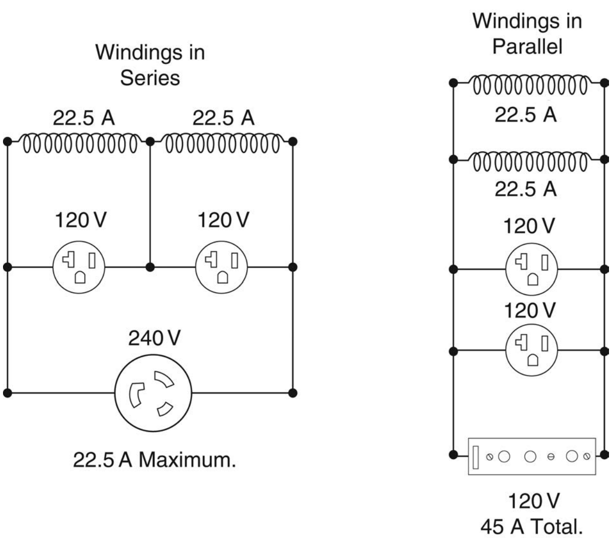


FIGURE 18.12

The current available from the windings is doubled when they are wired in parallel. A retrofit involves resizing all the electrical conductors to handle the higher current.

FIGURE 18.13

Adapter cable L14–30 to 60 A 240 V Stage pin.

FIGURE 18.14

EU6500 parallel cart includes two generators with a paralleling kit, and a 240-to-120 step-down transformer to enable 240 and 120 V concurrently.

(*Reproduced by permission of Guy Holt, ScreenLight and Grip*)

Parallel generators and step-down transformers

Two EU-series generators can be run in parallel to double the available capacity. Using a Paralleling Control Box, two Honda EU7000 generators can generate a 60 A/240 V circuit, capable of powering an ARRI M90 (Figure 18.14).

Another possible addition to this kit, a small portable step-down transformer can be used to then step-down the balance of the available power to 120 V for smaller 120 V loads. 240-to-120 V transformers are discussed in greater detail later.

Running the generator

The Honda EU7000i can be started from a recoil starter (pull start) in the event that the battery is flat, but normally you use the electric start, which is fully automatic. This generator can also be controlled remotely. To save fuel and reduce noise, a feature called the Eco-throttle automatically reduces motor speed when the load is reduced. This is a huge fuel saver (running at ¼ power, the generator can run for 14 hours on a tank of fuel); however, when you are adding substantial loads to the generator, you want to have it running at full speed, so turn the Eco-throttle feature off before adding them.

A system ground terminal is provided on the lower right side of the generator for grounding and bonding the non-current-carrying metal parts of the generator to a grounding electrode or bonding to other power sources.

Out of the box, the EU generators have a floating neutral, meaning the neutral (of the stator winding) is not bonded to the equipment ground, nor to the system ground terminal or the chassis of the generator. This means it cannot provide ground fault protection using circuit breakers in the normal way, so the generator is equipped with GFCI protection.

The EU7000i has a number of helpful displays. Three lights show you: (1) that the output circuits are energized (green), (2) if there is an overload, or inverter overheat (red), and (3) if the generator has sufficient oil (red). The generator automatically shuts down if the oil starts approaching a level that would cause engine damage. The unit also has an LCD display that can cycle through four different pieces of useful information by pressing its MODE button. These are: (1) maintenance hours, (2) power shown in VA, (3) engine RPM, and (4) battery voltage. In the event that the generator must shut down, the display will also tell you the reason—OIL, for example.

The fuel gauge is a mechanical type located on the top of the unit, next to the fuel filler cap. The battery is located behind a cover below the main controls and receptacles. The oil filler and pull start are inside the right-side access door. The air filter is inside the left-side access door.

Before operation:

- Be sure the generator is located at least 3 ft. from building walls, and placed on level ground, and do not leave the gas can or any other flammable materials close to it.
- Check fuel supply and oil level.
- Double check that the exhaust will ventilate freely, and that it is not blowing into a confined space. Never run a generator inside a vehicle or confined space.
- Set the output voltage (120 V only or 120/240 V) before turning the generator on.
- Disconnect all loads for startup.
- Open the fuel valve, and set the Eco-throttle to OFF (at least until the unit is warmed up).
- Start the unit by simply turning the start switch as you would a car.

The factory setup for the receptacles provides two separate 20 A breakers for the two Edison outlets (red and blue), a 30 A breaker for the L5–30 twistlock 120 V (red), and a 30 A breaker for each pole of the L14–30 240/120 V receptacle (red and blue). The maximum continuous load should not exceed 5500 VA (but according to the manual, may be as high as 7000 VA for 10 minutes or less). To keep the loads balanced when powering loads from various receptacles, you need to be aware of which receptacles are red leg and which are blue. Total load should not exceed 45.8 A.

Troubleshooting small generators

Older AVR-type generators do not always operate well with nonlinear loads. Figure 18.15 shows this waveform distortion on a scope. This waveform distortion can make it hard for other loads operating on the same circuit to operate properly. In fact, it has been pointed out that battery chargers, which

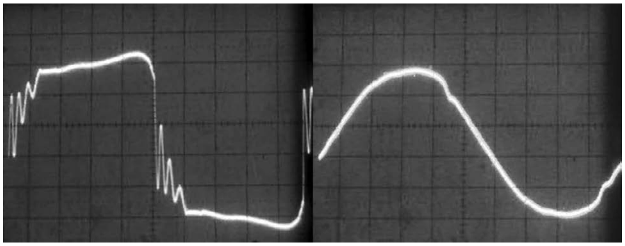


FIGURE 18.15

These two waveforms illustrate the effect of a nonlinear load on two different small portable generators. The load was two 1200 W HMIs, and a Kino Flo Wall-O-Lite; none of them power factor corrected. The waveform of the AVR generator (Honda 5500EX) on the left has a flattened peak, and jagged rise and fall. The waveform on the right is a (Honda EU6500) inverter-type generator. It shows very little waveform distortion.

(*Reproduced by permission of Guy Holt, ScreenLight and Grip*)

draw current at the peak of the waveform, will not function at all when the peak of the waveform is flattened as shown here, and are likely to heat up and burn out. Clearly using equipment with a high power factor and filtering would make a big difference here. It would ensure cleaner power, and more efficient use of available power. This is an important advantage when the power source is small to begin with.

With the older AVR style generators, the governor can be touchy and easily upset by variations in the load or fuel flow. It is a wise precaution to use flicker-free lights when powering from a putt-putt to allow greater tolerance for variation in hertz rate. The governor tends to be less stable when the load is very small. To increase stability, it helps to put a bit of a resistive load on the generator. Adding a tungsten light to the generator before striking an HMI dampens the hit, and helps the generator pick up the load. With no load on the generator, when the HMI is struck, the generator voltage dips, and this can set up an unstable oscillation, with the ballast trying to draw more current. This usually causes the ballast to shut down. A small incandescent load on the generator—even as little as 300 W—will stabilize the voltage when the HMI strikes. With this type of generator, it is a bad idea to change the load during the shot with flicker devices or sudden light cues. Inverter-style generators have built-in headroom for start-ups.

Hiccups in the power line can be caused by inconstant fuel flow. The generator must be on level ground. The fuel tank is mounted only slightly above the carburetor; if the generator is on a slope, with the fuel tank on the low side, fuel can get too low to flow properly, which disrupts the power. When powering lights on a moving vehicle or vessel, rocking or jerking can interrupt fuel flow. Keeping the tank topped off can help this. Small generators have gravity fed fuel systems. The best solution for using a generator on moving vehicles is to retrofit the unit with a fuel pump.

A common area of breakdown on the Honda AVR-type generators is the circuit that recharges the battery. If the circuit fails, the battery goes flat; as it does, the governor has difficulty maintaining consistent RPM. First the hertz rate becomes unstable, starts oscillating, and then slowly drifts lower and lower. If this happens, you can fix the problem temporarily (and get the shot) by jumping the battery with a car battery.

The performance of a small engine is greatly affected by air density. One can expect to lose engine performance with altitude—about 3.5 percent per 1000 ft. (above 3000 ft.). In addition, at high elevations the mixture must be leaned out or the fuel/air mixture will be too rich, causing the engine to run rough, burn too much fuel, and foul the spark plugs. The carburetor can be adjusted to make a lean fuel/air mixture to avoid this problem. If the carburetor is adjusted for a lean mixture it must be changed back before using the generator again at lower elevations. Otherwise, the fuel/air mixture will be overly lean when used nearer sea level, and this can cause very high cylinder temperatures and seriously damage the engine.

How does a generator work?

It is a convenient property of electrons that they can be induced to move through a conductor by passing the conductor through a magnetic field. An *alternator* creates electricity using this principle. A rotor (the rotating part of the alternator) turns inside a stator (the stationary part of the alternator). When the magnetic field of the rotor passes through the stator coils, current is induced in the coils. The coils pass first through the positive pole of the electromagnet and current flows in one direction. The coils then pass through the negative pole and the current flows in the opposite direction. If the positive and negative poles and the speed that the rotor turns are arranged so that current reverses direction 120 times/second, the result is a sinusoidal AC 60 Hz waveform. Changing the strength of the magnetic field varies the voltage of the electricity flowing in the coils.

It takes a significant amount of force to turn the rotor. In a generator, this is provided by the *prime mover*—a motor. Therefore, a generator consists of two parts: a motor, which burns fuel to create mechanical force, and an alternator, which converts that mechanical force into AC current. When the load is increased, the magnetic resistive force of the coils increases. This in turn increases the strain on the shaft, which would cause the engine to slow unless the throttle is immediately opened to compensate. So, a precision speed controller is needed to regulate the engine speed. The instant it senses the motor slowing or speeding up it sends a signal to the actuator to increase or decrease fuel flow—just as when a car starts to climb a hill, you have to put your foot down on the gas to maintain the same speed.

240-TO-120 V TRANSFORMER

A small portable step-down transformer, in the range of 7.5 to 12 kVA, can be helpful in a couple of different ways (Figure 18.16). When you have a 240 V circuit, either from a small generator or from a house circuit, the transformer enables the full power capacity of that circuit to be available at 120 V while keeping the load perfectly balanced. This allows bigger 120 V lights to be connected without overloading. In addition, when you have non-linear lighting loads from non-power factor corrected LEDs, HMIs or fluorescents, the transformer dampens noise from nonlinear loads to the generator. Similarly, a transformer makes GFCIs operate more reliably than they generally do when powered by a small generator.

For example, when using a 5500 W generator, the transformer draws from the generator's 240 V output, allowing the generator to have perfectly balanced current on both windings. The transformer provides all 5500 W output from a single 120 V circuit (45 A). Not only does this allow you to power

FIGURE 18.16

240-to-120 V step-down transformer with EU6500 generator.

(*Reproduced by permission of Guy Holt, ScreenLight and Grip*)

a 120 V 5k, it also allows you to more fully use the capacity of the generator. You can never run into the problem of overamping one circuit while there is still capacity available.

Similarly, if power is being taken from a 240 V house circuit (the 30 A dryer circuit in a house, for example), using a 240-to-120 V step-down transformer enables the entire 7200 W of power to be available from a single 120 V circuit.

Another potential benefit is that the windings of these transformers can also be tapped to boost voltage in increments of 6 V. Boosting voltage helps compensate for voltage drop over long cable runs, which makes it possible to run the generator further from set.

The circuits on the secondary side of a transformer are considered a separately derived system. As such, it must be grounded to earth. We'll cover more about transformers and earth grounding later in this chapter.

FULL-SIZE GENERATORS

"Studio" generators are typically diesel-powered plants. Duel 90–168 kW units are commonly mounted on the tractor of the production van. Trailer-mounted two axle "tow plants" are also common, ranging from small 24 kW up to 360 kW. Most generators used today are relatively simple to operate, fully automated, and self-diagnostic (Figure 18.17). Entertainment industry generators provide CamLok connection for the feeders. They are baffled to minimize noise for sound recording. They are very precisely electronically governed at 60 + 0.2 Hz to be reliable when used with HMI lights and are equipped with a hertz readout and hertz adjustment on the main control panel. Similarly, voltage is precisely maintained electronically and can be adjusted. Almost all power plants use diesel engines. The emissions requirements for gasoline engines are more complicated to achieve; as a result, gasoline-powered generators have become rare.

FIGURE 18.17

(A) Tractor-mounted twin 168 kVA generators. (B) Two axle, 168 kVA tow plant. The vents on the top open automatically when the engine is turned on. The side doors provide access to the engine. (C) On the back of the unit, the bottom doors cover the buss power distribution outlets and above that is the digital control panel.

(*Courtesy Illumination Dynamics, San Fernando, CA. An ARRI Group Company*)

Generators are rated in kilowatts. However, in the film business (and only in the film business), we commonly refer to generators as rated in amps. We will refer to a 108 kW plant as a 900 A plant—which is the total amperage capacity *at 120 V*. Real-world electricians (and electrical inspectors) refer to the generator as 108 kW, and the service as "300 A three-phase at 120 V." They would never call it a 900 A generator. In fact, if you said you had a 900 A plant, to them this would mean you had 900 A *per phase*. Table 18.6 shows some common sizes for generators and how they translate.

Two axle "tow plant" generators typically have a fuel capacity of 80–50 gallons. A 140-gallon tank typically can provide something like 117 gallons of usable fuel. Because the fuel tank is long, wide, and flat the tank can have large quantities of unusable fuel—below the level of the fuel pick-up if the unit is not level. A 60 kW (500 A) diesel generator under full load burns fuel at a rate of about 4.8 gallons/hour. A modern 144 kW (1200 A) plant burns 13.6 gallons/hour at full load, 6.9 at half load. A 500 A gasoline generator consumes about 6 gallons/hour at any load.

Generator manufacturers try to make their plants as bulletproof as possible. It is worth finding out what kinds of protections your particular generator provides. Some generators automatically shut down when they are about to run out of fuel. There is significant downtime when a diesel motor has run

Table 18.6 Common generator sizes: kW versus amperage, and total capacity versus working load

What we call it	What everybody else calls it	Maximum capacity per phase	Plan on using
Total Amperage Capacity (at 120 V) (A)	*Rating (kW)*	*Amps per phase at 120 V Three-phase (A)*	*Continuous working load (80% of total capacity) Amps per phase at 120 V Three-phase*
200	24	66	52
350	42	118	94
450	50.4	150	120
500	60	166	132
750	90	250	200
900	108	300	240
1000	120	333	266
1200	144	400	320
1400	168	466	372
1500	180	500	400
1800	216	600	480
2400	288	800	640
2500	300	833	666
3000	360	1000	800

Note: Shaded rows indicate most common sizes for modern power plant.

out of fuel, because you have to bleed the fuel lines to get the air out. Not all generators are equipped with this feature. Similarly, generator suppliers often incorporate redundancy of parts so that if something fails in the field, the generator can be brought back online quickly. For example, a generator may have dual voltage regulators, dual electronic governor controllers, and dual fuel pumps to provide redundancy in case a part fails.

Electrical configurations

A generator may produce different voltages and different configurations of power, but inside the alternator is three-phase—three sets of coils, arranged 120° out of phase from one another, creating three-phase AC current. To allow for a variety of different uses, each of the three alternator coils (marked L1, L2, and L3) are tapped in four places, creating 12 taps (marked 1–12). From this, many configurations are possible (Figure 18.18).

A large selection switch located inside one of the rear doors allows the user to choose the configuration. The switch arranges the configuration of the 12 taps to provide the desired type of service. *Before* the engine is started, the switch position must be selected (all circuits totally dead). Damage to this very

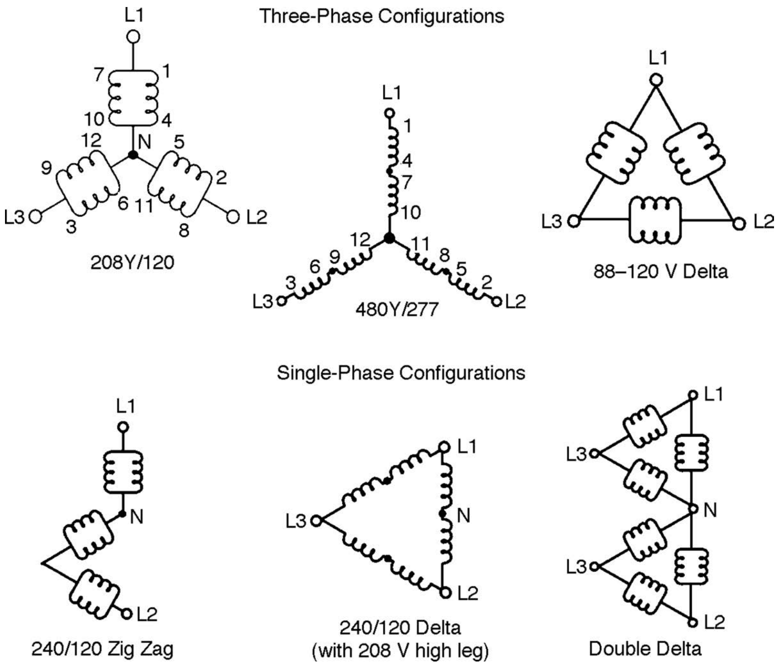


FIGURE 18.18

Alternator coils are tapped in 12 places to allow versatility in possible electrical configurations. A multipole, heavy-duty, rotary switch configures the coils. 208Y/120 three-phase is the standard configuration. The zig-zag configuration and double delta configuration can both be used to create 240/120 single phase from all six coils (tapped at L1, N, L2). On the zig-zag configuration the gap between N and L2 is the "open leg" of a delta, giving 120 V. Note that in each configuration, all six coils are tapped as evenly as possible.

expensive switch can result if the switch position is changed with the engine running, including while at idle. Typical selections are:

Single-phase 240/120—Two phase wires and neutral, plus ground (see Chapter 14). When configured this way, the capacity of the generator is reduced, generally by about a third.
Three-phase 208Y/120—Three phase wires and neutral, plus ground.
Three-phase 480Y/277—Three phase wires at 480 V and neutral, plus ground. Used for powering 480–208 V step-down transformers, or 480 V three-phase loads such as the SoftSun, or a large air conditioner.

Each time you change configurations, the voltage adjustment will have to be recalibrated. Do not connect loads without recalibrating the voltage. To remind yourself and others, each time the voltage is changed, the new voltage/configuration is written prominently on a piece of tape and attached where it will be clearly seen at the panel of the generator.

Large-scale live broadcast events, like the Academy Awards (Oscars), the Emmys, the Grammys, and the Olympics have to have a failsafe power system. In order to provide complete redundancy, generator suppliers have devised ways to run one generator in complete sync with another generator or with the utility power and run in parallel with it. This is called *paralleling* or *cogening*. The idea is that in the event that either one fails, due to utility power blackout or generator failure, the system will continue to operate without a single moment of interruption.

Control panel

Figure 18.19 shows the control panel of a typical modern generator. The OFF/START/RUN switch starts the generator at idle for warmup. The RUN position brings up to speed, ready to power the set. Displays show amperage for each phase, system voltage, and Hz rate. Adjustment to the voltage and Hz rate are provided on the panel. Typically, generator operators set the voltage slightly high (124 V) to help make up for inevitable voltage drop. Generator suppliers typically recommend the voltage not be adjusted more than 5 percent over line voltage, as this can lead to trouble with voltage regulation. The ammeters are handy for checking the balance of the load.

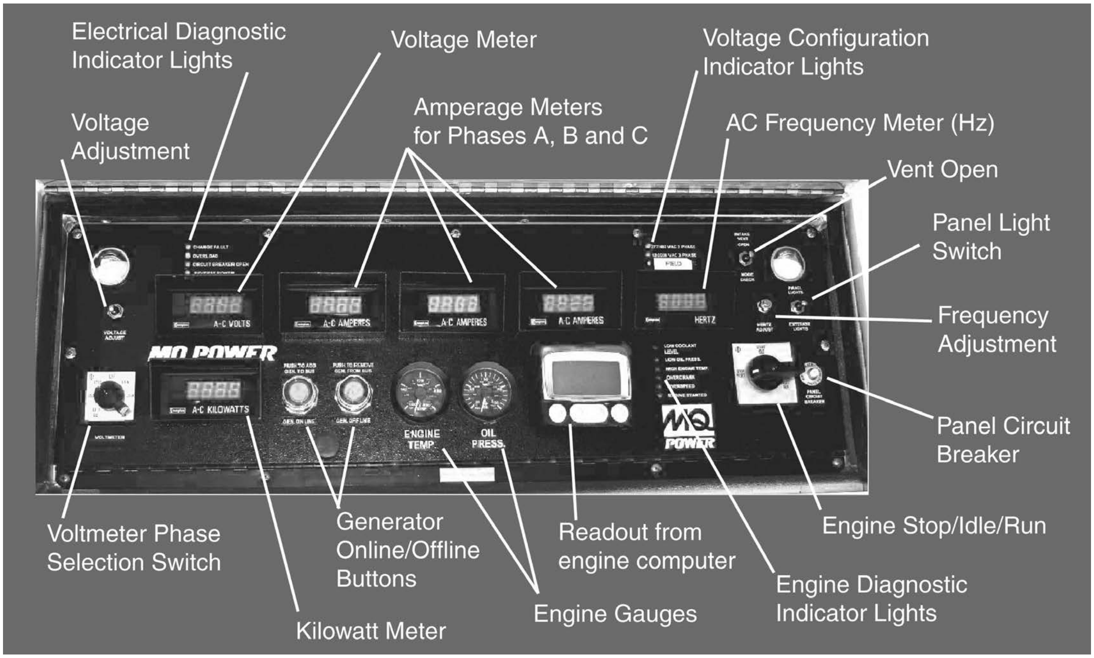


FIGURE 18.19

The digital control panel.

(*Courtesy Illumination Dynamics, San Fernando, CA. An ARRI Group Company*)

The panel also provides the engine instruments—water temperature and oil pressure. These should be checked as regularly as any of the others. High water temperature indicates low oil, low oil pressure, and lack of proper airflow to cool the engine. In any case, a high temperature reading should be addressed ASAP.

Notably absent from the control panel are fuel gauges. As 90 percent of problems with generators are fuel-related, this is something you might expect to have on the panel. Typically, the operator lowers a dipstick into the fuel tank to check fuel quantity.

The circuit breakers or electronic overcurrent protection switches are usually located inside the alternator compartment near the selection switch, or on the main control panel. In most situations, this overcurrent protection may serve as the overcurrent protection for the feeder cables. However, these breakers are there primarily to protect the alternator in the event of an overload or short circuit. Depending on the size of the cables connected, the AHJ may require an external form of circuit protection, or a disconnect so that power may be disconnected in an emergency (such as a generator fire). A generator is permitted to use a single circuit breaker even though the maximum current will depend on the voltage selection.

When 480 V power is used, the maximum current from the generator will be proportionally lower. For example, a 168 kW generator has 466 available amps per phase at 208/120 V, but that becomes 202 A per phase at 480 V. In order to provide circuit protection at the appropriate amperage the circuit breakers are set up with circuitry that either diverts the electricity through a separate set of appropriately rated circuit breakers when the switch is positioned for 480 V power, or uses a shunt trip in combination with a solenoid inside the breaker to enable the existing circuit breakers to be switched automatically to provide circuit protection at the appropriate rating.

Generator placement

The sound department has a vested interest in where the generator is placed. Despite baffles that deaden engine noise, generators can be a nuisance for the sound department. Place the generator around the corner of a building or behind a big vehicle, a little distance from the set. Point the noisiest parts (the exhaust ports) away from the set. Electricians must sometimes run very long lengths of feeder cable to get the generator far enough from the set; once placed, it can be a lot of trouble to move it, so it is worth getting it well placed initially.

Noise and diesel exhaust should also be considered in relation to residences. Residents are liable to get irate if you park a generator in an echo chamber, like an alley between apartment buildings, especially when people have their windows open or are trying to sleep. Not only can the noise be unbearable, the exhaust is noxious.

The generator operator or transportation personnel must make sure that the plant is secured and stationary. The emergency brake must be engaged, if equipped, or chocks must be placed under the wheels to prevent movement (fire code regulations). It is a common misconception that the generator must be perfectly level or the engine will be damaged. This is not generally true. The main consideration is for the fuel in the fuel tank, but if the fuel intake is properly installed (in the *center*, *curbside*, at the *bottom* of the tank), being out of level does not adversely affect fuel intake. If conditions dictate that you must run the generator out of level, make sure the fuel filler and vents are high and the fuel pickup point is low.

Finally, the fire marshal will have several concerns related to generators. The generator must not be parked under anything that is likely to catch on fire, such as dry foliage. (Remember that the exhaust ports point up.) It must not block fire hydrants or exits. A multipurpose fire extinguisher (20-BC) or equivalent must be available. It is a good idea where possible to take the fire extinguisher out of the engine compartment where it is stored.

When refueling, the generator must be shut down and a "static line" attached between the fueler and the generator. There's no smoking near the generator.

Selecting a generator

The size of generator selected for a job should be based on the power requirements of that job. Although one naturally might want a larger generator "just in case," overkill can be bad for the plant. A generator should be run at 70–80 percent of its rated maximum load. Over time, running under very light loads causes all sorts of problems, including glazing the cylinders, which can destroy the engine. Nothing is better for a rough-running engine than to run it under substantial load for a couple hours. Generator rental companies use *load banks* (big resistance banks) for this very purpose as part of a regular maintenance schedule. You see a lot of soot and smoke in the exhaust at first, until the engine cleans itself out.

In some situations, you will have to oversize the generator. A large plant is better able to pick up large loads. If light cues will involve large load changes, the plant should be oversized. Lightning Strikes! units require a larger generator. Large dimmer loads require the generator to be at least 1.5 times bigger that the nominal load.

Flexibility in load capacity is one advantage of having two tractor-mounted plants. In addition to having backup in case one plant fails, you have the ability to run a lot of power or very little as necessary. Tractors provide increased fuel capacity, up to 300 gallons, enough to keep a plant running for as long as 3 or 4 days.

The advantage of a tow plant is that it is generally quieter than a tractor-mounted plant; the large flat fuel tank effectively blocks sound, so it does not reverberate out from under the plant as it does with a tractor-mounted plant. When filming a period Western in a peaceful, remote stretch of New Mexico, you can hear a car 3 miles away—never mind a 200 HP diesel engine 500 ft. up the mesa. You need a quiet plant or you'll be running cable up hill and down dale.

480 V transformer

A transformer is used to transform AC voltage from one voltage to another. Figure 18.20 shows large 480 V delta to 208/120 V wye transformers powering a large number of dimmer racks and HMIs. The input side of the transformer, called the *primary*, accepts 480 V service such as from a utility fed supply panel or from a 480 V-capable generator. The output side is called the *secondary*.

When the power source is located a long distance from the shooting location, it is advantageous to run 480 V feeders from the power supply to a location near the set, and then use a transformer to step down to serviceable voltages. When the feeder run is very long, the voltage drop caused by the resistance of the cables can leave insufficient voltage at the set. A portable transformer solves this problem in a couple ways. First, it significantly reduces the amount of current in the feeders, which reduces voltage drop proportionally (see Table 18.7 in the next section). Second, transformers are often fitted with a tap switch that provides an adjustment of the output voltage to compensate for voltage drop. The

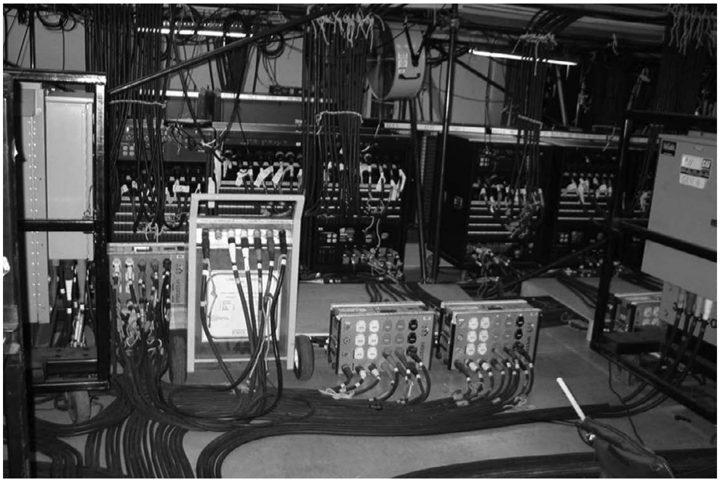


FIGURE 18.20

This rig has got it all. On the left and right sides of the picture are seen two 480 V transformers. Spider boxes lead to a row of dimmer racks. Socapex cables exit the racks heading straight up into the rig. A Bender Class C GFCI unit (on wheels, left) provides leakage current protection for feeder cables that power distribution in wet areas. Notice that plywood bridges separate the cables where they cross over one another and provide plenty of ventilation space for the cables that pass under the bridge. Note also large powerful fans hanging over the dimmer racks to keep the air circulating.

(*Courtesy Bender, Inc.*)

tap switch is typically adjusted by the supplier of the transformer. It can be set to provide a 2.5 percent or 5 percent voltage increase on the secondary.

To demonstrate the effect on voltage drop, consider this example. If the set requires 300 A/phase, that's 108 kVA of power. If we deliver that power at 480 V, the current in the feeders would be only 130 A. For a 600-ft. 4/0 cable run, you could expect a voltage drop of about 10 percent at 208 V, which would yield unacceptable voltages. However, the same 600-ft. run at 480 V would have a voltage drop of about 1.8 percent. (Voltage drop calculations are discussed in Chapter 17.)

At 208/120 V, the only way to mitigate voltage drop in the feeders is to increase the amount of cable by making parallel runs. Using 480 V feeders reduces the amount of cable by more than half. The cable is further reduced because a 480 V run does not have a neutral. It includes only three phases and ground. The transformer pays for itself by the savings in time, cable, and labor required to lay out long runs of cable.

Power (kVA)

Transformers are rated in kilovolt amperes, kVA. The kVA rating is the amount of power available on the secondary side of the transformer. For a three-phase transformer power is related to amperage and voltage like this:

$$I = \frac{P}{1.732 \times E}$$

Where P is the power in kVA and E is the phase-to-phase voltage.

For example, the maximum current for a three-phase transformer with a full load rating of 150 kVA would be:

Primary

$$I = \frac{150\ kVA}{1.732 \times 480\ V} = 180 \text{ A per phase}$$

Secondary

$$I = \frac{150\ kVA}{1.732 \times 208\ V} = 416 \text{ A per phase}$$

In reality, the amount of amperage available is based on the overcurrent protection devices (OCPD) installed. For portable transformers, suppliers typically use a lower current rating for the OCPD. Table 18.7 shows, for example, that the 150 kVA transformer (416 A), would typically be supplied with 400 A circuit breakers or fuses on the secondary.

Suppliers who serve our industry typically build their portable transformers with switches on both the primary and secondary sides, cam-type connectors, and standard 2.5 percent tap switches. They build the transformer with a roll cage to protect it and preserve proper spacing for ventilation and they mount it on wheels for relocating the unit. Transformers are very heavy and require a forklift for loading, unloading, or moving if it is more than a short distance. Always leave plenty of space around the transformer for ventilation. Overheating can damage the transformer and could lead to fire.

Table 18.7 Three-phase, 480 delta to 208/120 wye transformers

Transformer's full-load rating (kVA)	Amps per phase primary (A/phase)	Amps per phase secondary (A/phase)	Typical rating of OCPD (A/phase)
45	54	125	125
75	90	208	200
112.5	135	312	300
150	180	416	400
300	361	833	800
400	481	1110	1000
500	601	1388	1200
750	902	2082	2000 or 2500
1000	1203	2776	2500 or 3000

How transformers work

A transformer works by electromagnetic induction. We said earlier that electrons are induced to move through a conductor when the conductor passes through a magnetic field. This is Faraday's law of induction. While a transformer has no moving parts, it still works on this principle. A transformer has two coils in close proximity to one another, wrapped around the same laminated iron core. The coils are not electrically connected, but the magnetic field of the primary coil passes through the wires of the secondary coil as its magnetic field expands and contracts with each AC cycle. The movement of the magnetic field through the secondary coil induces voltage. The voltage is proportional to the number of turns of wire in the respective coils. If the secondary coil has half the number of turns as the primary, the voltage of the secondary is half that of the primary. Conversely, if the number of turns in the secondary is greater than that of the primary then it is called a *step-up* transformer, because it increases the voltage from primary to secondary. An *isolation* transformer is a transformer that has the same number of turns on both coils. An isolation transformer creates an electrically separate system without changing the voltage or current. These transformers are often used to isolate electronic equipment that may be sensitive to system noise, such as sound systems used at live events like concerts.

A three-phase transformer has three primary/secondary coil pairs, one for each phase. The configuration of the transformer, delta or wye, is determined by how the three secondary coils are connected to one another, as shown previously in Chapter 13.

Using a 480 V system

When 480 V power is used, the cable connectors and distribution equipment are color coded as follows:

Phase	Brown
Phase	Orange
Phase	Yellow
Neutral (if used)	Gray (preferred) or white
Ground	Green or green with yellow stripes

You can remember the color coding using the acronym BOY. Double-jacket type W cable or EISL Entertainment cable must be used, and any spider boxes or other distribution equipment must be labeled, designed, and listed for use with 480 V power, to ensure proper buss bar spacing.

A transformer creates what the NEC refers to a *separately derived system*. Any separately derived system is required to be grounded to earth. Unlike portable generators, which are sometimes relieved of the grounding requirement, there is no such exception for transformers. On location this may be by sinking a copper grounding rod, or, with proper authorization and the approval of the Authority Having Jurisdiction (AHJ), it may be by connecting to the grounding electrode system of a building. See "System Grounding," Chapter 13.

When using a 480 V system on set, every distribution box should be prominently labeled with the voltage and the power source's unique identifier, e.g., "Generator #2, 480 V AC."

By industry guidelines, people using 480 V power must be *qualified*, meaning that they have the experience, knowledge, and skills necessary to assemble, operate, and monitor the equipment safely and have received safety training to recognize and mitigate any hazards. This includes knowledge of the special distribution equipment used, color-coding and labeling procedures, special grounding procedures, knowing how to properly size the power source and the transformer, safe metering practices, and required personal protective equipment. It also requires training in how to recognize and avoid hazards associated with 480 V systems.

Serious potential hazards exist by mishandling 480 V service, including electrocution and arc blast. The risk of shock is increased by the ability of electricity to arc short distances through air (about 0.5 inches), which cannot happen at lower voltages. An *arc flash* occurs if electricity is able to arc between two points. When an arc occurs it ionizes the air, creating a dead short through air inside the arc plasma. With nothing to limit the current, electricity feeds into the plasma and is converted instantaneously into heat. The event lasts only an instant, but releases such extreme heat, it can burn hands and body parts instantly. The flash can damage retinas. An *arc blast* is an electrical explosion that happens when an arc flash is so hot that is vaporizes copper parts of the equipment. The copper expands explosively as it goes from a solid to a gas, carrying with it flame, toxic fumes, and a shower of molten copper. The heat, flame, and molten metal can instantly ignite a person's clothes, causing burns that are often fatal. The explosion can also cause hearing damage and eye damage. Arc blasts from 480 V panels are well known to electrical contractors as one of the most serious potential hazards of their trade. All this is to drive home the point that training and proper procedure is absolutely essential.

NFPA 70E, the Standard for Electrical Safety in the Workplace, requires that voltage-rated (class 00) rubber gloves be worn, with leather protectors over them for any task that could bring the worker's body or conductive tools within 12 inches of an exposed 480 V conductor. Industry safety bulletins require that these protections be worn if readings are taken from 480 V cam-type connectors. Normally however, there should not be any need to measure voltage from cam-type connectors. If you are using Luminys SoftSun units, the ballast provides test jacks and the readings can be safely taken from them. When powering a step-down transformer, voltage readings can be safely taken on the secondary side of the transformer at 208/120 V. The primary voltage can be read directly from the generator panel. It would be unusual that a lighting technician would have to take a voltage reading directly.

LINE DROPS FROM UTILITY POWER

A *line drop* is sometimes less expensive than renting a generator. If shooting takes place in one location over several weeks and the building cannot supply sufficient power, you can have the power company make a line drop from the power utilities' pole-mounted transformers and install a kilowatt-hour meter at the location. A licensed C10 electrical contractor can then install a service panel with main breakers for the system from which the film's distribution system can draw power. Although a line drop involves some significant initial expense, the line drop has advantages over a tie-in, because it is a designated circuit with sufficient amperage; it has advantages over a generator, because it is silent and does not burn fuel. The utility may or may not be able to accommodate you expeditiously, depending on what is available on the pole and how much power is required.

TIE-INS

A tie-in is a temporary tap drawn from a building's existing service panel. In locations such as a high-rise office building where it may be very difficult or impossible to run feeder cables up a 20-story building, a tie-in can save a great deal of labor and expense. The amount of power is limited to the excess capacity available from the existing system. Similarly, when filming in a warehouse, the building is likely to be supplied with an unused industrial-size transformer. Depending on your power demands, this may or may not provide enough power. The available capacity and available voltages can be assessed by checking the plate in the panels and transformer.

Opening a panel exposes the worker to the risk of shock and arc flash/arc blast. There have been a few grisly, tragic accidents in our industry associated with these kinds of hazards. Any tie-in must be made by a qualified person, such as a properly qualified building engineer or a licensed electrical contractor—for this discussion, let's just call him Joe. The decision to make a tie-in involves many parties including Joe, the building rep, the gaffer, and the UPM to determine whether a tie-in is feasible and provides a useful solution. A permit must be obtained to perform the tie-in, and an electrical inspector will likely inspect the work. Joe will terminate the tap cables to a main disconnect with appropriate overcurrent protection and appropriate connectors for the feeder cable (CamLok).

Under no circumstances should a non-qualified person open up an electrical panel, take meter readings from an open panel, or make a tie-in. It is illegal and potentially very dangerous to do so. Joe has the appropriate meters, personal protection equipment, tools, experience, training, and knowledge.

Approach protection

To comply with the NEC, once the tie-in is complete, any exposed energized conductors (like those in an open service panel) must be guarded from approach and accidental contact.

Additional safeguards include attaching rubber matting to the face of the panel, locking the door to the room, placing signs that say "Danger Live Cables" or "Danger High Voltage" at the doorway to the room and at the service panel. Additionally, it is recommended that no conductive materials or electrical equipment be stored, carried or placed within 10 ft. of any exposed, energized parts of the distribution system, including exposed connectors on the distribution system. The area around a tie-in must be barricaded in such a way as to prevent any unsuspecting person from approaching within certain boundaries. The minimum clearance distance for a non-qualified person is 42 inches for voltages up to 750 V. The arc flash boundary may be considerably larger, as determined by a qualified person by reference to the guidelines provided in NFPA 70E or the arc flash boundary marked on the equipment.

CHAPTER

19 Special circumstances and practices

SHOOTING ON MOVING VEHICLES

The standard method of shooting a scene in a moving car is to put the car—the *picture vehicle*—on a low-riding flatbed trailer called a *process trailer* (Figure 19.1A). The trailer rides low to the ground so that the height of the car above the pavement looks normal to the camera. The towing vehicle, the *insert car*, is equipped with a sound-baffled generator and various rails and platforms to which lights and cameras can be mounted. The largest trailers for this purpose have wings that can attach to either or both sides and are so wide that they require two lanes. The wings provide room for the camera, lights, and necessary crew. A limited number of crew are permitted to ride on a trailer and tow vehicle.

It usually works out well to tie power supplies to the speed-rail frame around the roof of the cab of the tow vehicle. Run cables along the speed rail, keeping them neatly tied and out of the way. Be sure that nothing will slip loose, rattle, drag, or get under the tires when the car gets on the road. The camera may be on the platform or mounted to the side door or the hood of the car, or mounted to the tow vehicle. Often the camera is supported on a crane arm (Figure 19.1B).

Many techniques are used for lighting the interior of a car. The basic challenge with daytime car interiors is the contrast between interior and exterior. A typical approach is to provide front key light and back and edge lights from outside the picture vehicle to raise the light level on the faces to a realistic relation to the exterior scenery. You might do this by mounting HMI sources on the insert vehicle or rig LEDs over the hood of the picture vehicle. Diffusion material is mounted on frames in front of the lights or sometimes attached to the windshield (assuming that the camera does not see the windshield).

Free driving, where the vehicle is actually driven by the actor, requires sources of remote power such as battery-powered lights, inverters (as discussed in Chapter 18), or the cigarette lighter circuit of the car. The camera operator is either in the front seat or back seat, or the camera is mounted to the door or the hood.

The lighting on a person's face in a moving car at night is a favorite challenge of DPs and gaffers. In reality, light sources are in constant motion and varying between yellow sodium vapor, blue-green mercury vapor, car headlights, and other sources. To light the actors inside the car, LED ribbon or other small fixtures taped to the dashboard or to the visor can provide an ambient level inside the car. The DP may decide to rig some harder sources outside the picture vehicle. Additional lights may be used to enhance the light of passing traffic and streetlights by bringing the lights up and down on dimmers or panning them across the actors. LED pixel tubes, programmed so the light travels down the tube, can create light movement. Ultimately the lighting has to be motivated by the environment visible in the shot. If there are lit buildings or other naturally occurring background lighting, a high ASA setting on the camera and fast lenses, the background may take care of itself.

FIGURE 19.1

Rigging lights to a moving vehicle: (A) a car on a process trailer; (B) shotmaker truck towing a car.

(*Courtesy Shotmaker Co., Valencia, CA*)

Poor man's process and other techniques

Car scenes are often shot on a sound stage using LED screen, green screen or, for night scenes, a poor man's process. Shooting on stage avoids the challenges of closing streets, weather delays, obtaining permits, hiring police escorts, and so on.

Poor man's process is the name for shooting a stationary car and using an array of light gags to simulate passing vehicles, vehicles following, passing street lights, and so on. The grips bounce the car a little, and the camera operator helps sell a little movement.

For nighttime shots, gaffers sometimes simulate passing streetlights with a "whirly gag." This is two lights mounted to opposite ends of a 20-ft. piece of speedrail pipe, which is rotated around and around on a tall stand so that the lights pass over the car one after the other. The light from the fixtures comes onto the driver, travels down, and disappears as the light passes overhead, reflected in the windshield as it goes by. Although it registers for just a moment, you have to choose a light fixture that can pass as a streetlight and keep any gel tidy in a frame.

Another poor man's process technique is to mount two small lights to a doorway dolly as if they are the headlights of a following vehicle on a dark highway. As the dolly is moved a little left and right behind the vehicle very slowly, from a frontal camera position it appears that the highway has a bend, or the following car is changing lanes. To simulate the light of passing storefronts, lighting technicians with handheld fluorescent lights pan their lights on and off, while swinging the light to give it movement. The beam of an oncoming car might be simulated by using a stable moving platform (an electrician riding on a doorway dolly). The lamp operator tilts the light slowly onto the front of the car, lets it get brighter as the dolly approaches the car, and then pans it off as the dolly comes past the front of the car. Everyone has their own tricks for doing poor man's process gags.

In-camera driving effects include using an LED screen or rear-screen projection or green screen (matte photography). These techniques require that the scene outside the windows, the *plate*, be shot separately and either displayed during filming or married together during postproduction. These can be day or night scenes.

The advantage of using LED screens is that they can be placed all around the vehicle. The outside media reflects on the surfaces in and outside the vehicle. Glass, plastic, leather, and metal parts become alive with subtle changes in color and intensity. Even without getting as elaborate as using LED screens, moving reflections on car surfaces can be created by something simple. As long as it is kept well out of focus, a moving gobo pattern shining onto a large white board can convey the movement of clouds.

For day scenes, the gaffer will sometimes put a light and lamp operator on a jib arm. As the crane slowly arms left and right, the sunlight appears to shift as if the car is turning.

LIGHTING IN AND AROUND WATER

Working in wet locations presents an extra challenge for the electrical department. In this section, we'll look first at how to handle electrical safety when working around water. This gives us a base of knowledge we then apply to the additional challenge of shooting under water. We'll look at the protection equipment necessary to keep the set safe, and the specialized fixtures and techniques used to light it.

Working with electricity around water and damp environments

A *ground fault* is a condition where, due to a fault in the wires or equipment, the housing of an electrical device has become electrified and current from the device is seeking any path back to ground potential. The danger of water is that it greatly reduces the resistance between you and ground. In wet grass, standing water, or a swimming pool, water is a conductor. Salt water (which is essentially what the human body is made of) is a better conductor than fresh water. Neither is a very good conductor, but both can still pose a threat to life if a ground fault exists. To get a shock, a person must become part of a closed circuit. When immersed in water, a diver is well grounded. The greatest danger is to reach out of the water and touch a metal device that has an electrical fault in it. Electricity will travel straight through the body: in through the arm, through the lungs and heart, and out through the lower half of the body. This scenario could very easily kill a person.

When working in rain (real or manufactured) everything and everyone tends to get wet, and wet hands, gloves, and feet pose little resistance should you come into contact with a fault. A similar hazard exists any time the ground is thoroughly wet. In fact, water is a better conductor when it is mixed with the minerals of soil. A muddy field is more conductive than a freshwater pool.

To protect people from electrical hazard in wet locations certain precautions must be taken. Light fixtures must be properly grounded and GFCI protection must be used on all circuits that are in proximity to water. Connection points are elevated on “swamp boxes,” milk crates, or apple boxes. Electrical connections can be protected to some degree by wrapping them in Visqueen or heavy-duty plastic garbage bags to prevent rain or splashed water falling onto them. When cable is to be run in wet areas, it should be inspected prior to use. Eliminate any cables with deep nicks or cuts in the insulation.

Another effective way to protect cable connections that are not designed for wet locations is to wrap the connections with a silicone-based fusing tape such as Rescue Tape. This tape is applied by stretching the tape and wrapping it so that it overlaps itself. The tape is elastic, and stretching it activates a process by which it fuses to itself in a few seconds and creates a watertight seal. To remove the tape, it has to be cut with a knife, but it does not adhere to anything but itself, so there is no sticky residue.

Some equipment is designed with a certain amount of protection from water. Equipment with an IP rating for which the last digit is 6, 7, or 8 is well protected. Equipment that has a NEMA 3R or NEMA 4 rating is designed to the NEMA standard for outdoor use, which provides a degree of protection against damage to the equipment from ingress of water (see Appendix E for more about NEMA and IP ratings).

Most of the distribution equipment we commonly use is not rated for outdoor use, which is not to say that it can’t be used outdoors—it just has no protection against dirt, dust, and water. Stage Pin (Bates) connectors, lug spider boxes, Edison plugs, and sockets provide no protection from water. These connection points must be kept away from water and raised and wrapped to protect from errant spray, splashes, or condensation as described earlier.

GFCI protection

It is a common misconception that a circuit breaker is there to protect you. A circuit breaker is there to prevent fire created by heat from an overcurrent or short circuit and protect the equipment. The amount of current it takes to electrocute a person is much smaller than the amount needed to trip a circuit breaker. An electrical shock current of one hundred milliamps (100 mA or 0.1 A) is a very serious shock capable of causing paralysis of the lungs and heart muscle. The smallest circuit breaker we use is 20 A—that’s about two hundred times more current than is needed to kill you.

To protect against serious harm from electrical shock, the circuit must be monitored by a Class A GFCI (Ground Fault Circuit Interrupter). This type of device will interrupt the circuit if it detects current leakage that is greater than 6 mA. At 6 mA, almost all adults and children can let go of the source of the shock. At higher currents, people are progressively less able to overcome muscle contractions caused by the shock, and therefore less able to disconnect themselves from the fault source. A GFCI will de-energize the circuit in less time than it takes to receive a harmful amount of current. Any time electrical equipment is to be used in close proximity to water, GFCIs should be used for the circuits powering that equipment. Around a pool or tank, we know from experience that when divers or actors are getting in and out of the pool, water is going to splash and drain in all directions. Therefore, electrical gear anywhere nearby must be protected by GFCI. Any time lights are suspended over water, they must be GFCI-protected. Even though the lights are hung securely and use safety cables, one has to protect against the possibility of failure or accident. This also applies to any and all electrical tools and devices used in close proximity to water such as work lights, hair dryers, heaters, vacuums, compressors, pumps, 120 V drills, and so on.

When working around water, it is a good idea for one person in the set lighting department to be designated to monitor the set continually for electrical safety and handle the power needs of other departments. A worker may decide to place a work light (not protected by GFCI) right next to the pool. Someone may try to run over the HMI cables with a heavy cart. Someone may try to plug into a GFCI and trip it with a piece of untested equipment. The designated person may be the gaffer, if duties allow him or her to remain at the site, or another lighting technician.

GFCI devices

When used, GFCI devices should be tested at the start of the day. GFCIs have TEST and RESET buttons. Pressing TEST should trip the GFCI.

Shock-Block (Littelfuse) and Bender are both manufacturers of GFCI systems for use in various industries. For our industry, they have developed a variety of devices to provide for almost all our common distribution scenarios (see Table 19.1).

On wet sets, a class A GFCI should protect each light (Figure 19.2). Shooting around a pool or fountain or in rain, you'll need this protection.

If the amount of water is more extensive, then GFCI protection may be needed for the entire distribution system. When this is done, a tiered system of protection is used. Higher amperage GFCI protection is installed upstream of the Class A devices. These are typically Class C GFCI devices, which do not provide protection at a low enough current to protect personnel, but are installed at the major

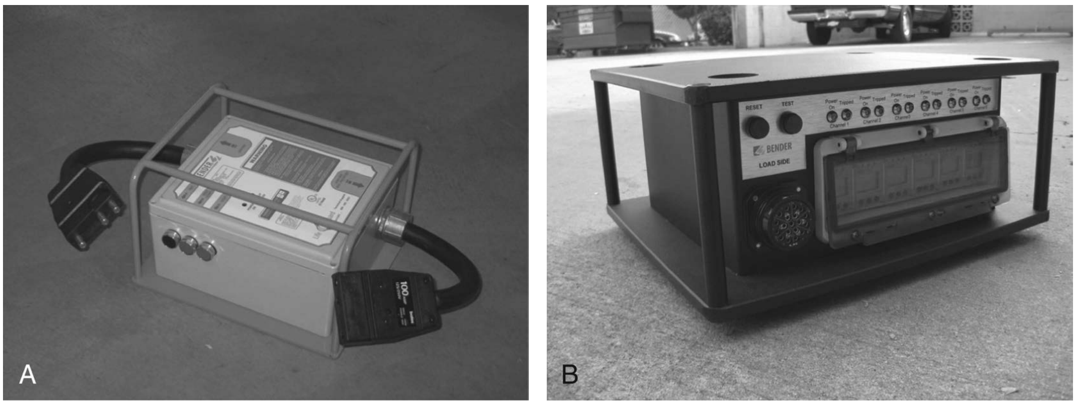


FIGURE 19.2

Class A GFCI personnel protection. (A) 100 A Class A GFCI. A small display on the front of the unit shows the level of current leakage. Three buttons on the side control the contactors. (B) This unit provides Class A GFCI protection for six circuits in a Socapex cable. Each unit incorporates a test button to check whether the GFCI is working. It also has an OFF button and a RESET/ON button.

(*Courtesy Lifeguard by Bender, Inc.*)

distribution junction points to provide ground fault protection for the cable and distribution equipment (Figure 19.3). Using a coordinated system of devices in which the trip time and trip current are lower on the GFCIs near the load and higher on the GFCIs toward the source, the system ensures that the downstream elements trip before the upstream elements. If ground leakage current occurs at the load, the GFCI immediately upstream of the short trips before any larger circuit protection upstream trips, preempting a larger power outage. The effect is to isolate and keep the problem circuit from bringing the whole system down.

Almost all electrical devices leak some current. When many lights are used, these small amounts of leakage can add up. This is the primary reason that it is better to use many small GFCI circuits rather than ganging lots of lights onto one larger one. Some GFCIs have a chain of LED lights that display the level of leakage at a given moment. This helps the lighting technician know when the total leakage is approaching the maximum allowed by the GFCI and helps identify loads that are leaking badly. By monitoring the LEDs while equipment is plugged and unplugged, an electrician can discover the amount of current leakage due to a particular load. The electrician can use this information to separate the loads on different GFCIs to prevent unnecessary tripping, or to eliminate loads that have too much leakage. Many GFCI units also monitor ground presence and power phasing. If either of these is not correct, the unit does not reset and identifies the problem on its display.

Shock-Block units can be used on a dimmer line, downstream of the dimmer. Some Bender units require power to operate, so Bender makes special dimmable units that have an auxiliary power input to power the GFCI device. Inquire with the manufacturer.

Some of the larger units can be switched over for use with 480 V power. This is accomplished with an internal switch that should be set by the manufacturer or supplier.

FIGURE 19.3

Class C GFCI system protection. This unit has a capacity of 400 A per phase at 208, 240, or 480 V (with or without neutral).

(*Courtesy Lifeguard by Bender, Inc.*)

Table 19.1 GFCI equipment

Type	Amperes (A)	Total amperes (A)	Volts (V)	Connector (in and out)	Manufacturer
Class A GFCI	20	20	120	Edison	Bender
Class A GFCI	5 × 20	100	120	100 A Bates-in, Edison-out	Bender
Class A GFCI	6 × 20	120	120	Socapex	Bender
Class A GFCI	100	100	120	Bates	Bender Shock-Block
Class A GFCI	100	100	240	Bates	Bender Shock-Block
Class A GFCI	3 × 100	300	208/120	Cam-Lok-in, Bates-out	Bender
Class A GFCI	100 per phase, three-phase	300	208/120	Cam-Lok	Shock-Block
Class C	200 per phase, three-phase	600	208/120	Cam-Lok	Shock-Block
Class C	250 per phase, three-phase	750	208/120 or 480/240	Cam-Lok	Bender
Class C	400 per phase, three-phase	1200	208/120 or 480/240	Cam-Lok	Bender Shock-Block
Class C	800 per phase, three-phase	2400	208/120 or 480/240	Cam-Lok	Shock-Block

Testing equipment

As a matter of safety, and because you don't want the GFCIs to be tripping all the time, all the electrical equipment has to be tested for leakage current before being used with GFCIs.

There are a number of ways to go about testing for leakage current:

Inline GFCI (6 mA). A simple, practical test method for small lights and stingers is to plug into a 20 A portable GFCI unit (Figure 19.4B). The GFCI will trip if it detects greater than 6 mA of leakage current. This will not tell you anything about leakage smaller than 6 mA, but it eliminates equipment that has a significant ground fault. You can use a 100 A GFCI to test larger lights.

e-cart. An e-cart (Figure 19.4C) is a testing station equipped with every kind of connector and provides current leakage information for whatever is plugged into it.

Current leakage meter. Fluke, Hioke, and others make clamp-on meters for leakage testing (Figure 19.4A). These are specialized meters capable of detecting very small current differentials. They give a read-out of the exact amount of leakage detected.

AC/DC switches like those on tungsten 10k lights have been known to trip the GFCI when switched. You may have to leave the light switch on, and turn the unit on and off from the distribution box or the GFCI. Experience has shown that it is very often homemade equipment and cables that develop

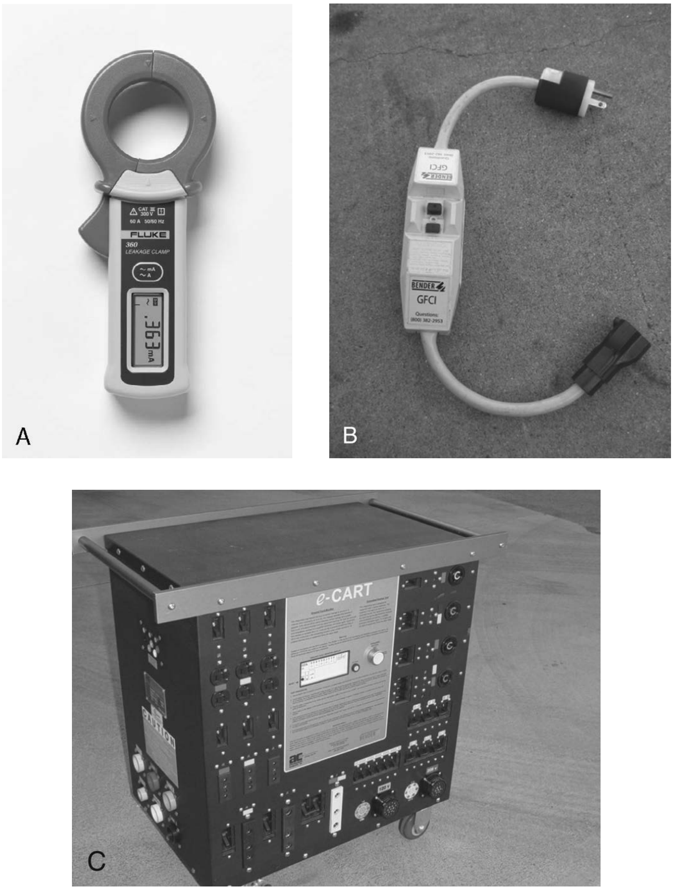


FIGURE 19.4

(A) Fluke leakage tester; (B) inline waterproof Class A GFCI; (C) e-cart.

(*A Courtesy Fluke. B and C Courtesy Lifeguard by Bender, Inc.*)

a problem. The earth leakage may be due to a piece of gear used by the sound department, video playback, or effects department. Practical lamps are also a common source of earth leakage current. Of course, folks in those departments may swear up and down that their equipment is not causing the problem; if you have one of these testing options handy, you can help them confirm their claim, or not.

Protecting equipment

One of the primary concerns when shooting in the rain—real or artificial—is that the lights are protected from falling and blowing moisture. If water falls or blows onto the hot lens, the thermal shock can crack or shatter the lens, especially when the bulb is in flood position, where it makes the lens hottest. If water leaks into the housing and touches the globe, the globe will burn out or explode. With LEDs and HMIs, water can burn out electronics. Burnt out electronics from water ingress is one of the most common reasons LEDs require major servicing ($$$). Water can also cause corrosion to the metal parts of the fixtures. Some lights are designed to shed water to some degree while most are not (see Appendix E).

First, for hot lights, protect the lens with a gel frame of heat-shield gel or a thin color (⅛ CTO or ⅛ CTB). Second, place rain hats over the lights. The best solution for protecting equipment is to use custom fit rain hats, like those from Rob's Rain Hats (Figure 19.5). Necessity being the mother of

FIGURE 19.5

A) ARRI M40 with rain hat. B) 18 kW Fresnel with rain hat.

(*Courtesy Rob's Rain Hats*)

invention, these purpose-built aluminum protectors were developed in Florida where rain storms roll across the state daily. They address all the issues that you are sure to discover using improvised rain hats. They are available in many shapes and sizes, for almost every light and ballast you might be using, including popular LED lights. They are properly constructed to be safe and to last. They are light weight and store flat. They are designed by people who know production and know our equipment so you don't have problems with things like ventilation.

Improvised rain hats can be made out of Celo screen (a tough, plastic-covered, wire screen); a flag covered with a garbage bag works for small lights; a four-by flag wrapped in Visqueen for bigger lights. A 12-by or 20-by griff is handy to cover a number of units at once. (Check for holes in the griff first.) Rain hats should be positioned so that rain runs off away from the fixture; don't let rain collect and form a pool in the flag.

Lighting rain

Rain shots are typically created using rain towers (provided by the special effects department) or pipes suspended over the acting area. The effects supervisor will typically be able to give the gaffer a good idea where he or she expects the water to fall. Falling water is most visible to the camera when lit from the back. Falling water will not read very well when lit from the front.

UNDERWATER LIGHTING

There are many practical problems involved in putting lights and live leads into water. Having any large amperages running through cables increases the danger posed in the event that a hot wire contacts the water. Bulbs must be submerged before they are turned on, because the temperature differential between the hot globe and the cool water can cause the glass of a bulb or par lens to crack or explode. If the bulb breaks under water, the result is an electrified conductor in contact with water.

The developments in underwater lighting and camera housings in the 1990s turned a corner for this specialization of filmmaking. Lighting underwater became safer and more efficient. Simultaneously, new equipment greatly expanded what is possible underwater and improved the quality of underwater cinematography. Underwater lights have been put to work in swimming pools, in large water tank sets, in lakes, and in the open ocean. Underwater lights are often enlisted to light up swimming pools or fountains. A light placed at the bottom of a pool makes the entire thing glow and throws moving highlights on surrounding people, set dressing, and architecture. The lights work great in rain scenes, flood scenes, and storm scenes aboard ships, in which gallons and gallons of water may pour across the deck. These can be treacherous sets to shoot, because with wind and water, things can easily get knocked down. Deploying underwater units in water-laden areas of the set greatly reduces the risk of electrical accident, should a light be knocked into the water or broken.

Electricity in water

A bare wire underwater sets up an electrical field around it as it seeks all paths to complete a circuit (to ground or the neutral wire). The primary route is the path of least resistance. If the neutral or grounding wire is close by, as in the case of a sheared cable, the field is very strong between the two wires and spreads around the fault, weakening with distance. The size of the field depends on the amperage available and the impedance imposed by the size of the wires. This is the reason why it is better to use lots of lower-amperage cables rather than a few very high-amperage ones. For example, if a 10 A circuit power cord in fresh water gets cut by a boat propeller, water sets up a field with a diameter of about 5.6 ft. (minimum safe distance). A cable carrying 100 A, on the other hand, sets up a field 49 ft. in diameter.

Another reason many low-amperage cables are preferable to a few high-amperage ones is that GFCIs on 20 A circuits are very dependable. The higher the amperage, the greater the noise in the system and the less dependable the GFCIs become. You get more nuisance trips.

A diver can feel it when he or she is coming close to an electrical field. If you ever put your tongue on a 9 V battery, you know the taste, and you can feel a tingle in the fillings in your teeth. Closer to the field, you begin to feel the tingle of electricity in your body. A diver inside a strong field may experience the effects of electrical shock: trouble breathing, muscle freeze, cardiac fibrillation, and cardiac arrest.

Modern underwater fixtures

For an underwater lighting system to be safe, it must: (1) be a completely sealed system, watertight from cable to bulb; (2) provide a sensing device and shutdown mechanism in case an electrical fault occurs; and (3) overcome the problem of thermal stress on the glass that is in contact with water.

James Cameron's epic adventure film *The Abyss* revolutionized underwater lighting technology. Forty percent of the live action footage was filmed underwater in a huge tank 209 ft. in diameter and 55 ft. deep. The project offered two young inventors the opportunity to realize a project they had had in mind for some time. Pete Romano, an underwater cameraman, and Richard Mula, a gaffer and engineer, developed the 1200 W HMI SeaPar, an efficient underwater PAR light, to meet the needs of this extremely demanding project (Figure 19.6). The SeaPars work equally well out of water, in the rain,

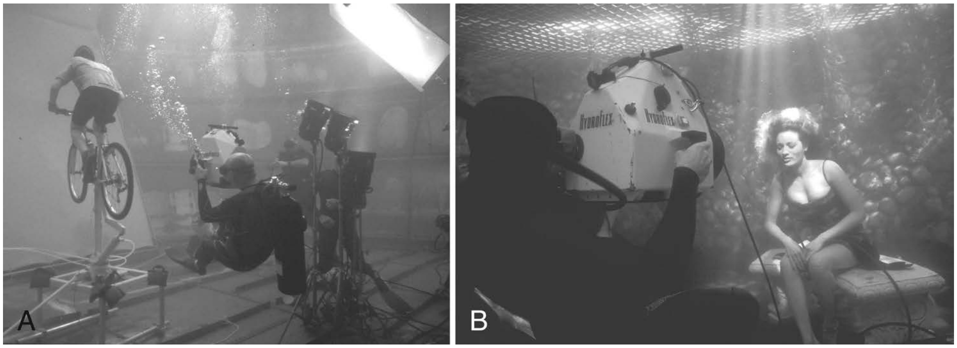


FIGURE 19.6

(A) Underwater lights bounced into a white reflector light in an underwater green screen shot. (B) Light streams through a lattice floating on the surface for this shot from a music video.

(*Courtesy HydroFlex Inc., Los Angeles, CA*) or submerged to depths of more than 250 ft. Subsequently, a whole line of tungsten, HMI, fluorescent, and LED lights sprung from this initial system, which are now available from HydroFlex.

The system is watertight. Ballasts and main distribution cables remain above the surface. The head cables run down into the water. The lights use watertight plugs that can be plugged and unplugged underwater with the power off. The connectors have locking sleeves to prevent kick-outs. Divers are protected from the hazard of a lead that is unplugged being accidentally energized under water because the female plug naturally holds air within the deep contact pockets so that electricity does not come into contact with water. All cables and connectors are watertight. The connection point on the head is made so that even if the head cable gets cut, water cannot enter the head.

To provide a fault-sensitive shutdown mechanism, the system operates on AC current with a grounding lead. All metal parts are grounded. The HMI ballasts are fitted with two Class A GFCI devices that sense the presence of leakage current. If there is more than a 5 mA differential between the hot leg (outgoing current) and the neutral leg (return current), indicating that fault current is leaking through to ground, a relay cuts power to the ballast. This is less current than required to harm an individual, even if the person is in contact with the fault source.

The second GFCI serves as a redundant backup. In addition, a fourth lead is used: a ground-return lead connected to a relay circuit constantly monitors the integrity of the grounding lead and shuts down the power if the ground is removed or lost. Finally, the outside glass covers on these fixtures are made of special thermo shock-resistant glass that can withstand sudden extreme temperature changes.

The underwater lighting arsenal

An entire line of underwater HMI, tungsten, fluorescent, LED, and xenon light fixtures are available commercially. HydroFlex offers tungsten pars in 5k SE, 2k SE, 1k (PAR 64), and 650 W (PAR 36) sizes, as well as a small MR-16 fixture. HydroFlex also offers various HMI pars, including 4k SE, and 1200 W SE Hydropars PAR. An 8k HMI broad/cyc fixture called the *HydroRama* employs twin axially opposing 4k SE globes set in a reflector. This is a very bright broad fixture, good for lighting large areas, large sets, or green screens. The HydroRama fixture is adaptable to take twin 5k SE bulbs, making it a 10k tungsten-balanced broad/cyc light. The larger fixtures may not be used out of water, as they depend on water-cooling.

A Litepanels 1 × 1 LED fixture adapted for underwater use, the SeaSun, is a handy fixture for hiding in small sets such as a sinking car. This is a 5600 K unit weighing 1 lb. in water that can be used in or out of water. It makes a good handheld soft light.

HydroFlex has several self-contained flashlight fixtures that can be used either by actors on camera or as a small off-camera fill light. Among them are the 21 W MHL Splashlight (daylight-balanced) and the 100 W tungsten Hartenberger (dimmable to three settings). HydroFlex adapted many of the familiar Kino fixtures for underwater use. The lights include the HydroFlo 9-in. kit; 6-ft., 4-ft., 2-ft., 15-in., and 9-in. individual tubes; 4-ft., four-bank and 4-ft., eight-bank and 15-in., two-bank (Mick Light) soft boxes; and 4-ft., four-bank and 4-ft., eight-bank panel lights for lighting green screens.

Other options for underwater lighting are also available from Pace. Architectural submersible fixtures such as the Color Kinetics C-Splash (RGB color LED fixture) are designed to be used in fountains and pools.

Features of underwater fixtures

It is a property of physics that spreader lenses have very little effect if they are on the outside of the fixture, surrounded by water. Underwater pars that use spreader lenses have to house their spreader lens inside the watertight cover glass. Spreader lenses can be exchanged (out of water) by simply unbuckling the cover on the front of the fixture.

The 4k HMI Hydropar and 5k tungsten Hydropar do not use spreader lenses. Instead they have interchangeable spot, medium, or wide reflectors (which can be exchanged in or out of water without disturbing the sealed globe envelope). The 2.5k HMI and 2k tungsten Hydropar use changeable Fresnel lenses, which are inside the buckled fixture and must be changed on dry land. The larger fixtures cannot be used out of water, or only for timed periods.

Surface support

When divers are lighting underwater, there should always be a support person stationed at the surface close at hand. This person is there to hand equipment down to the divers as needed, but they can also do a great deal to save the diver from having to make trips to the surface. If a light trips off, a surface support person who is paying attention can take note and check for problems at their end. If a light stand is no longer in use, the diver can extend the stand out of the water while remaining at the bottom so that it can be pulled out from above. The support person can monitor GFCIs leakage current levels when lights are being added to avoid trips. This person also keeps track of the cables coming out of the water and makes sure that they are labeled. Lights should be labeled for easy identification underwater. With par lights, for example, the beam width of the lens of reflector (WFL, MED, NSP, VNSP) should be written on the top front of each head using 2-in. white electrical tape and a fat-tip Sharpie.

Acting as surface support can involve many hours of doing very little while a small crew works underwater. But it is a necessary and important job, because the diver's work is very physically demanding. It is important not to get pulled away or abandon this position without getting another electrician to cover. Nothing is more disheartening to a diver than to emerge from a long period under water needing assistance, only to find that everyone has wandered off.

LIGHTING FOR MATTE PHOTOGRAPHY

It seems like almost every film and TV show we work on requires at least a few composite shots using a green or blue screen. For a composite, the foreground action and the background action are filmed separately, and then combined to make it appear as if the two coexisted in the same space and time. For example, consider a shot of a man dangling by his fingertips from a 40th-story ledge with ant-like taxicabs visible far below. This is two shots. The *plate* shot is the background, a view from the 40th floor looking down at the taxicabs in the street with no ledge in the foreground. The plate shot could even be a miniature model. The foreground action is a shot looking down at a man dangling from a ledge with a matte screen behind him. The singular color of the matte screen (typically blue or green) allows the foreground element to be cleanly separated by digitally removing that very specific color, allowing the plate to take its place in the background. The composite is made by scanning the two shots at very high resolution into a computer and compositing them digitally. For the two shots to be wed effectively, there are a number of considerations for lighting.

Pure screen color and density

The details of how the colored screen is removed and replaced with the background plate are beyond the scope of this discussion, but suffice it to say that the compositor is able to get the best results with the purest color screen, especially in separating fine detail like blowing hair or transparent elements like smoke. If the screen is contaminated with other color, shadows, or differences in saturation, it is much more difficult for the compositor to retain fine edge detail, and the matte will not look good or the image may need to be cleaned up by rotoscoping frame by frame. Rotoscoping is a time-consuming, expensive solution. Most often, it is far easier and cheaper to take the time to light a clean, pure matte screen on set.

Visual effects professionals have developed a number of ingenious ways to produce the purest possible matte. They start by controlling the color of the screen and the lights and refining them to a very specific single color, usually a specific green, but maybe a blue or red. Innovators in compositing have developed digital green screens and paints that fall at a narrow portion of a camera's spectral sensitivity curves where color is purest. This is lit with fluorescent or LED lighting having the same color spike, around 436 nm blue, 545 nm green.

The matte screen must be lit evenly. The compositor relies on uniformity in density to produce good separations. One should shoot for a variation across the visible section of the matte screen of not more than a stop. Front-lighting a solid green or blue screen using fluorescent or LED panels yields very good results and has become the norm. Because they produce such soft light and are so surprisingly bright, they are more than adequate to front-light even a very large matte screen. A row of evenly spaced SkyPanels or 4-bank, 4-ft. fluorescent fixtures along the bottom and top of a 20-ft. high matte screen typically produce an adequate brightness. With larger screens, you can bump up to 8-bank or 10-bank fixtures. Using DMX512-controlled fixtures allows easy adjustment of the screen brightness as needed. None of this saturated, colored light can be allowed to hit the foreground action, so egg crate louvers, door extensions, black wrap, and teasers are necessary.

Lighting the foreground

The foreground lighting must make the subject appear to be in the same environment as appears in the background plate. Contrast and color temperature should be matched as closely as possible. Attention to the direction and feel of the key light and the kind of ambient light shown in the plate shot are important when lighting the foreground shot.

Backlight, edge light, or sidelight is important with matte shots. Keep in mind that, when the background is dropped out, the foreground subject may as well be standing in black limbo. If the background plate is of a bright environment, some of that light should appear to be hitting the subject in the form of edge and backlight. Backlights also help wash out any green light wrapping onto the actor from the screen, which can contaminate the matte.

Some forethought is required in hanging the backlights. The lights must be arranged in such a way that the fluorescent lights front-lighting the matte screen and the backlights do not interfere with one another (Figure 19.7). They often want to occupy the same place or cast shadows of one another.

The foreground lighting has to be kept completely off the matte screen, and the matte screen has to be kept completely off any reflective or glossy parts of the foreground subject. Reflections of the matte screen appear as holes in the matte. To keep front light off the matte screen, allow plenty of space between the screen and the foreground action—15–25 ft. It is a common mistake to underestimate both the size of the screen and space in the soundstage needed for matte screen shots. These shots also require more floor space for flags in front of the front lights to cut white light off the background.

Masking off the matte screen where it is not needed reduces reflections of the matte screen in props, set dressing, and wardrobe. Dulling spray can be used on shiny objects. White cards and flags can be set around the edges of shiny objects to block the reflection. These can be removed in post-production using a quick crude matte called a "garbage matte." The compositor can remove the grip equipment from the shot later, as long as it is separated from the subject by the green background. Angle them so the card or flag is reflected in the shiny surface from the camera's viewpoint instead of the screen. Note: shots of curved chrome-like objects may have to be dealt with using another compositing technique, because depending on the shot and the action, it may be impossible to properly contend with reflections.

For example, when an actor is to be seen from head to foot walking around in a virtual set, the matte screen behind the actor must seamlessly meet the floor under his feet. You could do this with a seamless cyc painted green, but you would have to light it with white light. This creates a lot of challenges for the DP and the compositor. A better way, if the shot allows, is to lay out a mirror-plex floor, which reflects the green screen to camera (Figure 19.7). This can be a very effective technique. Precautions must be taken to allow the screen and the mirrored floor to meet seamlessly. The compositors have to rotoscope where the actor's feet touch their own reflection in the mirror. However, making this small concession to have an otherwise clean matte is far preferable to the alternative.

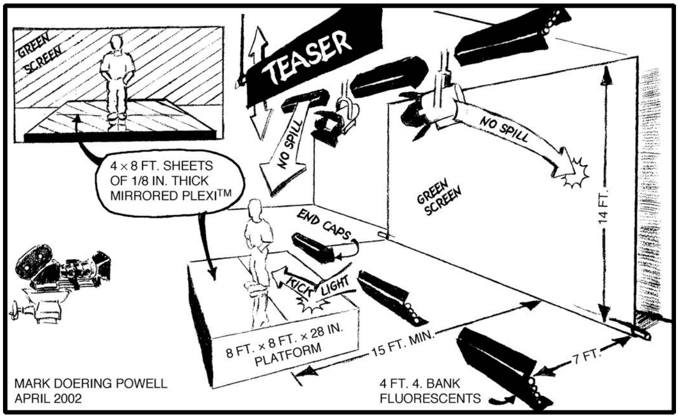


FIGURE 19.7

Using the thinnest possible Mirrored Plexi™ sheets on a small platform under the actor, the camera sees a seamless matte color background all the way to the actor's feet. At the bottom, the screen is rolled onto a pipe to hold it flat to the ground (ties would be seen by camera). The fluorescent or LED fixtures lighting the screen from below and above are placed a distance away from the screen (7 ft., in this case); for even coverage, it works well if this distance is about half the height of the matte screen (14 ft.). The lights are spaced no more than 3 or 4 ft. apart and must extend beyond the edge of the screen to light the screen evenly all the way to the edge. Each fluorescent is capped on both ends with black wrap to prevent spill onto the actor. Note that all the lights must be flagged, teased, or wrapped in black wrap to prevent spill from the foreground onto the background screen and vice versa, as are the lights lighting the actor (not shown here). The backlights cannot be placed where they will block the upper fluorescent lights. If there were more space behind the matte screen, the backlights could also have been hung there, which also helps prevent spill back onto the screen. Note that the backlights kick off the mirror floor onto the actor's legs. This can be helped with judicious use of bottom barn doors and black wrap or flags. The teaser is adjustable up and down and so that it can be placed to keep all the backlights from flaring the camera lens.

(*Illustration by Mark Doering-Powell*)

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

CHAPTER

Specialty lighting equipment

20

SOFTSUN

SoftSun fixtures come in sizes from moderately large to enormous (3.3k, 3.6k, 10k, 25k, 50k, 100k, and 200k which are all rectangular fixtures, and a 3.5k round par fixture). They are daylight-balanced (5400 K), flicker free, and can be dimmed from their power supply from 100 percent to just 5 percent via a handheld digital remote control or DMX512. The color temperature is virtually unchanged by dimming. Most models are rectangular in shape, to accommodate the linear ESL lamp (enhanced spectrum long arc). Thus, the SoftSun lamp and reflector form a large-aperture direct light source (Figure 20.1). The rectangular units have a wide spread horizontally (most models 100° or more) but a focusable vertical spread (the 50k unit has an 11° spread in spot position and 35° spread in flood). Though these units normally are oriented horizontally, they can be deployed in any orientation. The 3.5k unit has a softer quality due to its large round parabolic reflector.

The larger SoftSun units have proven themselves invaluable for day exteriors to help create a consistent sun source, especially when the real sun ducks in and out of clouds or sinks behind the horizon. In these changing conditions, the dimming feature is especially helpful for maintaining balanced light levels. Because of its greater power and spread, the light can be backed up to cover more area with a single source. Due to the light's wide horizontal spread, it can replace two or three 12k or 18k Fresnels. DPs sometimes find this advantageous, because it allows them to deploy a single source which can help create a more natural look.

The 3.3k unit has proven especially good for lighting car interiors. SoftSun lamps pose no explosion hazard, and the lamps are shock-mounted and rugged enough to survive a high-speed chase. The size and shape of the 3.3k lends itself to lighting through car windows (26 in. long, 12 in. high, 9 in. deep). It weighs 24 lb.

The ESL lamps keep consistent color temperature as they age, and therefore they also match lamp to lamp. They also remain consistent (within 100 K) throughout their dimmable range. The spectral power distribution is regular with no spikes, which shows a truer match to daylight than other daylight sources. The CRI is 96 or better.

The 50k, 100k, and 200k units are very large (the 50k is 82 in. long, 33 in. high, 23 in. deep) and heavy (the 50k head weighs 210 lb., the 100k weighs 300 lb.). The bail is equipped with three 1⅛-in. junior pins: center and outboard sides. The light is most stable placed on two side-by-side super cranks, although a single Cinevator can handle the 50k. Very often, the necessary flexibility is gained by placing the fixture in a Condor so it can be easily moved around, on the arm. Especially on uneven terrain, moving the light on two stands is difficult.

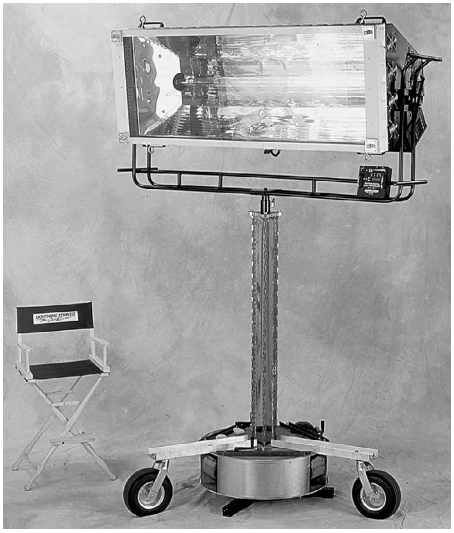


FIGURE 20.1

100 kW SoftSun.

(*Courtesy Luminys Corp.*)

All the larger SoftSun units have Cam-Lok tails. The 50k flicker-free ballast requires a three-phase power 208–240 V AC at 220 A per leg (three phase wires plus ground), 50/60 Hz. So be prepared with 4/0 cable to power this light. Luminys also makes a 50/100 kW ballast that can power either light. It runs off a 480 V three-phase generator (380/415 V in Europe). This also allows the 100 kW unit to still use 4/0 cable feeds. All the SoftSun heads have quiet-running cooling fans.

LIGHTING BALLOONS

By placing HMI, tungsten or LED sources inside a sealed diffusion ball filled with helium, a balloon light can float over the action areas creating soft 360° light without the need for a high platform (Figure 20.2). Lighting balloons are particularly well suited for illuminating large delicate interior locations, such as an old cathedral or historic building, where rigging lights could damage the location. Lighting balloons are also often used simply for time efficiency, because they can eliminate rigging time and are relatively easy to adjust and move.

Balloons are often enlisted to create soft-light ambience on exterior night scenes. For this application, balloons may afford the DP some advantages over rigging large lights in a Condor, depending on the desired look. Balloons provide a more even light, with softer shadows, and spread 360° with a gradual falloff. For night exteriors, the softer look helps disguise the presence of artificial lights. This is especially valuable in wilderness or rural settings, where the only motivated ambient source is moonlight. A soft source is also useful in urban scenes to lessen specular glints off of parked cars (although you have to watch out that the balloon is not visible in reflections in car windshields).

FIGURE 20.2

Lighting balloons provide ambience (A) in a building with sensitive architecture, (B) under the thick canopy of a Hawaiian jungle. They are much faster to move around in the dense undergrowth than 18ks on stands. The gaffer also used these 6k balloons as key light by bunching two or three and employing soft-frost diffusion.

(*Courtesy Mike Bauman*)

Balloons also have practical advantages. To create an equivalent soft source from a Condor requires quite a bit of rigging. Most balloons can be set up in an hour or less and moved from one position to another relatively quickly. It is a fairly simple matter to hide the black cable and tag lines, compared to hiding a Condor. They can be controlled from the ground. Tungsten versions can be dimmed, and HMIs on electronic ballasts can be dimmed down to 50 percent.

Balloons are available from various suppliers and individuals. Specifications for balloon lights are listed on manufacturers' Web sites.

Tube balloons, which are sausage-shaped, have a lower profile, so they afford the camera a wider shot when the balloons are used on interiors with lower ceilings such as indoor swimming pools, auditoriums, or churches. Vertical dimensions range from 5 to 8½ ft., depending on wattage. Different suppliers have different dimensions. Tube balloons tend to cast the most light out the sides of their long axis, making them ideal for lighting a church aisle, for example. A long aisle might be lit with two or three tube balloons in a line.

Some suppliers have developed helpful accessories. To give just one example, Lights Up accessories include their Yarmulke polysilk top cover, which cuts top spill. Black-out skirts (designed with snaps and Velcro for quick adjustable application) contain side spill and prevent the walls from being lit on interior sets). Lights Up balloons use black tag lines, which attach with a snap ring or quick link. The black lines are fairly easy to hide and do not have reflective highlights (unlike monofilament lines). Most Lights Up units are available with detachable head cables, so the balloon can be moved easily when working around architectural obstacles.

Most balloon companies send out their equipment with a technician. Experience has shown that sending balloons up and taking them down is a tricky enough operation to warrant having one person single-mindedly dedicated to supervising operations and caring for the balloon.

On the larger balloons, the balloon is attached by its head cable to its road case, which houses the ballasts (HMI units) and winch. Three tag lines are also attached to set the position and height of the balloon. These are tied off to weights, sandbags, or other sturdy tag points. Rigging and stabilization equipment are often required to set the balloon in a difficult spot and prevent the balloon from bobbing and twisting excessively in wind. Lights Up deploys a "wind net" (a netting that wraps over the top of the balloon to help distribute forces evenly around the envelope of the balloon, stabilize it, and prevent unnecessary stresses).

Balloons cannot generally be used in winds greater than 25 mph. They cannot be used if there is lightning in the area. They must be kept well clear of power lines and sharp objects. Also keep them away from sprinkler heads. Balloons can be rained on, although the smaller balloons may not stay afloat if they get too heavy with water. The larger balloons have more lift and can withstand rain and downdrafts better than the smaller balloons. At higher elevations, balloons lose lift and may need to be supported with rigging.

Balloons can be rigged any number of ways, the main concern being not to puncture or overstress the envelope. A balloon can be rested against a ceiling, provided the ceiling is stable and free of sharp edges. Cabling can be draped off to one side. Balloons can be supported on cable lines run between trees in a forest. They can be flown from a Condor arm for stability. In long-term, semi-permanent sets on a sound stage, balloons can be filled with air instead of helium and hung upside down from the perms on sound stages. This approach limits their flexibility. Without helium, they become quite heavy.

LIGHTNING EFFECTS

Creating a convincing flash of lightning is a lighting challenge with a long history of solutions. It requires a very bright, very brief flash that is several stops brighter than the exposure used for the set lighting. To be convincing, it should flicker slightly and vary from flash to flash.

For many years, the brightest, most convincing lightning effect was accomplished with a scissor arc. A scissor arc seems like pure madness today; it consists of a bundle of carbon rods wrapped in wire, fed with large amounts of DC power, and attached to a scissor device that brought the carbons together with the opposite electrode. When the two were brought together, all hell broke loose, and an extremely bright sputtering flash lit up everything within a block. Fragments of hot carbon showered the area around the device, sometimes burning holes right through the blacktop. Needless to say, this approach had some safety issues.

Lightning Strikes!

Lightning Strikes! (a product of Luminys Systems Corp.) developed a line of programmable lightning fixtures that can drench the set in light for up to 3 seconds of continuous light at full intensity, or a sequence of various intensities for up to 8 seconds (Figure 20.3). The unique 1 millisecond response time of the lamp combined with the ability to dim from 100 percent to 5 percent allows for rapid changes in intensity to simulate a natural lightning flash or flash from an explosion. The lights are available in a wide range of sizes and features.

Luminys Lightning Strikes! units: sizes and features

Paparazzi head	8k	Small 8k units are commonly used to simulate flash photography
Linear heads	25k, 40k, 70k, 250k, 500k	Up to 3 seconds at full intensity. Up to 8 seconds at varying intensities
Focusable linear heads	40k, 70k, and 250k	Vertical beam spread adjustable between 12° in spot position and 35° full flood
Parabolic reflector heads	8k, 40k, and 200k	Yield greater center beam output per watt than the linear units
LongStrike units	99k, 299k	Can sustain a full power blast of light for up to 10 seconds

Several heads can be connected to a central control unit and fired simultaneously or separately. The color temperature is 5400 K, which does not change when dimmed. The units can be very precisely controlled and flash sequences can be programmed, so identical flashes can be repeated in take after take. The units can be ordered fully sealed in waterproof housings for use with rain towers. The 70k head's peak output yields 350 fc at 100 ft. with a 45° vertical beam spread, 90° horizontal beam. The smaller lightning units are ideal for interior sets or narrow exterior shots (25 or 40 kW for small sets; 70 kW and larger for large sets and night exteriors).

The Lightning Strikes! controllers and lighting units offer an open field of effects possibilities. Experimenting with different combinations and timings will help you create an optimal effect for your application. For example, for a lightning effect firing two units separately, moments apart, from slightly different directions, and reducing brightness on the second flash enhance a lightning effect.

FIGURE 20.3

A 250,000 W Lightning Strikes! unit.

(*Courtesy Luminys Systems Corp. Lightning Strikes! Los Angeles, CA*)

The 40 kW unit can be fitted with a QuickColor system, a specially adapted Wybron color changer and programmable control unit. The color changer provides additional heat protection for the gel scroll. A choice of 10 colors can be selected by DMX512 control. A special handheld control unit comes with the system that provides flash and color control. It can be programmed with up to three-color sequences.

The larger units (250 kW and up) are powerful enough to drench even large expansive sets. They can compete with daylight, so they are ideal for lighting daytime exterior storm scenes.

The LongStrike units are a separate product line most commonly used for high-speed cinematography or table-top applications, but can be used for lighting effects that require long blasts of light. These lights idle at a low level (about 1000 W) and then boost up to full power, 30,000–150,000 W, in 1 millisecond. They are extremely stable and absolutely flicker free up to 1,000,000 frames/s which is often used for scientific or military applications.

Control units

A variety of different control units are available for Lightning Strikes! units. For most applications the *undulating controller*, which comes standard with each light, is used to create manual or automatic random lightning flashes.

The *precision fader* is a programmable controller with which one can create, repeat, and loop up and down fades. It is great for creating an explosion effect, for example, with a big initial flash and slow decay, spiked with lesser secondary explosions. Each sequence can last up to 4 seconds, and the unit can hold up to four sequences. The unit comes with four preprogrammed sequences, but you can create custom sequences using a joystick to edit the sequence. Each sequence can change level up to 24 times/second. Machine gun fire flashes can also be created with an on, off, on, off pattern.

The *quad controller* controls up to four lights separately or in unison with eight memory banks that record firing sequences for playback. The quad controller can also be hooked up to a MIDI sequencer running on a laptop computer and triggered from SMPTE time code. The flash sequence is preprogrammed into the MIDI sequencer. During filming, the MIDI sequencer synchronizes to the time code (from a video or audio playback unit), triggering the flashes at exact (repeatable) points in time.

The lights can also be run from a standard DMX512 dimmer console by using an interface box called the *DMX to LS ISO converter*. Brightness level and "mode" are controlled on two adjacent channels and the "mode" pot controls constant slow undulation, medium undulation, or fast undulation. By your assignment of the DMX512 addresses, multiple lights can either be synchronized or operated separately.

An optical or acoustic sensor hidden in the set can also trigger units. A flash camera or a loud noise (gunshot) can be used to trigger the lightning strikes. The duration of strike can be extended from 1 to 36 frames with a choice of intensity level for each frame. Because the Lightning Strikes! flash lasts a minimum of 1/24th second, it will be caught on film (whereas a normal strobe flash is about 1/10,000th second, which is caught on film only if the shutter of the motion picture camera happens to be open at that instant).

The *16-light sequencer* can chase up to 16 lights at a time. Frames on and off can be preset and repeated. The sequencer can be synchronized to the camera shutter for multiple passes or blue screen work.

Power requirements

Table 20.1 lists specifications for the Lightning Strikes! units as well as power requirements. All units operate on 208–250 V service (single phase, or two legs of a three-phase service), except the 8k and 25k units, which are 120 V AC.

The 70k unit draws about 300 A when fired. Because the time is so short, it can safely be run on 62 A house current (it is treated like an electric motor starting load). Although this is a fairly substantial intermittent load, the peak power is within 5 percent of nominal RMS power, meaning that there is no momentary drain much greater than the nominal power, as there is when striking HMI units, for example.

Running Lightning Strikes! on generators

According to the manufacturer, the generator can be sized as little as almost half the kilowatt output of the fixture. For example, a 70 kW Lightning Strikes! unit can be run off a 40 kW generator (350 A at 120 V AC). Generator companies recommend that, when two 70,000 W heads are used, the plant should have at least a 750 A capacity; when three 70,000 W heads are used, the plant should have at least a 1200 A capacity. A sudden heavy load like that of Lightning Strikes! affects all the lights on a generator. The other lights may blink each time the strike hits. To guard against surge current affecting the set lighting, most gaffers order an additional generator to handle the Lightning Strikes! units. If you have to run both on the same generator, use the smaller units (70k or less), keep the bursts short, and have no more than half the amperage capacity of the generator devoted to lightning units.

Thundervoltz battery packs

Alternately, Thundervolts battery pack units eliminate the problem of putting large sudden loads on the generator. All Lightning Strikes! units (except the 25k) can be run off Thundervoltz battery packs. These are specially designed oversized battery-powered packs with an inverter and charger to provide AC specifically for Lightning Strikes! units. The packs deliver power enough to flash the units indefinitely, as long as the AC charger is connected to a power source. The 450 lb. Thundervoltz runs two

Table 20.1 Luminys Lightning Strikes! fixture

Fixture	Number of units	25,000 W	40,000 W	70,000 W	250,000 W	500,000 W
Weight (lb.)		24	30	34	55	63
Head dimension (in.)		25 × 12 × 9	29 × 12 × 9	32 × 12 × 9	42 × 17 × 11	42 × 19 × 15
Voltage (Hz)		120 only	208–250 V AC 50/60	208–250 V AC 50/60	208–250 V AC 50/60	208–250 V AC 50/60
Current (momentary) (A)		210	175	300	1050	2100
Power requirements						
Mains or house (A)	1	40 minimum	40 minimum	63 minimum, 100 optimum	200 minimum, 300 optimum	400 minimum
	2	80	80	125	400	800
	3	120	120	200	600	1200
Generator (kW)	1	24	25	40	180	360
(A)		200 (at 120 V)	200 (at 120 V)	350 (at 120 V)	1500 (at 120 V)	3000 (at 120 V)
	2	42	60	90	360	720
(A)		350 (at 120 V)	500 (at 120 V)	750 (at 120 V)	3000 (at 120 V)	6000 (at 120 V)
	3	60	90	144	540	1.080 MW
(A)		500 (at 120 V)	750 (at 120 V)	1200 (at 120 V)	4500 (at 120 V)	9000 (at 120 V)
Battery pack			Thundervoltz	Thundervoltz	Thundervoltz	Thundervoltz
(W)			40,000	70,000	250,000	500,000
Input required			8 A, 100–250 V AC	10 A, 100–250 V AC	20 A, 100–250 V AC	30 A, 100–250 V AC
Dimensions (in.)			29 × 29 × 26	29 × 29 × 26	2 units each 26 × 24 × 26	2 units each 31 × 32 × 34
Weight (lb.)			425	425	1000	1300

40k units or a single 70k unit. The 1300 lb. double Thundervoltz runs two 250 kW units or a single 500 kW unit. The battery packs are mounted on heavy-duty pneumatic tires.

AUTOMATED LIGHTS

A long tradition of showmanship in rock-and-roll lighting brought us moving lights, which have come to be used in all segments of entertainment—theater, trade shows, television broadcasts, and live events of all sorts. Automated luminaries (generally called moving lights or simply "movers") are capable of creating breathtaking effects in the hands of a creative designer and a skilled lighting control programmer. Typically, in concert applications, an array of moving lights are choreographed in coordinated patterns to make sweeping pans and flourishes, weaving beams of light into patterns in the (fogged) air and moving colored projections across the stage surfaces.

In motion pictures and television, moving lights are used for lighting effects of all kinds. To give just a few examples, moving lights have been employed to simulate the changing beam of a movie projector, to animate a static image of the ocean on a translight, as an overhead helicopter light, to emulate passing car headlights, or simply as a remotely controlled spotlight.

But probably the most useful application for a moving light is in situations where a lighting technician can't get to the light to adjust them. For example, if dozens of background artists would have to be moved in order for the lighting crew to bring a lift into the set, a great deal of time can be saved by using a light with remote pan, tilt, and focus.

The operation of moving lights is complex, requiring an appropriately sophisticated control console and the skills of a programmer for whom this is a specialty and possibly one or more moving light technicians.

The lights have dozens of features. Standard features on a profile spot fixture include:

- Pan and tilt.
- Zoom and focus. Zoom controls how narrowly concentrated the beam is. Focus defines the sharpness of a projected image, and beam edge.
- Variable iris, which changes the diameter of the beam without changing brightness.
- Dimming and blackout.
- Variable strobe shutter.
- CMY (cyan, magenta, yellow) color mixing, which allows the luminaire to create light in a wide range of colors.
- Color correction wheel, which allows daylight-balanced arc lamp fixtures to adjust to any color temperature by adjusting the amount of CTO correction.
- Color wheel, which provides a number of specific colors that can be customized for the job at hand.
- Gobo wheel, which provides a selection of different patterns that are used to project graphic patterns or textures on stage surfaces, and—by carving a pattern into the beam—it is endowed with a streaming quality.
- Rotating gobos, which can be programmed to rotate with adjustable speed and direction. By setting a stationary gobo with a rotating one, moving texture effects can be created that give an impression of a wide range of graphic or impressionistic effects, including moving water, fire, shifting dappled light, and so on.

A typical moving light has six or more gobo slots. The gobos can be exchanged as required by the lighting designer. Each manufacturer provides a particular set of gobos with their light, so when a lighting designer or gaffer orders a particular light, he or she might be expecting to have access to particular gobos. However, some rental houses may use different gobos in their lights, or may not install the gobos in the same slot number as others. This can lead to unhappy surprises on set and programming headaches. It is a good idea to specify which gobos you want, and in which order, so that all the lights are configured in the same way, with the gobos you need. Rental managers are used to customers specifying exactly how they want the lights delivered. It is common practice in the rock-and-roll world.

Selecting moving lights

The number of different moving lights on the market today is truly mind-boggling. The manufacturers' Web sites provide detailed descriptions, support, and really great video demonstrations. It may be very helpful to have a conversation with your programmer about the effects you intend to create. Programmers have experience with a wide variety of lights and will be able to tell you which lights are most appropriate and what is available in the local market. If you are unsure which mover is best, do a test or demo. Rental managers are very willing to loan movers for tests and demos. It is not a bad idea to compare different brands side by side.

Moving lights can be broken down into major categories as follows:

Profile spotlight versus wash

A profile spot has a relatively narrow beam, which can be used to project gobos. Typically, the beam can be zoomed from around 10° to around 30° or more, depending on the model. A wash fixture has a much wider field than a profile fixture, and is therefore not as bright. They are used for covering larger areas with colored light. Wash fixtures do not have gobos and projections.

Moving yoke or moving mirror

A moving yoke fixture has a very wide range of motion. A typical yoke-mounted light can rotate 540° and tilt 270°. A moving mirror fixture like the Cyberlight has much less range of movement (170° or 180° of pan and 110° of tilt). However, a moving mirror can move the beam much faster than a moving yoke fixture. When considering speed, it is important to consider how close the lights are to the subject. The further away the lights are placed, the faster the beam travels across the stage (fewer degrees of rotation for the same amount of beam travel). For filming, we tend to need to place the lights closer, and this results in a slower speed of travel across the ground.

Tungsten lamp, metal halide, LED

The vast majority of moving lights have daylight-balanced metal-halide arc lamps—short-arc HTI, HMI, or MSR lamps, which typically have a color temperature of 6000–8000 K and a CRI of 75–80. Many moving lights have a color correction filter that can be used for 3200 K filming (if not, you can add CTO to the color wheel). Nonetheless, in certain situations, it may be desirable to use a tungsten light source, especially if the light may be used to light the performers (as opposed to just lighting the air). Tungsten lamps can be dimmed electrically; metal halide lamps are dimmed using a mechanical dimmer. On the other hand, metal halide lamps put out a great deal more light per watt. The entrance of LED into the moving light market opens up yet another set of options.

Wattage

Moving lights tend to come in standard wattages. Most manufacturers make metal halide arc fixtures in 250, 300, 575, 700, 1200, and 1500 W wash and profile fixtures. 1800 and 2500 W fixtures are also becoming more commonplace. Tungsten fixtures are typically 575, 750, or 1000 W.

Indoor use or outdoor use

Lights that are rated for outdoor use are designed to be subjected to the elements for long periods of time. I have heard stories from programmers who got caught in monsoon rains while using (indoor-rated) moving lights outside. Not only were the lights unharmed, but they continued to operate. The programmer put the lights in a continuous ballyhoo, so rainwater could not collect inside the fixtures. Such antics aside, outdoor-rated lights provide the needed International Protection rating (IP rating) to ensure reliable use in the elements (see Appendix E).

Beyond these general categories, there are other important distinctions between different moving lights. These include unique features, weight, the amount of noise they make, brightness (efficiency of the optical train), appearance, and price. One moving light technician I know uses a “coolness-to-weight ratio” to evaluate the usability of moving lights. He has devised an equation that divides the number of cool tricks a given light can do by its weight. A heavy fixture had better be able to perform a lot of cool tricks or it gets a poor score. A light like the Clay Paky Alpha 700 (Figure 20.4) is fast, bright, quiet, and—best of all—lightweight, so it gets a very high sore on the “coolness-to-weight ratio.”

Possibly the most critical difference, when using lights close to microphones, will be noise. Most moving lights use fans, except for a couple, like High End Systems’s SolaFrame Theater (LED) or Studio Color 575, that is convection-cooled. They also have motors and moving parts that whir and buzz and chatter a little. Some lights are designed for use in theatrical venues with quieter motors. Some also use baffles with noise-absorbing insulation to quiet acoustic noise.

Another factor that affects the noisiness of a light fixture is the need for fans. The majority of moving lights use arc lamps, which generate more concentrated heat than tungsten fixtures do. They always employ an infrared reflector, also known as a hot mirror, in front of the lamp to prevent the moving parts from overheating. This creates considerable heat buildup and is a big reason that fans are required. Lights that use an incandescent lamp, on the other hand, sometimes require little or no forced-air cooling. When stationary, they are silent. The Vari-Lite VL1000 and the ETC Source Four Revolution are examples. They cannot strobe, as a doused light typically can, but the lamp can be electronically dimmed, and runs quietly.

FIGURE 20.4

Clay Paky Alpha Beam 700 (far right) and Alpha Spot HPE 700 (second from right). The large lights further down the row are SHOWBEAM 2.5 by High End Systems.

(*Courtesy Mike Bauman*)

Moving lights are also distinguished from one another by special features. Gaffers especially like framing shutters like those on the SolaFrame fixture from High End Systems. Shutters make straight cuts into the left, right, top, and bottom of the beam and can be rotated and moved to any angle—an automated version of the shutters on an ellipsoidal spotlight. This is great for cutting the light right where you want it—onto a bounce board, for example. The framing system on the Alpha 1200 profile is unique, in that each shutter can eclipse the entire beam. It can therefore be programmed to make interesting reveals like a sliding door.

Features such as image shake, animated gobos, and rotating prism can be an important part of the alchemy the programmer uses to create certain lighting effects. For example, the shake feature can give the impression of a machine malfunctioning (which happens at some point in pretty much every science fiction movie).

The PRG Bad Boy is a 1200 W spot unit with a large front lens and exceptional 8 × zoom capability (7–56°). This gives it a very distinctive large bright beam. According to PRG, the lamp can also be boosted to 1400 W. The pan, tilt, and zoom are exceptionally fast for a moving-yoke fixture, which enables some really breathtaking effects. The Clay Paky Alpha Beam 1500 is also known for its exceptionally bright beam and very fast motors.

Some moving lights simply look cool. When moving lights are going to be on-camera elements, this may even be the overriding consideration. The Vari*Lite VL500 has a front end that looks like the fan blades of a jet engine. Increasingly, moving lights are available with features like RGB LEDs encircling the lens, which can be programmed to make all kinds of chase, strobe, and pattern effects, so the light fixture itself becomes a visual element. The ShowBeam 2.5 (by High End Systems) is a 2500 W profile spot with this distinctive look. This light is also known for its unique twin beam effect, in which the beam is split into two discrete hard-edged beams with variable control over the deviation and rotation speed.

The Cyberlight is probably the best-known moving-mirror style fixture. Although the pan tilt range is smaller than a moving yoke fixture, the light can produce a full array of effects, including a multi-image prism, split color, near photo-quality image projection, wave glass, and a mosaic color effect. The light comes out the end of the fixture and hits a moving mirror, which is panned and tilted by a high-resolution, microstepping motor capable of panning the beam smoothly 170° and tilting 110°. A side effect of a moving mirror is that gobos or projected images rotate when the light is panned, and it is much more difficult to program straight-line pans.

Of course, your budget is also going to be a factor when selecting lights for a job. Top-of-the-line and relatively new fixtures cost more, but you can get the full range of effects from older lights that cost a fraction as much.

Moving lights may seem like they can do anything, and for the most part, they can. However, to ensure reliability and longevity, it is advisable to avoid leaving them running continuously without a rest. These lights contain lots of electronics—circuit boards and even microprocessors. Although the motors used are generally very strong and dependable, nonetheless parts can and will fail. A ballyhoo using a bunch of moving lights is a wonderful look, but leaving it running for hours at a time takes a toll. You say, “But they’re rock-and-roll lights! Moving is what they were created to do.” This is true, but when have you gone to a rock show that lasted 12 or 16 hours, with the lights moving nonstop? If you’re doing a gig that does require the lights to move continuously, make a pause cue and rest the lights whenever possible between takes. This is preventive maintenance, and the moving light tech will thank you for it.

Working with moving lights

Typically, when moving lights are added to the lighting package, a moving light technician is added as well. This is someone who knows all the details of how to unpack, rig, set up, lamp, repair, and troubleshoot these lights. If you do not have a "tech," you are left thumbing through the light's operating manual and making phone calls. For each light, you'll need to ascertain how to lock and unlock the pan and tilt, how to navigate the setup menus, how to address the light, and how to set all the other profile options for your particular application. The setup menu contains various user selectable parameters, such as what it will do when it loses the DMX512 signal, whether it will autostrike, and so on. Each moving light will typically require a couple of dozen DMX512 channels. The programmer needs to specify what mode he or she wants the lights set to, and what address to give each light. Depending on the model, the light may need to have AC power before it can be addressed. Some models are equipped with an onboard battery that enables addressing without the need for AC. This is very convenient when you are rigging and you don't yet have power.

Once the light is powered and turned on at the switch, it can then be given the instruction to strike via the control console. At that point, it will strike and proceed to calibrate itself. This process takes several minutes. When calibration is complete, the light will "home"—go to its default home position. At this time, the light may be controlled from the console.

Moving lights can be quite heavy. Most require a couple of people to lift. They have a lot of moving parts and sensitive electronics, so steps should be taken to minimize opportunity for them to get banged up in the process of rigging and wrapping. Ideally, the truss can be lowered on chain motors to a convenient working height and the road cases can be rolled right up to the truss for rigging. All the lights must be oriented the same way on the truss. Moving lights typically clamp to the pipe or truss using two couplers or claws. A variety of couplers exist that make this process easier than it is when using standard couplers. Two popular models are the Mega Claw (The Light Source) and the Tee Slot Coupler (City Theatrical) discussed in Chapter 10. Moving yoke lights put a considerable amount of torque on the truss when they move. Once raised in place, the truss must be fixed in place or it will swing and wobble when the lights move.

When ordering the lights you will need to determine the following: what type of electrical service it takes (many are autoranging from 100 to 240 V, 50 or 60 Hz; others are 208 to 240 V only, and some are 120 V only); what type of connector is on the power cord (L6–20, L6–30, PowerCON, TRUE1, or Edison). Ideally, the distribution equipment that provides the circuit protection for the individual lights is located on ground level along with the control console. This makes it easy for the programmer to reboot the light if it develops a bug. To that end, the circuit breakers should be labeled with the fixture number so that you know which switch to reset. The distribution will be in large rolling racks with rows of Socapex outputs (Figure 20.5). It is usually most convenient to run Socapex cable from the distribution box to the lights, and then break-out to female fixture connectors, to connect the lights. It is important to color code the Socapex cable when working with more than one voltage. You may be working with 120, 208 V, and dimmer power all fed through different Socapex cables. Generally, yellow is the established color to denote 208 V power, and white or gray for 110 V, but people often use their own system of colors. Color coding the cable is essential to protect equipment, and very helpful when troubleshooting.

FIGURE 20.5

Distribution rack for moving lights.

(*Courtesy AC Power Distribution, Inc.*)

REMOTE PAN AND TILT FOR CONVENTIONAL LIGHTS

A number of manufacturers make DMX512-controlled motorized yokes for conventional fixtures such as a Source Four ellipsoidal spotlight (see Chapter 8). The Source Four can also be fitted with a moving mirror attachment. These are relatively inexpensive accessories that can offer real-time savings.

It is often the very large heads that we would like to be able to control remotely—when lights are attached to an aerial lift boom arm (Condor), for example. The ARRI MaxMover (Figure 20.6) is a large-capacity remote-controlled stirrup that can be adjusted in width and adapted for most large lights, including ARRI HMIs from 6 up to 24 kW (including 12ks by a couple of other manufacturers as well), 12k and 24k ARRI tungsten heads, and even the 12-light Maxi-Brute.

To mount the light, the light's existing yoke is removed, adaptor plates are attached to the head, and the remote stirrup is adjusted to fit right to the adaptor plates. The maximum load is 176 lb. The MaxMover provides pan, tilt, and focus (flood/spot) control from either an analog controller (standard) that comes with a 160-ft. cable, or a DMX converter (optional) that may be connected using a cable or operated wirelessly. The analog controller provides joystick-type pan and tilt knobs and pushbuttons for focus. An LED display shows when the flood/spot mechanism has hit its (software) stop. The analog control does not provide ballast control. There are a couple of different DMX512 converters that can be used.

The "basic" DMX setup replicates the controls of the analog control using three channels to control pan, tilt, and focus. Pan and tilt operate like a joystick, with 50 percent being the zero movement position. It is meant for manual control using any simple dimmer board. The more advanced method, Fully Programmable or "FP," uses eight channels, has 16-bit resolution, and employs separate channels for pan speed and tilt speed. It is designed to be triggered by a light cue in the same manner as moving lights. A moving light console works most easily with the FP DMX option.

FIGURE 20.6

ARRI MaxMover.

(*Courtesy ARRI Lighting*)

The MaxMover comes with operating instructions that the user should definitely read. There are a number of things one needs to be aware of—for example, you should not plug in cables when the power is on. There is a specific procedure for mounting, balancing, and calibrating a light to the MaxMover.

The MaxMover can operate either overslung or underslung. A good way to rig to a Condor basket is by attaching a short length of truss or pipe to the underside of the basket. This truss is centered under the basket so that it avoids the kinds of out-of-center load problem posed by mounting a light on the railing. The remote head can be underslung from the truss. This placement of the light has another advantage over placing it in the basket; the light can be placed closer to the top frame edge of the camera's shot.

MEDIA SERVERS AND VIDEO PROJECTORS FOR LIGHTING EFFECTS

Motion graphics and video playback have become staples of broadcasting, theater, dance, concerts, and corporate events. Figure 20.7 shows a concert with live video being displayed on an enormous scale. In recent years, media servers have been designed to be controlled directly using a lighting control console and a common control protocol such as DMX512 or MIDI. A media server is a computer with ample graphics and processing power, storage, and RAM, which uses software developed specifically to store, play back, and manipulate digital media content (video, motion graphics, photographs). As a result of the trend by manufacturers to treat a media server as a lighting device, programming them has become the console programmer's responsibility.

A media server is used in conjunction with a video projector, digital lighting device, or LED display. Media servers provide the ability to combine and layer multiple images. The images may be manipulated and distorted in various ways. Some of these are practical; others are for effect. These

FIGURE 20.7

An enormous screen (180 ft. wide, 450 m^2 total) backed Coldplay for their 2009/2010 stadium tour called "Viva." The screen is a 30-mm spider of LEDs sourced from XL Video Worldwide. The screen is curved in both aspects. Control was via a Catalyst media server (High End Systems), triggered via an MA Lighting console. The screen enabled the lighting designer to get away from the standard square wall configuration and produce an immersive "eye."

(*Courtesy Paul Normandale*)

include zoom, focus, color balance, and keystone correction (correcting distortion caused by the projector being positioned off-angle to the projection screen). Manipulation includes fades and dissolves between layers, color distortion, scaling and positioning, orientation, slow motion, soft edge, blending, and more.

Each layer of video may require 40 or more DMX512 channels. Media servers such as Catalyst (by Richard Bleasdale), Axon (High End Systems), M-box (PRG), Pandora Box (Coolux), and Hippotizer (Green Hippo, Ltd.) can provide eight or more layers. The channel count for running a media server can easily get into hundreds of channels. The DL-3 (from High End Systems; see Figure 20.8) is a media server built into the base of a projector, which has a moving light yoke. With a unit like this, the projector can be panned and tilted remotely. The DL-3 has a more limited number of layers than standalone servers, but it simplifies the setup by containing everything in one automated unit.

The graphics files for the source material can be JPEG, TIFF, bitmap (BMP), or video such as MPEG2, AVI, or QuickTime (MOV). Accordingly, the source material can itself be manipulated using programs such as Adobe Photoshop, Adobe Illustrator, Adobe After Effects, and Apple Final Cut Pro. The creation of the source material is a shared responsibility. In cases where the source material is essentially a technical matter, it may be done by the programmer. When images possess more specific design elements the material is typically created or sourced by the art department.

In addition to projecting on a screen, media servers are used in motion picture work to create various kinds of effects such as projecting repeatable images on an actor's face, creating a wall of rain, creating water reflections, creating reactive lighting effects, and so on.

FIGURE 20.8

The DL-3 is a projector with a moving light yoke and a media server built in.

(*Courtesy High End Systems*)

XENON LIGHTS

Xenon globes have a very short arc length and an extremely bright arc, which makes them easy to collimate into a highly focused beam with very little scatter (Figure 20.9).

The beam is perfectly circular and very narrow. The beam diameter can be controlled with an electronic flood/spot switch on the head and ballast. The intense shaft of daylight-balanced (5600 K) light is sometimes used to simulate sunlight or a searchlight. Xenon fixtures are used in concerts and light shows to create very bright shafts of moving light. Their vibration-resistant design also makes them suitable for use in helicopter and armored tank searchlights.

Strong Britelight and other manufacturers offer a line of high-output xenon lights designed primarily for concert, theatrical, and motion picture use. They are made in various sizes. The smallest, the Maxa Beam, is a powerful 75 W torch-type flashlight that can be powered by a clip-on battery or by 110 V mains. In full spot, the flashlight can deliver 600 fc at a distance of 100 ft. The power supplies for larger units (2000, 4000, 7000, and 10,000 W) may take either 208–230 V single-phase or 208–230 V three-phase, depending on the type. The power supplies provide the startup charge and regulate power to the head. On/off and flood/spot functions can be controlled from the ballast and the head. Xenon lights operate on a pulse DC (equivalent to square-wave current), which allows flicker-free filming at any frame rate up to 10,000 fps.

The lights can be ordered with a normal yoke or a remote-control articulating base, color changer, and douser accessories. When operated by a computer-controlled remote, a line of xenon lights can be preprogrammed to perform moving beam effects in unison, for example.

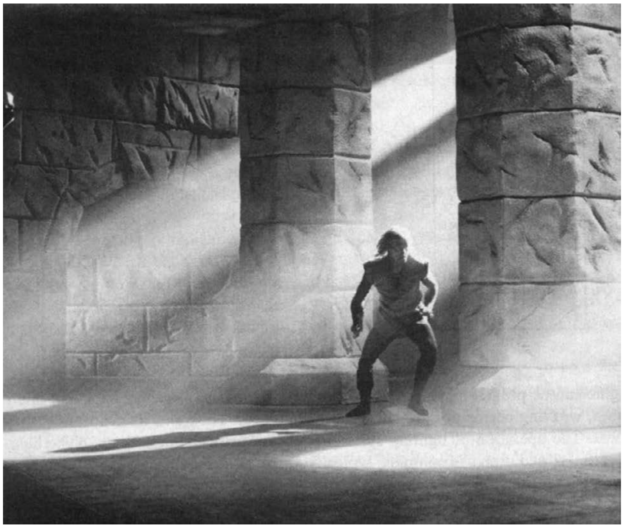


FIGURE 20.9

Xenon lights have a very small arc gap, allowing the beam to be focused into an intense, very narrow shaft. (*Courtesy of Xenotech, Inc., Sun Valley, CA*)

Xenon globes have a lamp life of greater than 2000 hours. There is no color shift over the life of the globe, and the color temperature is independent of voltage and current fluctuations. Xenon lamps require very careful temperature regulation, and they must use forced-air cooling, which makes them somewhat noisy. Forced-air cooling should continue for at least 5 minutes after the light has been turned off. Also because of cooling requirements xenons cannot be aimed downward. A mirror accessory must be used to redirect the beam when steep downward angles are required.

During the life of the globe, evaporated tungsten is deposited on the upper inner wall of the envelope and slowly reduces light output (Figure 20.10). The globe should be turned over after half its rated life. These unavoidable deposits are what define the end of a globe's usefulness. Frequent ignition charges accelerate the wear of the electrodes and hasten the darkening of the envelope. Xenon light operators should therefore try to avoid unnecessary shutdowns and startups. If the light is temporarily not needed, pan it into the sky rather than shutting it off.

A xenon bulb is always under substantial internal pressure, and the pressure increases when hot. A xenon globe does not break, it explodes. It must always be handled with the utmost care and should never be handled until completely cooled. Bulb manufacturers recommend the use of protective eyewear (or, better, a full-face mask), cotton gloves, and even protective bodywear when handling the globes. For safety reasons, globes should not be operated more than 25 percent past their rated lifetime. Xenon globes must be installed with proper polarity. If operated with improper polarity, the bulb can be rendered useless in a short amount of time.

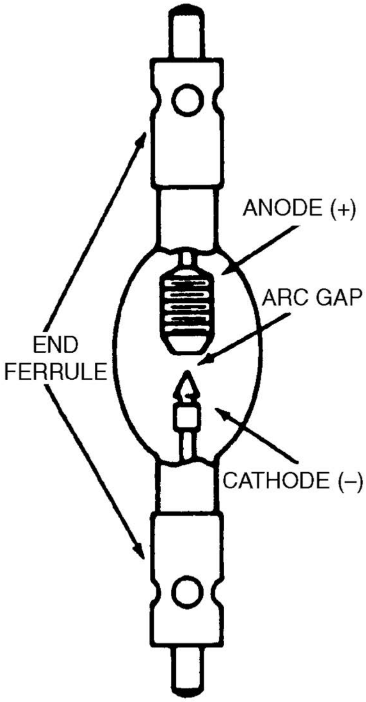


FIGURE 20.10

A xenon globe.

FOLLOW SPOTS

Follow spots, with their powerful long throw, are a staple of music concerts, skating events, award shows, theatrical performances, and circus events (Figure 20.11). Follow spots are typically used as front lights to highlight and set apart the performer from the rest of the stage as they move. Follow spots are also commonly positioned as sidelights or backlights from truss positions. The effect of multiple follow spots tracking a single performer has the kind of splendor that is exciting for an audience.

On a show where the lighting cues are being called over headsets, operating a follow spot is a discipline that requires concentration, ability, and experience. Somewhat like operating a camera, there is a system for feeding the operator the information they need to pick up a performer, there is a protocol that is followed in terms of aesthetics, and the operator is expected to execute their assignment with smoothness and precision, good judgment, and professionalism. In film and television work, seasoned follow spot operators will be hired when the show is cued in the tradition of theater and concert lighting. However, for an incidental scene in a movie or TV show, it is more than likely the gaffer will call the cues, and any one of the lighting technicians may be assigned to operate the follow spot. This presents a great opportunity to become practiced at a skill that can broaden your universe of employment contacts into entirely different branches of the entertainment business.

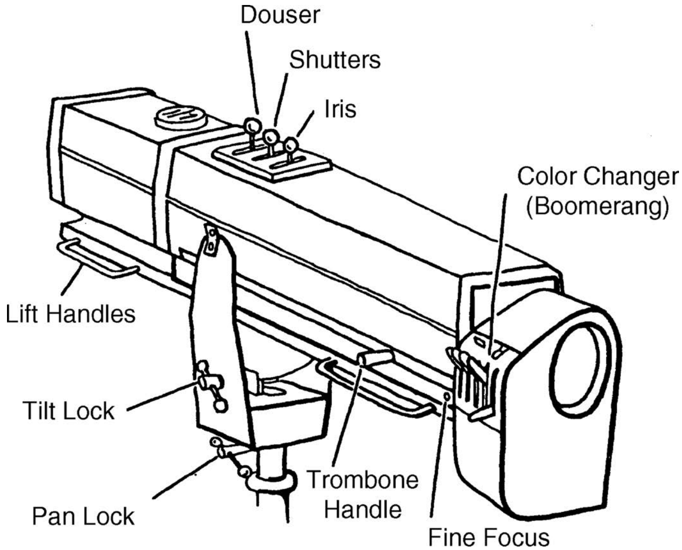


FIGURE 20.11

The Strong Super Trouper follow spot.

(*Equipment courtesy of Strong International, Inc., Omaha, NE*)

Follow spots are mounted so that the operator may pan and tilt the light smoothly to follow action on the stage. Pan and tilt have brakes to lock the light when unattended. In addition, a follow spot has four primary control adjustments, which the operator uses frequently. Three of the four primary adjustments are made with levers on the top of the light:

Douser: The back knob dowses the entire beam. This is the control used to bring the light up on a performer, and to go to black when the performer exits. It can be used to fade the beam (in a two-count fade, for example) or to snap to black.

Shutters or chopper: The center lever brings horizontal shutters into the top and bottom of the circular pool, creating more of a rectangle. This is often used when the light is covering a group of people to keep the wide beam from spilling off the front of the stage. It is sometimes used instead of the douser to make the light "wink" out.

Iris: The front lever controls the size of the circular pool of light. It does this by cutting the light with an iris. The light level remains unchanged.

Color changer or boomerang: At the front of most follow spots are a group of levers, usually six, that introduce different gel frames into the beam.

The two secondary controls are the *trombone* handle and the *focus* knob.

Trombone: A handle on the side of the light that slides forward or back in a slot. It sets the size and intensity of the beam. This allows a more concentrated, narrow beam for long throws and a wider, less concentrated beam for shorter throws. The gaffer or lighting designer (LD) will set the brightness level using the trombone.

Focus: The sharpness of the beam edge is adjusted with this knob, typically located near the front of the follow spot. Depending on the application, a sharp beam edge is often desired. Whenever the trombone position is changed, the focus must also be adjusted.

The size and light source type vary with application. In our work, we frequently simply use a Source Four ellipsoidal as a spotlight; however, these lack the kinds of controls needed for professional follow spot operation (see Chapter 8 for a description of Source Four follow spot retrofits). Small 1k quartz-bulb follow spots, such as the Strong Trouperette, are common for short throws of 30–60 ft. (100 fc), such as in a night club or school auditorium. Slightly larger 575 W HMI and 700 W xenon units have throws of 50–160 ft. (100 fc). Large follow spots, such as the Strong Super Trouper with a 1k or 2k xenon globe, are used for lighting performers from the back of very large auditoriums and arenas. The Super Trouper has a throw of 130–340 ft. (100 fc). The Gladiator and other similar follow spots, using 2500 and 3000 W xenon globes, have throws of up to 460 ft. (100 fc).

The larger follow spots typically have an L6–30 (30 A, 240 V twist lock) connector on the power cord. Typical power supplies are 240 V. If 208 V power is being used, a buck and boost transformer can be employed to bring the voltage up. Typically, the ballast is tucked right up against the base of the light. One head feeder is all that is necessary, although a spare is a very good idea.

Preparing the follow spot

As soon as the follow spot operator takes position, he or she will want to set up the light with marks and settings that are needed for the performance. You need to be ready to come out of black, on target, with the correct headroom, and at the right beam size, color, and intensity. If the light has not already been gelled, the operator will want to place new gels in the gel frames. The condition of the gels should be checked every day. A typical gel complement for film and television looks something like this:

Slot 1	Minus green (¼ or ½)
Slot 2	¼ CTO
Slot 3	½ CTO
Slot 4	ND 3
Slot 5	Another ND or a color
Slot 6	Color

If more colors are needed, you can always tape gel over the front of the light. Typically, the CTO will not change, so this is a good one to tape on. The operator should write down which gels are located in which slots and post it on the light so that anyone operating the light will instantly know the color positions. Wrap a small piece of gaffer's tape around the fourth lever of the color changer, so that you can identify the levers by feel in the dark. Count forward or backward from four.

The gaffer meters the light onstage and gives you one or more working intensity settings; mark the settings on the barrel and make sure that the trombone does not slide out of adjustment. With the douser full open, the operator moves the trombone forward for greater intensity (if the LD says “bone-in”) or back for less intensity (“bone-back”). Once a level is set, the operator marks the trombone position (tape usually won’t stick to the side of the hot light, so you can attach it to the front handle, and mark it with a Sharpie). The gaffer may set different trombone settings for upstage, center, and downstage; mark and label each. He or she could also use the neutral density gel to achieve the correct light level.

Once the trombone is set for intensity, the iris is used to size the beam. The operator will set the size of the beam to cover a performer from head to foot. The iris lever position is marked. The operator may also want to mark the iris settings for other sizes too, such as half-body, or a wider group of people.

One of the hardest things to do with consistency is come out of black exactly on target. To accomplish this, professional follow spot operators use a scope or sighting device, such as a Spot Dot, which they attach to the light and carefully align with the beam.

Check to make sure everything is working smoothly. Check all of the controls. Balance the light so that you are not holding the weight, as this will tire out your arm. Check the pan and tilt. The drag is adjustable. The light should be loose and responsive, not sticky.

Shine the beam on a flat wall and check whether the beam is completely even. If one area is brighter than another, you need to adjust the position of the lamp in the reflector. Sometimes there is a panel that covers the adjustment controls on the back of the light. Figure 20.12 shows lamp adjustment mechanism for a Super Trouper.

Operating the follow spot

The follow spot operator stands on the right side of the light within reach of all the controls. Professional follow spot operators equip themselves with long gloves or “arm burners” to protect their left hand and forearm so that they can rest their arm on the top of the light without being burned.

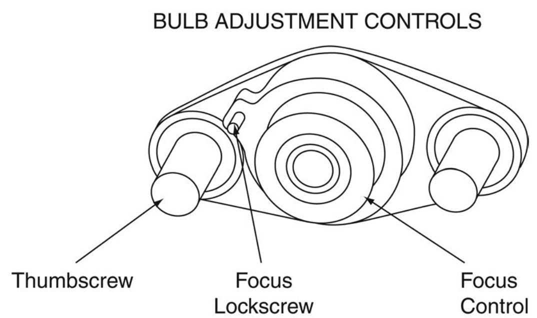


FIGURE 20.12

Two knobs at the back of the fixtures are used to center the lamp and adjust the field evenness. The thumbscrews lock the whole assembly in place. If you loosen them a little, the entire assembly can be moved left, right, up, and down. Center the brightest part of the beam, then tighten the thumbscrews. Then use the focus control to even out the field (release the focus lockscrew before adjusting).

(*Courtesy Strong International, Inc., Omaha, NE*)

The basic tenets of follow spot operation are as follows. Always keep the performer's face lit; if necessary, lose other parts of the body. Leave adequate headroom (a hand's length above the head is standard). Unless otherwise specified, light the performer from head to foot. Panning and tilting must be smooth and in perfect harmony with the movements of the performer, neither leading them nor lagging, and keeping small movements fluid and subtle so as not to be distracting. Standard sizes you may be asked to cover include: full body, half-body, head and shoulders, or "hold the guitar" (however low that is). When you receive direction to *iris out* from head and shoulders to full body, tilt the light down as you iris out so that the light stays centered on the body. Avoid spilling light onto the apron lip, proscenium, back wall or drops, or other performers. When a group of performers are to be covered with a single light, the beam has to be widened out so much that the top and bottom of the beam start to create unwanted spill problems. In this case, you may be asked to *strip it out*; use the shutter to cut the top and bottom of the beam, again making the beam cover the performers from head to foot.

When follow spots are trained on multiple performers, and they are moving around the stage, at some point it is likely that two lights will overlap. This doubles the light intensity. To avoid this problem, follow spot operators have standard right-of-way rules. The rule is that the downstage performer takes precedence, and the upstage follow spot must douse to half as the two lights overlap. When large numbers of performers are onstage, the stage manager may use a zone defense, which means that each follow spot sticks to a given area and abuts the beam to the next follow spot.

During a performance, a stage manager will be talking to the follow spot operators over a PL system (a belt pack, two-way communications system). You can tape your push-to-talk button to the light's handle so that you don't have to remove your hand from the light to talk. A stage manager will usually give a *warning* of an upcoming pickup and say who is being picked up, where they are entering from, and gel color. This is followed by a *standby* cue, and a *go* cue.

> "Warning on a pickup, spot number two, frame three, full body on a man in black, entering down left in one."
> "Stand by spot two, frame three on the man."
> "Spot two. GO."

Upon receiving a warning, the operator selects the color (frame three in this example), adjusts the iris to the size that will give full body coverage, and swings the light into position using the sight. When he or she gets to the "go" cue, the operator opens the douser and picks up the performer.

Another common command is to *ballyhoo*—this is the classic sweep of light over the stage and the audience in big random figure eights.

The *boomerang* (color changer) typically has six gel frames, which can be introduced into the beam using one of six levers on the end of the barrel. By common convention, the changer levers are numbered from 1 to 6 from front to back. Most changers are designed so that you can roll through the colors; as each new lever is applied, the previous lever automatically releases. You can release all the levers and go to white light by pressing a button underneath the changer levers. If you want to add a color without releasing the previous color, hold your finger over the lever as you engage the new color.

When the spot is not in use on stage, it may be panned off into the ceiling of the arena or into the sky, or it may be doused. Xenon lights should not be turned off unnecessarily, as this drastically decreases the life of the very expensive xenon bulbs. The douser can be closed for several minutes without causing damage to the light. Do not use the iris or shutter to do this, however, as they will be damaged. Like any xenon light, xenon follow spots use a power supply that converts current to DC. Xenon bulbs are flicker-free at any frame rate and have a daylight color temperature. The bulbs are extremely sensitive to temperature and must be cooled with fans when running. After shutdown, the bulb must be allowed to cool with fans running for at least 5 minutes. *Never shut down the power before the light has been allowed to cool*.

Xenon lamps are under internal pressure. When hot, the pressure increases to a degree that they can explode if not handled properly. When cool, the lamp may explode if dropped or mishandled. Lamp changes should be made by a qualified person only, wearing proper personal protective equipment including a face shield, clean cotton gloves, and a welder's jacket. The Super Trouper has an adjustment on the ballast for correcting the lamp current. As the lamp ages, this adjustment will need to be changed. The owner's manual specifies the lamp current that should be seen at the lamp housing, and the amount of current that may not be exceeded. Check the manual for details.

Follow spots are designed to be used with colored gels. Despite their candlepower, they should not burn through gel; the optics are arranged so that the beam is least hot as it passes through the gel stage of the barrel. In addition, large follow spots use cooling fans to cool the gel in use. If the gel burns through quickly in one place, it is a sign that the bulb or reflector may be out of alignment. Adjustment knobs on the back of the larger lights are used to align the bulb. If the gel fades quickly, you may want to check to see whether the gel fan is working (if the light is so equipped, the fan is on the underside of the boomerang) and that the air intake is not clogged.

BLACK LIGHTS

Ultraviolet (UV) light or black light occupies a place in the electromagnetic spectrum just below violet, the shortest visible wavelength of light. It is invisible radiant energy. The UV spectrum is subdivided as follows:

UV-A	350–380 nm: black light
UV-B	300–340 nm: used for suntanning
UV-C	200–280 nm: harmful, burns can result

Right around 365 nm, in the middle of the UV-A spectrum, you get maximum transmission for exciting luminescent pigments and materials. When acted on by UV rays, fluorescent and phosphorescent materials are excited to a retroreflective state and emit visible light and vibrant color. Because black light works on some materials and not others, you can create interesting images, such as a disembodied pair of white gloves juggling three glowing orange balls.

Black light fixtures

Black-light blue fluorescent tubes (BLB: 4 ft., 40 W) have little punch; however, when used close up, they can be quite effective. However, in a 4-bank, 8-bank, or 10-bank fixture (like a Kino Flo that has a bright reflector and high-output ballast), fluorescent black lights can make white fabrics and fluorescent colors pop even from a pretty good distance.

Mercury-vapor or metal-halide floodlights ranging from 250 to 400 W are also available from theatrical rental houses. These lamps use a deep-dyed, pot-poured, rolled, or blown glass filter. To create radiant energy at about 365 nm, one needs a light with high-UV output (mercury vapor or metal halide) and a carefully designed UV filter that blocks the visible light (400–700 nm) and the UV-B and UV-C wavelengths.

For lamps larger than 400 W, a UV dichroic coating is necessary to take the extreme heat. Such filters can be used on fixtures up to 18k HMI and xenon lights. Phoebus carries dichroic UV lenses for their xenon lights. Automated Entertainment, in Burbank, developed UV filters for 12k and 18k HMIs and 200, 1200, 2500 W, and 4k SE PARs. Automated also has its own UV and "glow-in-the-dark" pigments and dyes.

Wildfire Inc. is another innovator in this area. It developed a line of UV lights, including a 400 W Fresnel, 400 W floodlight, 400 W ellipsoidal spotlight, and 250 W wide spotlight in a 20°, 50°, or 90° beam diameter. The units operate with ballasts and head feeders like HMIs. Wildfire also offers a wide variety of luminescent materials and paints, including nontoxic dyes, hair spray, lipstick, fabrics, plastics, adhesive tapes, confetti, PVC flexible tubing, and more.

DN Labs is also active in this market, with a line of small lights and specially formulated, highly efficient luminescent rods and sheets that can be machined and won't break.

Photographing with black light

To glow, vibrantly fluorescent pigments should be overexposed by one stop. The effect is less vibrant at exposure and dull one stop under exposure. A UV filter must be used on the camera lens, because the lens cannot focus UV light the same way it can focus the visible spectrum. Without the UV filter, UV produces a hazy softening in the image.

UV light can be combined with conventional light and still create a luminescent effect. The balance depends on how much the effect is to be featured. One could light the scene normally and add UV lights on luminescent materials to give them an extra vibrancy, or a scene could be lit to a lower level with conventional lights so that the luminescent materials stand out. The extreme effect is to black out everything but the luminescent elements. Black makeup eliminates all traces of the performer's skin. With nothing but black light lighting a scene, a woman wearing a luminescent wig and dress, for example, will appear to have no hands or face—only the clothes and hair show up.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

CHAPTER 21

LED color science and technology

The promise of LED technology, and its potential for unprecedented color control, has challenged manufacturers, gaffers, DPs, and colorists to understand the spectrum in ways we had not contemplated before. The field of LED color science has matured now to a point where there is a body of new knowledge, a new vocabulary we can apply, but things are still being worked out. The industry has revised systems of evaluating color quality, and developed new instruments to make measurements, and in doing so has discovered that the systems have imperfections and beg new questions. The industry has standardized ways to provide different lights with common reference points for identifying and matching colors. This provides ways for a programmer to communicate with lights by different manufacturers to produce the same specific color, but we have discovered in the process that every camera sees those color coordinates slightly differently. We have vastly expanded the gamut of colors a light can create, and then had to grapple with how those colors are mapped onto the color space of the distribution and display medium where those colors may not exist.

The state of the art has come an enormous distance in only a few years. Gaffers and DPs are routinely achieving stunning, innovative effects with this technology that they may not even have thought of without it. We are past the bumpy beginning and into an exciting young adulthood of the digital era of lighting. This chapter is as much about understanding the questions as it is about the solutions.

As detailed in Chapter 7, the market has developed a wide variety of color systems to create white light and colored light using LEDs (Figure 21.1). Each light uses a set of specific colors to create white. In colorimetry, *metamerism* is the perceived matching of colors that are created with different spectral power distributions. In other words, the red, green, and blue LEDs of one light may be different wavelengths than the red, green, and blue of another light, yet the two lights can both generate most of the same colors by the way the three colors are mixed. The color points of the LEDs that a manufacturer selects for their full-color lights vary a great deal, yet they all can produce specific colors, like 5600 K and 3200 K for example, that are a metameric match and appear visually identical to the human eye.

However, we do not shoot movies with the human eye. We have to use cameras. The spectral sensitivity curves of cameras vary between camera models and manufacturers.

Consider the stages that affect the acquisition of color:[1]

1. The color of the light (the spectral distribution of wavelengths which, as we have said, can be created using different color recipes that can generate metamers).

[1] After acquisition, the image goes through a color correction process. The signal is then transposed into a display format (P3 for theatrical projection, NTSC for broadcast and cable for traditional TV, Rec. 2020 for HDR streaming, Rec. 709 for regular streaming). When the signal reaches the display device (TV, projector, monitor, phone, etc.) it is split back into red, green, and blue, and these are the colors that are finally received by human eyeballs.

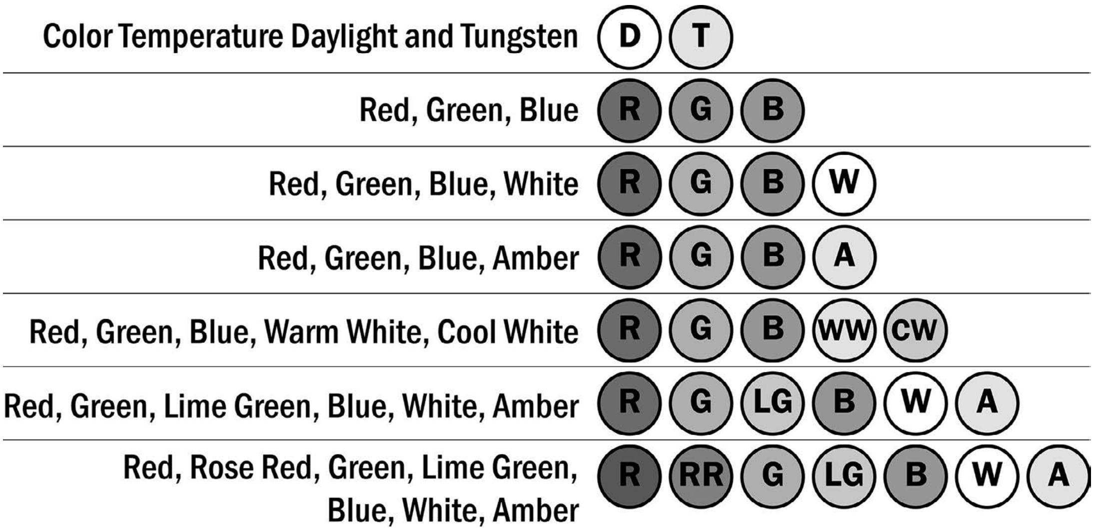


FIGURE 21.1

Examples of LED color systems. There are also many others.

2. The color of the object the light reflects off of (which we would like to be able to render faithfully).
3. The eye, camera sensor, or light meter that receives the light and how it processes that information.

At each step, the relative strengths of wavelengths may be altered. First, if the light source lacks energy in the area of the spectrum where there is high reflectance of an object, the object cannot reflect that color faithfully. Second, due to the differences between cameras, two light sources that create a metameric match to the human eye may be seen as slightly different colors by a digital camera. Additionally, two different cameras may record the same color differently because, even though we see a metameric match, the cameras respond slightly differently to the makeup of the spectrum from the light source.

So, there are two parts to the problem of color rendition, the spectrum of the light source and the interaction of that light source with the camera.

SYSTEMS FOR EVALUATING COLOR RENDERING

In applications where color rendition is critical, only illuminants with very good color performance are capable of faithfully rendering the proper hue and depth of saturation. Creatives in many departments have spent a great deal of effort carefully picking colors for makeup, wardrobe, hair, sets, props, commercial products and logos. It is part of the cinematographer's responsibility to protect those creative intentions. Colors cannot be correctly represented if a light source is weak in critical areas. If the color rendering of a light source is poor, fixing it in postproduction may involve time and unsatisfying compromises.

Significant effort has been expended trying to figure out the best way to evaluate the color performance of solid-state lights in a way that is accurate and helpful. Turns out, this is difficult. Various indices have been developed to aid in the evaluation of color rendering of leds. The antiquated CRI system is not capable of evaluating leds. Better systems include extended CRI 15 (Re), CQS, TM-30-18, TlCI-2012, TlMF-2013, and SSI. A modern color meter like the Sekonic C-800 can evaluate the color of a light and characterize it using these indices.

It is educational to understand the objectives of these systems, how they work, and especially, their limitations and shortfalls. While all of these indices give an idea whether the color rendering of a light will be generally good or not so good, in specific cases they have been shown to be inaccurate, both over- and under-estimating color rendering quality. Furthermore, none of them take into account the differences between cameras. And really, a 0-100 score does not furnish the gaffer and DP much information that they can act on. Much more has been written about this subject than we have space for here, and you can easily Google it if you need to know more. The essentials are as follows.

What's wrong with CRI?

The standard system used to evaluate color rendering of lights since the mid-twentieth century has been the *color rendering index* (CRI). The CRI index was developed when fluorescent and metal halide light sources started to proliferate. CRI assumes the colors are observed by a "standard [human] observer," not by a camera. It was never intended for use in motion picture/television and has limitations that make it inappropriate and misleading as a comparison method for cinematography. Nevertheless, we have to understand it because CRI is still an obligatory reference used by all the lighting manufacturers. Luckily, other metrics are finding greater traction as time goes on.

CRI is a rating, from 1 to 100, meant to express the accuracy of a light's rendering of color when compared with a perfect reference source of the same Correlated Color Temperature. Daylight is a perfect 100. A rating above 90 is considered accurate color rendition for photography. With a CRI above 80, the eye can still make accurate color judgments and the color rendering is termed *acceptable*; however, on camera some colors will be affected. Between 60 and 80 color rendering is *moderate*. Below 60 color rendering is *poor* or *distorted*.

The CRI of a lamp is determined by illuminating eight standard test colors with the test light and comparing it mathematically to the same test colors illuminated with an ideal reference source. The CRI value is the average of the eight results, CRI(Ra). The average of only eight colors is virtually meaningless by itself when measuring a source whose spectra is made up of peaks and valleys. A low overall CRI number, say less than 85, probably means the light's spectrum has deficiencies. HMI and LED manufacturers express frustration, however, because a lamp with a pretty good spectrum of color, but having peaks and valleys in its spectrum, may not hit the eight test colors dead on, and can end up with a lower CRI than another lamp that has no greater color rendering on average, but happens to represent the eight test colors well.

Extended CRI, CRI 15

A slightly improved system that seems to have some traction at this writing is the Extended CRI scale, CRI 15 (Re). This system adds seven additional colors to the original eight CRI colors, making 15 reference colors, which are evaluated on a scale of 0–100. Critically, the additional colors include two

FIGURE 21.2

Sekonic C-800 spectrometer display in comparison mode. The display shows the readings from two illuminants using the CRI 15 index. It shows the 15 sample colors and their respective scores. At the top Ra is the average of the 15 scores. CCT is the correlated color temperature.

(*Courtesy MAC Group and Sekonic®*)

skin tone colors: R15, medium skin tone, and R13, light skin tone. Another key reference is the new R9, a saturated red, which is a difficult color for a phosphor-based LED to render well. A spectrometer can measure how well each color is represented in the fixture's "white" light output (Figure 21.2). Many lighting manufacturers publish these values as well.[2]

[2] CQS and TM-30–18 are similar methods of evaluation which are based on a human observer and do not account for differences in spectral sensitivities of cameras. Color Quality Scale (CQS) is a similar scale developed by researchers at the National Institute of Standards and Technology (NIST). It was created to address specific flaws in the CRI scale to make it meaningful for LEDs. It uses 15 carefully selected, more deeply saturated colors, which gives the light's spectrum a smaller target to hit, but actually results in higher overall scores for most high-performing lights. The reference colors are chosen to account for human color preference. TM-30–18 was developed by the Illuminating Engineering Society (IES) in 2016. It uses 99 color samples. In addition to a fidelity index (Rf), TM-30–18 also considers color saturation by providing a gamut index (Rg). TM-30-18 provides graphics that show where the color deficiencies are, not simply that they exist.

TLCI-2012 and TLMF-2013

It is very hard to judge how an irregular, noncontinuous spectrum is going to line up with the specific sensitivities of a given camera sensor. The response of a digital camera sensor will be different from one to the next.

The desire to add the camera as a variable for evaluating color is a logical response to this problem; however, there are many kinds of cameras and they change fairly regularly. The TLCI-2012 system is based on algorithms for responses of modern (at the time) HDTV, CCD, and CMOS cameras. The TLCI has gained some traction with lighting manufacturers.

Television Lighting Consistency Index (TLCI), developed by the EBU Technical committee, uses the measured spectral data of the source lighting a 24 patch Macbeth chart and it uses algorithms to make a software simulation of camera response (Figure 21.3). The 24 samples are averaged to obtain a single value, Q_a, an index from 0 to 100.

The scale is constrained so that a value of 50 corresponds to the cutoff below which the color is not correctable. For film-style shooting the scale means: 100–90, perfect; 95–70, easy to get most colors right; 80–55, can get some colors right; 60–40, hard to get much right; 50–25, hard to get anything

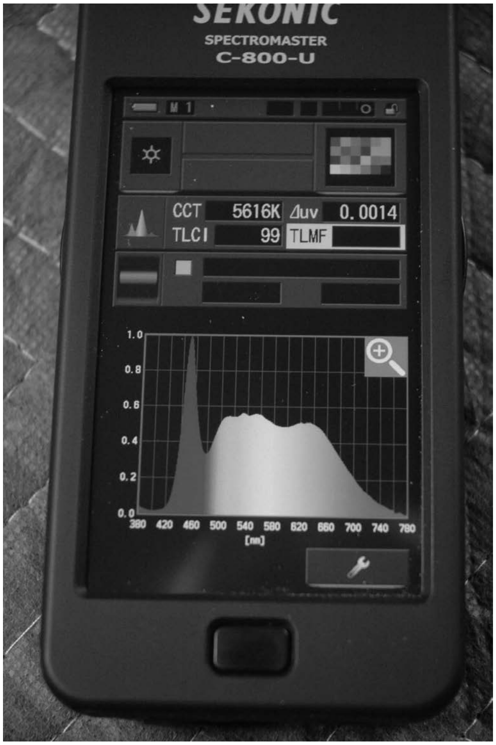


FIGURE 21.3

TLCI-2012 reading on a Sekonic C-800 meter.

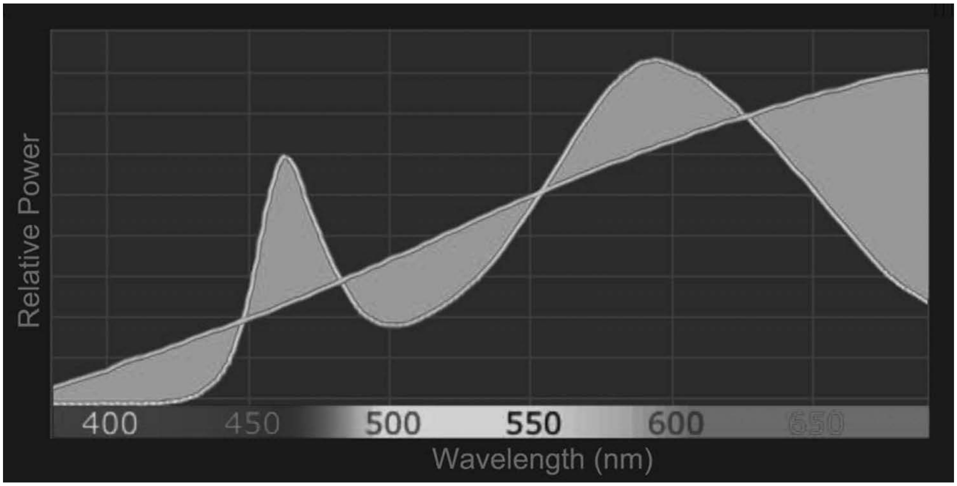


FIGURE 21.4

The SSI index is based on the variance (shaded area between the lines) between the spectral power distributions of a reference source (studio tungsten light in this case) and a test source (a typical phosphor-based white LED in this case).

right; below that, hopeless. The meanings have considerable overlap because, in the words of the publication, opinions vary and the chosen metrics are not perfect.[3] It is questionable how well the index relates to the constantly evolving range of today's cinema cameras. Inaccuracies in the evaluation have been noted, such as a light with a noticeable green/magenta shift getting a high TLCI value due to TLCI auto white-balancing to the display.

Spectral Similarity Index (SSI)

The Spectral Similarity Index was developed by the Academy of Motion Picture Arts and Sciences with industry experts. The idea of SSI is to get away from comparisons based on human vision or of any particular camera or spectral sensitivity. Instead it measures how closely the spectrum of the test source is to a reference spectrum, such as tungsten, daylight, or some other selected reference. The SSI value is always denoted with the reference illuminant, for example SSI[3200 K], SSI[2900 K] or SSI[D55].

Figure 21.4 shows a graph of spectral content of two sources. The reference source, a tungsten light (the linear distribution) and the test source, a 3200 K phosphor LED. The area that is filled in between the lines represents the difference between the test source and the reference source. The size of this area is used to calculate the SSI value. The scale is meant to be seen as a "confidence factor" that colors will be rendered as expected. The index is scaled so that values above 90 indicate a high

[3] EBU, Operating Eurovision and Euroradio, Tech 3355, *Method for the Assessment of the Colorimetric Properties of Luminaires. The Television Lighting Consistency Index (TLCI-2012) and the Television Luminaire Matching factor (TLMF-2013)*.

degree of predictability; 90–80 will be pretty good. The lower the score the greater the likelihood that some cameras are not going to represent the color well, while some may. Generally, a score lower than 60 indicates there will probably be colors that render poorly with any camera. According to the SSI white paper, "The simplicity of the SSI approach allows for relative ease in choosing sources that will provide properly rendered colors with any camera or film stock and colors that match those as seen by the eye."[4] Scores on the SSI scale are generally lower and more discriminating than other evaluation methods discussed here. It has been noted that, since SSI does not take into account the spectral response of the camera, a source that provides high color fidelity in the areas of the spectrum most important to the camera can still receive a low SSI because there are less important areas that are divergent from the reference source.

What to watch for

When using untried equipment for color-critical shots, it is a good idea to perform tests beforehand, using the light sources, subjects, camera, and postproduction process that is to be used for the shoot if possible. This is true of any untested LED light, but especially if you find yourself dealing with consumer grade lights and lights designed for another market (e.g., architectural or theatrical markets).

Here are some things to look for. Phosphor-based LEDs have no output at wavelengths shorter than about 425 nm, which means that violet colors on illuminated objects don't render well, even with the coolest-white LEDs, which makes them very different than daylight and other high-color temperature white sources. This is why the CRI(Re) score for saturated blue, R12, is almost always lower than others, unless the light has a blue LED that is more saturated than the 465 nm blue pump color of the phosphor LED. Many cameras have sensitivity down below 400 nm and even into the UV range.

There is a dip in output in the medium blue-cyan-turquoise range between 465 and 510 nm, which not only makes it difficult to render those aqua-type colors on illuminated objects, but also skin tones and warm, amber-yellow colors don't stand out well for lack of a complementary color within the spectrum. In the long-wavelengths, the warm tones can also taper off. The red, R9, test sample on the CRI metrics is a bellwether for how much red the light has. With LEDs it is never as strong as the other reference colors, but it is also important to understand that the better cameras have little sensitivity above 680 nm. This helps limit problems with IR ND filters. R9 is actually outside the Rec. 709 color gamut. Metrics that are based on human response look for a match with tungsten or daylight, which both extend all the way out past 700 nm, which makes colors like R9 less useful as a metric for predicting camera response. Under white LEDs the warm colors can look somewhat washed out, but this also depends on the specific camera and the debayering algorithm/criteria used. To fill in the weak spots in the spectrum, some full-color fixtures may mix in additional LEDs like amber, rose red, or red LEDs, and may also provide a deeper blue at the lower end of the spectrum and help the mid-range with the addition of blue and green.

The ETC Source Four Lustr has eight LED colors. The goal of the light's design is to expand the color gamut and create more of the colors that theatrical lighting designers are accustomed to using (from their gel swatch books) and be able to deliver each of those colors with reasonable intensity. The Lustr fills in all the dips in the spectrum. However, when we are capturing images with a camera using white light, the goal is slightly different. A camera has to render colors accurately across the spectrum.

[4] *Spectral Similarity Index (SSI) Overview*, 2018–12–04, Copyright © Academy of Motion Picture Arts and Sciences.

The spectral sensitivity of a camera looks like three steep peaks at red, green, and blue. You might wonder if filling-in all the dips in the spectrum really matters if the camera only cares about three colors. If a light can mix the three colors in a way that makes 3200 K CCT, then we should have perfect color, right? No surprise, it is not that simple.

Why different cameras see the same colors differently

The limitation of all the indexes is that each camera sees colors differently, as does the human eye. It is difficult to predict with any specificity what color problems you could have based on the manufacturers' published data or readings from the color meter. The Sekonic C-800 CRI 15 bar graph display can give you some idea of the weak areas to watch for. It is best used to get relative information by comparison between two sources. For example, it will show if one source is skewed slightly green compared to another one. However, it does not give any information regarding the response of the camera.

Frieder Hochheim, founder of Kino Flo, shared some of the data their team has gathered. Kino Flo developed software to analyze measurements of a precision spectrometer predicated on the response curves of professional cinema cameras. To do this they had to perform testing, looking at the spectral sensitivity of each camera. The Kino Flo system used what they call the *Photographic Rendering Index* (PRI). Lighting a Macbeth test chart with a variety of lights, they compared the response of a range of cameras. They found many examples where two cameras saw the color makeup of differently formulated led lights dissimilarly. They frequently found differences of a quarter minus green correction between cameras and even found some instances where the difference exceeded full minus green correction between two cameras.

The tests also revealed that, despite all the lights they tested having good PRI numbers, lights with broader, more continuous, white spectrum tended to be closer to cameras' white points than RGBW formulations or formulations that use seven or eight emitter colors to create white light. There was less variation in the different cameras' responses to the broader spectrum than to the other formulations. Depending on the formulation and the color temperature selected, one or other camera would require between ¼ to full minus green correction, while the broader spectrum light required consistently less correction for all cameras. From their research, Kino Flo developed lighting LUTs, described in Chapter 7.

Hochheim's conclusions were: that there are differences between even very good "white" lights; that these differences may be more or less apparent depending on the camera and other variables, which can make them difficult to discern; and finally that "Having a good broad spectrum white light goes a long way to solving color rendering issues."

GAMUT

Color *gamut* is the range of colors that a given system can record or display. Figure 21.5 shows the color space of Rec. 709, the HD format and the Rec. 2020 color space, ultra-high-definition television (UHDTV) with standard dynamic range (SDR) and wide color gamut (WCG). The color space of Rec. 2020 is the same as Rec. 2100, high dynamic range (HDR). HD cameras are designed to record colors within the Rec. 709 color space and HD monitors are designed to be able to display those colors. The gamut of a given camera is equipment-specific; however, generally HD cameras cannot capture colors that are too far outside this triangle.

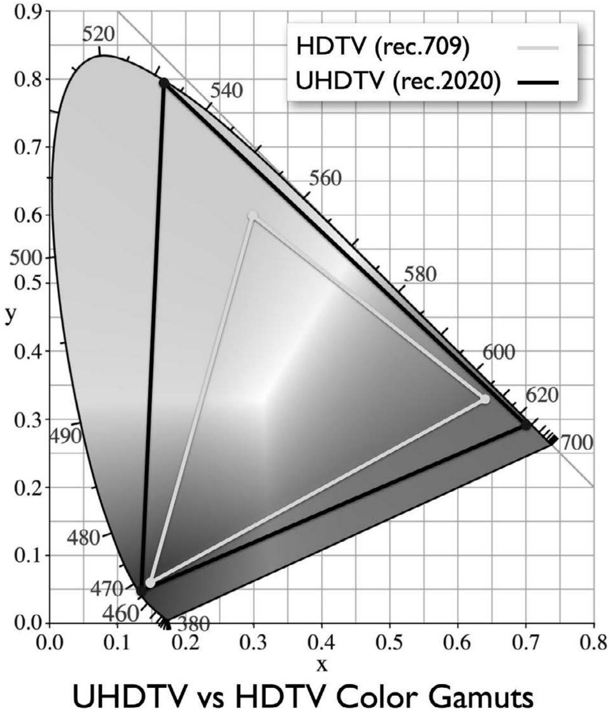


FIGURE 21.5

The Rec. 709 and Rec. 2020 color spaces shown in a CIE chromaticity diagram.

There are other important color spaces. DCI-P3 is the color space for theatrical digital projection. ACES is an all-inclusive color space defined by the Academy of Motion Picture Arts and Sciences. It provides a framework for postproduction workflow that is future proofed by containing the entire color space visible to humans. A high-end camera in RAW mode can capture the lion's share of the visible gamut, while a camera in standard HD captures little more than what is outlined by Rec. 709.

A full-color lighting fixture has a defined gamut as well. To use the simplest example, the color gamut of an RGB fixture is defined by the color points of the red, green, and blue LEDs that the manufacturer decides to use. These color points can vary a great deal from one light to another. Three color points outline a triangle. The colors inside that triangle represent the gamut of colors the light can achieve.

If the color of the light is outside the color gamut of the camera, color clipping can occur. Deeply saturated color washes and even fluorescent-colored clothing or set dressing can be out-of-gamut colors. Similar to overexposure, color clipping is the total loss of image detail within an oversaturated color. Color clipping is visible on a good monitor (500–700 nits). The color becomes flat and there is no detail or gradation except perhaps where the light levels taper off a bit. A 1000 nit monitor can show with some certainty areas where problems will become very obvious on a 4000 nit projector or monitor. On the waveform monitor in parade view, the color has a flat top, showing there is no gradation. On the vector scope, clipping shows as blobs at the edges of the scope.

nit. A unit of luminous intensity. It is the light emitted per unit area and is used to specify the brightness of display devices.

When a saturated color is captured in a larger color space, like Rec. 2020 or a RAW format, it will be displayable in that format. However, when an image recorded in Rec. 2020 is down-converted for streaming in Rec. 709 for example, colors that are out of gamut are transposed. There are automated processes to do this, but the results are not always acceptable, and can require expensive and time-consuming postproduction tweaking.

Selecting the color space of a light

Netflix, now the biggest producer of original content in the world, disseminated requirements for colors to be recorded in gamut. Some lighting manufacturers have addressed this challenge by enabling the user to select the color space that the light operates in. In this mode, the light will limit the colors it emits to only colors that are within the chosen gamut. At this writing ARRI, Kino Flo, and LiteGear provide a way to limit the color space of their full-color LED panels.

MATCHING COLORS, ANSI E1.54

Manufacturers use different RGB color points as the basis of their color mixing. This means each light can have a different gamut. Prior to 2015 the industry had no standard for communicating colors, so a system was needed so that a lighting console programmer could ask different lights for a specific color, and the lights would have some common reference by which to generate that color accurately. At the time, a given set of RGB or HSI values input into 20 different lights would render 20 different colors.

Thanks to ESTA's Technical Standards Program, ANSI E1.54 was created. It established a color space, standard color points, and white point. Regardless of the way different lights create their color, by referencing a standard set of color points, the lights can calculate their own unique offsets, so that they will produce the same color as one another. This means a control console can ask for a given gel color, for example, and will get the same color from all the lights.

This is normally what is meant when you see the phrase *calibrated color space*. Calibrated color space is also sometimes called Kodak Pro Photo Color Gamut or ESTA E1.54. ARRI, Kino Flo, and others use calibrated color. However, if a lighting manufacturer does not write the required software offsets into their firmware per the ANSI Standard, then you are back to matching with a color meter or monitor.

LED TECHNOLOGY

In the 1990s, the first efficient blue LEDs were developed, paving the way for RGB and white phosphor LEDs. Subsequent advances in brightness, optics, heat management, and electronic control finally made these tiny light sources viable as small illumination devices. The potential of the technology for a myriad of applications, from automobile lights to lightbulbs for the home, motivated huge investment in research and development of LEDs by major manufacturers. A frenzy of commerce has followed. LED manufacturers have developed turn-key systems for fixture designers and an ever-growing number of companies are designing an eclectic range of LED lighting fixtures for the motion picture/television market, as well as theatrical and architectural applications.

A typical LED fixture comprises four major component parts:

- the LED emitters,
- the fixture's heat sink,
- a power supply (AC to DC) and control unit (containing the driver and dimming control) which may be housed together or separately,
- and any augmenting optics.

The emitter includes the die, a thermal heat sink, lens, and outer package (Figure 21.6). The *die* is the actual LED chip within the emitter. The color of the light is determined by the energy gap of this semiconductor and chemistry of the metals. The thermal heat sink that is part of the emitter pulls the heat away from the chip and conducts it to the mass of the larger fixture (the fixture's heat sink).

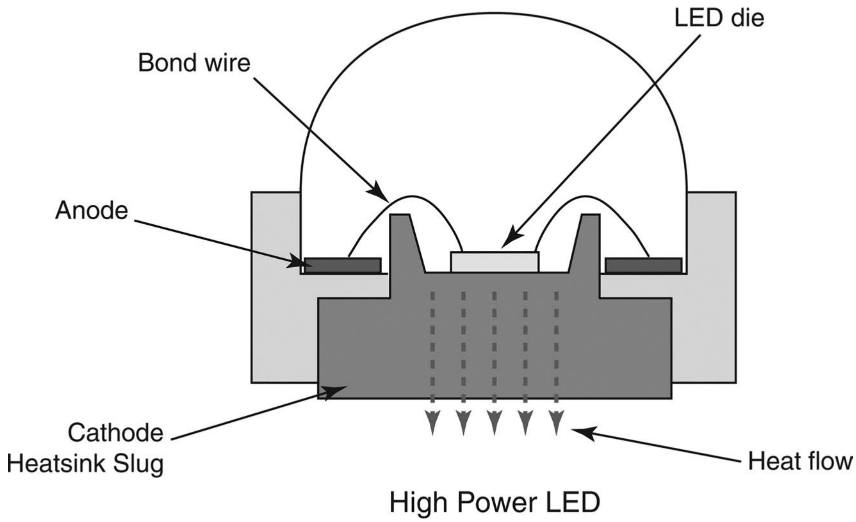


FIGURE 21.6

LED emitter. At its center is a diode chip, the die, capable of converting electricity to light energy very efficiently. Heat is dissipated into the thermal heat sink. A silicon lens covers this chip.

(*Illustration courtesy Mike Wood*)

LED power supply, controller, driver, and dimming

The drive electronics are designed to limit the current to the LED's specifications. In this regard LEDs are very sensitive; too much current can shorten their useful life from 50,000 hours to nothing in an instant. Controlling drive current is critical to the LED's brightness and useful life. An LED is a current-driven device, meaning that the intensity of the light generated depends on the amount of electric current flowing through it. To achieve the greatest intensity, fixture designers try to design their lights with as high a drive current as possible, but there is a three-way relationship between brightness, lamp life, and heat. LEDs are brighter at a higher current, but they lose efficiency if their operating temperature is allowed to rise. The balance a fixture designer can strike will also depend on the limitations posed by the spacing of emitters, and the efficiency of the heat management. If a light has a large heat sink, fins, or fans can be driven harder than on one that doesn't.

The lethal effect of overheating has prompted some manufacturers to provide safeguards against over-temperature situations by automatically increasing the speed of the cooling fan, and at some point, automatically reducing power or shutting off altogether if the light approaches red-line. This should serve to draw the user's attention to the heat issue. It can usually be remedied by providing shade or better ventilation.

There are a couple of different ways manufacturers can arrange dimming. One way is to vary the drive current usually using pulse amplitude modulation (PAM). PAM is a method of current control that employs very high-speed on/off switching to limit the current. By varying the timing of the switching, the current can be lowered to dim the LED. A fixture dimmed using PAM will cut-out abruptly before it reaches full dim.

The other way to dim LEDs is to use pulse width modulation (PWM) downstream of the driver. PWM modulates the intensity by varying the duty cycle at high frequency. This allows smooth dimming to nearly zero. For LED lights marketed for film and television, the frequency of the electronic power supplies, and PWM dimmer is typically greater than 20,000 Hz, and does not pose a risk of flicker at normal frame rates. Nila has actually done tests up to 7000 fps without capturing any flicker. However, LEDs designed for the consumer market or club venues, for example, may use power supplies that cycle at 1 kHz or even lower, and these pose a definite risk of flicker, especially when the LED itself is being photographed at higher than normal frame rates. One way you can test if a light uses a low Hz rate is to wave the light or wave your hand in front of the light. If it seems to strobe as it moves, it is not a high Hz rate. Testing is recommended.

LED useful life

LEDs themselves very rarely just fail or suddenly burn out unless seriously overheated. Electronics fail, especially if they get wet, but normally the LEDs just fade slowly over time, at a fairly consistent rate. Their useful life is defined in terms of *lumen maintenance*—the number of hours the emitter will operate on average before the lumen output decreases below a given percentage of initial light output. For example, the emitter manufacturer will specify that an LED will produce at least 70 percent (denoted L70) of its initial output for 50,000 hours, when driven at a particular current and a particular junction temperature. This is also sometimes stated as L75 or L50 (75 percent and 50 percent respectively). The L value that the manufacturer uses to produce their advertised lamp life figure makes a big difference. As a practical matter, a light that puts out less than 70 percent of its initial output would be considered pretty useless for our purposes.

Depending how the light designer configures the electronics and heat dissipation and exactly which LEDs they choose, the estimated lamp life can vary quite a bit. Manufacturers of lights used in our industry advertise lamp life from 20,000 to 100,000 hours, but 40,000–50,000 is typical. If you ran a 50,000-hour LED 8 hours a day, every day including weekends and holidays, the light would lose 10 percent of the initial output in about 6 years. At that rate, it would take a little over 17 years to reach 70 percent output. Of course, once the LEDs are worn out, you typically have to replace the whole fixture. Another factor that is easily overlooked in all this is that the circuit components employed in the drive electronics have a shorter mean time to failure than the LEDs themselves, and may end up being the weakest link.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

APPENDIX

Photometric calculations and tables

A

Light manufacturers provide photometric data on their websites that normally include beam angle and candle power. Beam angle data allows you to calculate the beam diameter of a light at any distance you choose. Knowing the candle power allows you to calculate foot-candle intensity at any distance.

Some manufacturers provide photometric calculators on their Web sites. ARRI Lighting's Web site features a very nice calculator program.

CONVERTING TO FOOT-CANDLES

Use Table A.1 to figure out about how many foot-candles you need to achieve a desired f-stop. The ISO may be adjusted to account for exposure differences due to filters, frame rates, and intentional over- or underexposure.

CALCULATING FIELD DIAMETER

If you want to know how much area a beam of light covers at a particular distance, see Table A.2.

For ellipsoidal fixtures, manufacturers often list a "multiplier" to use to find field diameter. Table A.2 lists specifications for various commonly used ellipsoidals. Included in this table (and in any manufacturer's catalog) is the multiplier used to calculate field diameter at a given throw. For example, the Source Four 36^{o} fixture has a multiplier of 0.65. If the throw is 20 ft., we can calculate the field diameter:

$$\text{distance} \times \text{multiplier} = \text{field diameter}$$

$$20\text{ ft.} \times 0.65 = 13\text{ ft.}$$

CALCULATING INTENSITY

To get a rough idea of how much light you get from a given fixture at a given distance, you can look up the candle power (cd) of almost any light fixture on the manufacturer's Web site. Plug this number into Table A.3 to find the approximate reading in foot-candles. Then use Table A.1 to find the corresponding f-stop. Note that manufacturers' photometric data are based on optimal performance. Your situation on the set is never optimal. Many everyday factors conspire to reduce the performance of a fixture: the age of a bulb, dirt on the lens and reflector, suboptimal voltage, smoke or dirt in the air, and so forth. Needless to say, your results may vary.

We can calculate the intensity of a light at any distance using the inverse square law. To find the amount of light, divide the source candle power given in candela (cd) by the distance squared:

$$\frac{\text{Source (cd)}}{D^2\ \text{(ft.)}} = \text{fc}, \quad \text{or} \frac{\text{Source (cd)}}{D^2\ \text{(m)}} = \text{lux}$$

Or use Table A.3 to ascertain the light level of any fixture at any distance. For example, a Source Four 36° fixture has a source intensity of 84,929 cd. The intensity at 20 ft. is therefore:

$$\frac{84{,}929}{(20\ \text{ft.})^2} = 212\ \text{fc}$$

You can use this equation to calculate the source intensity (cd) of a given fixture by measuring the fc level at a given distance or to calculate the distance necessary to achieve a particular fc level from a given fixture:

$$\text{cd} = \text{fc} \times D^2, \ \text{where } D = \frac{\text{fixture intensity (cd)}}{\text{light level (fc)}}$$

Table A.1 Foot-candles at various f-stop and ISO settings

ISO	*f*/1.0	*f*/1.4	*f*/2	*f*/2.8	*f*/4	*f*/5.6	*f*/8	*f*/11	*f*/16	*f*/22
10	120	250	500	1000	2000	4000	8000	16,000	32,000	64,000
12	100	200	400	800	1600	3200	6400	12,800	25,000	50,000
16	80	160	320	640	1250	2500	5000	10,000	20,000	40,000
20	64	125	250	500	1000	2000	4000	8000	16,000	32,000
25	50	100	200	400	800	1600	3200	6400	12,800	25,000
32	40	80	160	320	640	1250	2500	5000	10,000	20,000
40	32	64	125	250	500	1000	2000	4000	8000	16,000
50	25	50	100	200	400	800	1600	3200	6400	12,800
64	20	40	80	160	320	640	1250	2500	5000	10,000
80	16	32	64	125	250	500	1000	2000	4000	8000
100	12	25	50	100	200	400	800	1600	3200	6400
125	10	20	40	80	160	320	640	1250	2500	5000
160	8	16	32	64	125	250	500	1000	2000	4000
200	6.4	13	25	50	100	200	400	800	1600	3200
250	5	10	20	40	80	160	320	640	1250	2500
320	4	8	16	32	64	125	250	500	1000	2000
400	3.2	6.4	13	25	50	100	200	400	800	1600
500	2.5	5	10	20	40	80	160	320	640	1280
640	2	4	8	16	32	64	120	240	500	1000
800	1.6	3.2	6.4	12	24	50	100	200	400	800
1000	1.2	2.5	5	10	20	40	80	160	320	640

Notes: *Incident light in foot-candles. Frame rate: 24 fps. Exposure time:* 1/50s *(180° shutter opening)*

Table A.2 Beam diameter (in ft.) at various distances

Beam Angle (°)	Multiplier	Distance (ft.) 5	10	15	20	25	30	40	50	75	100	150	200	250
2	0.03	0.2	0.3	0.5	0.7	0.9	1.0	1.4	1.7	2.6	3.5	5.2	7.0	8.7
4	0.07	0.3	0.7	1.0	1.4	1.7	2.1	2.8	3.5	5.2	7.0	10.5	14.0	17.5
6	0.10	0.5	1.0	1.6	2.1	2.6	3.1	4.2	5.2	7.9	10.5	15.7	21.0	26.2
8	0.14	0.7	1.4	2.1	2.8	3.5	4.2	5.6	7.0	10.5	14.0	21.0	28.0	35.0
10	0.17	0.9	1.7	2.6	3.5	4.4	5.2	7.0	8.7	13.1	17.5	26.2	35.0	43.7
12	0.21	1.1	2.1	3.2	4.2	5.3	6.3	8.4	10.5	15.8	21.0	31.5	42.0	52.6
14	0.25	1.2	2.5	3.7	4.9	6.1	7.4	9.8	12.3	18.4	24.6	36.8	49.1	61.4
16	0.28	1.4	2.8	4.2	5.6	7.0	8.4	11.2	14.1	21.1	28.1	42.2	56.2	70.3
18	0.32	1.6	3.2	4.8	6.3	7.9	9.5	12.7	15.8	23.8	31.7	47.5	63.4	79.2
20	0.35	1.8	3.5	5.3	7.1	8.8	10.6	14.1	17.6	26.4	35.3	52.9	70.5	88.2
22	0.39	1.9	3.9	5.8	7.8	9.7	11.7	15.6	19.4	29.2	38.9	58.3	77.8	97.2
24	0.43	2.1	4.3	6.4	8.5	10.6	12.8	17.0	21.3	31.9	42.5	63.8	85.0	106.3
26	0.46	2.3	4.6	6.9	9.2	11.5	13.9	18.5	23.1	34.6	46.2	69.3	92.3	115.4
28	0.50	2.5	5.0	7.5	10.0	12.5	15.0	19.9	24.9	37.4	49.9	74.8	99.7	124.7
30	0.54	2.7	5.4	8.0	10.7	13.4	16.1	21.4	26.8	40.2	53.6	80.4	107.2	134.0
32	0.57	2.9	5.7	8.6	11.5	14.3	17.2	22.9	28.7	43.0	57.3	86.0	114.7	143.4
34	0.61	3.1	6.1	9.2	12.2	15.3	18.3	24.5	30.6	45.9	61.1	91.7	122.3	152.9
36	0.65	3.2	6.5	9.7	13.0	16.2	19.5	26.0	32.5	48.7	65.0	97.5	130.0	162.5
38	0.69	3.4	6.9	10.3	13.8	17.2	20.7	27.5	34.4	51.6	68.9	103.3	137.7	172.2
40	0.73	3.6	7.3	10.9	14.6	18.2	21.8	29.1	36.4	54.6	72.8	109.2	145.6	182.0
42	0.77	3.8	7.7	11.5	15.4	19.2	23.0	30.7	38.4	57.6	76.8	115.2	153.5	191.9
44	0.81	4.0	8.1	12.1	16.2	20.2	24.2	32.3	40.4	60.6	80.8	121.2	161.6	202.0
46	0.85	4.2	8.5	12.7	17.0	21.2	25.5	34.0	42.4	63.7	84.9	127.3	169.8	212.2
48	0.89	4.5	8.9	13.4	17.8	22.3	26.7	35.6	44.5	66.8	89.0	133.6	178.1	222.6
50	0.93	4.7	9.3	14.0	18.7	23.3	28.0	37.3	46.6	69.9	93.3	139.9	186.5	233.2
52	0.98	4.9	9.8	14.6	19.5	24.4	29.3	39.0	48.8	73.2	97.5	146.3	195.1	243.9
54	1.02	5.1	10.2	15.3	20.4	25.5	30.6	40.8	51.0	76.4	101.9	152.9	203.8	254.8
56	1.06	5.3	10.6	16.0	21.3	26.6	31.9	42.5	53.2	79.8	106.3	159.5	212.7	265.9
58	1.11	5.5	11.1	16.6	22.2	27.7	33.3	44.3	55.4	83.1	110.9	166.3	221.7	277.2
60	1.15	5.8	11.5	17.3	23.1	28.9	34.6	46.2	57.7	86.6	115.5	173.2	230.9	288.7
62	1.20	6.0	12.0	18.0	24.0	30.0	36.1	48.1	60.1	90.1	120.2	180.3	240.3	300.4
64	1.25	6.2	12.5	18.7	25.0	31.2	37.5	50.0	62.5	93.7	125.0	187.5	249.9	312.4
66	1.30	6.5	13.0	19.5	26.0	32.5	39.0	52.0	64.9	97.4	129.9	194.8	259.8	324.7
68	1.35	6.7	13.5	20.2	27.0	33.7	40.5	54.0	67.5	101.2	134.9	202.4	269.8	337.3
70	1.40	7.0	14.0	21.0	28.0	35.0	42.0	56.0	70.0	105.0	140.0	210.1	280.1	350.1
72	1.45	7.3	14.5	21.8	29.1	36.3	43.6	58.1	72.7	109.0	145.3	218.0	290.6	363.3
74	1.51	7.5	15.1	22.6	30.1	37.7	45.2	60.3	75.4	113.0	150.7	226.1	301.4	376.8
76	1.56	7.8	15.6	23.4	31.3	39.1	46.9	62.5	78.1	117.2	156.3	234.4	312.5	390.6
78	1.62	8.1	16.2	24.3	32.4	40.5	48.6	64.8	81.0	121.5	162.0	242.9	323.9	404.9
80	1.68	8.4	16.8	25.2	33.6	42.0	50.3	67.1	83.9	125.9	167.8	251.7	335.6	419.5
82	1.74	8.7	17.4	26.1	34.8	43.5	52.2	69.5	86.9	130.4	173.9	260.8	347.7	434.6
84	1.80	9.0	18.0	27.0	36.0	45.0	54.0	72.0	90.0	135.1	180.1	270.1	360.2	450.2

Note: *Multiply distance times multiplier to get diameter at any distance.*

Table A.3 Brightness in foot-candles of fixtures at various distance (each shades area represents a range of $^1/_3$ of an f-stop)

						Distance (ft.)									
Fixture	**Modifiers**	**Candella**	**Output**	**f-Stop (250 ASA1/50s) at 20 ft.**	**f-Stop (250 ASA1/50s) at 80 ft.**	**2**	**3**	**5**	**10**	**15**	**20**	**25**	**30**	**40**	**50**
		938		f-0.7		235	104	38	9	4	2	2	1	1	0
		1250				313	139	50	13	6	3	2	1	1	1
200 W Joker-Bug	w/Chimera		1300												
Kino-Flo Diva-Lite 200			1500												
		1600				400	178	64	16	7	4	3	2	1	1
Kino-Flo 2-ft. 4-bank	w/o Louver		1800												
		1875		f-1		469	208	75	19	8	5	3	2	1	1
100 W Pepper	Flood		2300												
Kino-Flo 2-ft. 2-bank	w/o Louver		2100												
100 W Dedo	Flood		2147												
		2500		f-⅓		625	278	100	25	11	6	4	3	2	1
Kino-Flo 4-ft. 2-bank	w/o Louver		2700												
Kino-Flo Diva-Lite 400			3000												
		3200		f-1⅔		800	356	128	32	14	8	5	4	2	1
750 Zip															
400 W Joker-Bug	SW w/ Chimera		3200												
150 W Dedo	Flood, 3400 K		3483												
Kino-Flo 4-ft. 4-bank	w/o Louver		3500												
		3750		f-1.4		938	417	150	38	17	9	6	4	2	2
200 W Pepper	Flood		3900												
		5000		f-1.4 ⅓		1250	556	200	50	22	13	8	6	3	2
1k Soft															
100 W Pepper	Spot		5500												
300 W Pepper	Flood		4600												
Kino-Flo Flathead 80	w/o Louver		6000												
420 W Pepper	Flood		6100												
		6400		f-1.4 ⅔		1600	711	256	64	28	16	10	7	4	3
200 W HMI Fresnel	Flood														
		7500				1875	833	300	75	33	19	12	8	5	3

Continued

Table A.3 Continued

						Distance (ft.)									
						3	**5**	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**60**
		7500		f-2		833	300	75	33	19	12	8	5	3	2
650 W Fresnel	Flood														
Kino-Flo Wall-O-Lite	w/o Louver		7500												
400 W Dedo 436	Flood		7614												
650 W Dedo 650	Flood		8100												
200 W Joker-Bug	SW		9000												
		10,000		f-2 ⅓		1111	400	100	44	25	16	11	6	4	3
2k Soft															
200 W Pepper	Spot		10,500												
650 W Pepper	Flood		11,000												
200 W Joker-Bug	FF		11,700												
400 W Dedo 400D	Flood		11,907												
		12,500		f-2 ⅔		1389	500	125	56	31	20	14	8	5	3
Kino-Flo Blanket Light			13,700												
400 W Joker-Bug	FF		14,400												
		15,000		f-2.8		1667	600	150	67	38	24	17	9	6	4
4k Soft															
1k Baby Fresnel	Flood														
1k Mickey Mole	Flood														
400 W Joker-Bug	SWF		18,800												
		20,000		f-2.8 ⅓		2222	800	200	89	50	32	22	13	8	6
575 W HMI Fresnel	Flood														
		25,000		f-2.8 ⅔			1000	250	111	63	40	28	16	10	7
300 W Pepper	Spot		27,500												
3.3k SoftSun	Flood		27,500												
200 W Joker-Bug	W		30,200												
		30,000		f-4	f-1		1200	300	133	75	48	33	19	12	8
2k Mighty Mole	Flood														
800 W Joker-Bug	FF		38,800												
		40,000		f-4 ⅓			1600	400	178	100	64	44	25	16	11
8k Soft															
420 W Pepper	Spot		44,400												
400 W Joker-Bug	WF		44,400												
2k Blonde or Arrilight	Flood														
1k PAR 64	WF														
		50,000		f-4 ⅔			2000	500	222	125	80	56	31	20	14
2k 8″ Junior Fresnel	Flood														
100 W Dedo	Spot		50,220												
650 W Pepper	Spot		52,800												
3.3k SoftSun	Spot		55,000												
		60,000		f-5.6	f-1.4		2400	600	267	150	96	67	38	24	17

					Distance (ft.)										
						5	10	15	20	25	30	40	50	60	70
		60,000		f-5.6	f-1.4	2400	600	267	150	96	67	38	24	17	12
1200 W HMI Fresnel	Flood														
150 W Dedo	Spot														
	3400 K		62,700												
		80,000		f-5.6 ⅓		3200	800	356	200	128	89	50	32	22	16
5k Baby Senior															
Fresnel	Flood														
200 W Joker-Bug	M		96,800												
		1,00,000		f-5.6 ⅔		4000	1000	444	250	160	111	63	40	28	20
1200 W HMI PAR	SWF														
650 W Dedo 650	Spot		1,15,843												
		1,20,000		f-8	f-2	4800	1200	533	300	192	133	75	48	33	24
10k Baby Tenner	Flood														
400 W Dedo 436	Spot		1,20,366												
1k Mickey Mole	Spot														
400 W Joker-Bug	M		1,52,000												
2500 W HMI Fresnel	Flood														
2500 W HMI Par	SWF														
1k PAR 64	MF														
		1,60,000		f-8 ⅓		6400	1600	711	400	256	178	100	64	44	33
4k HMI Fresnel	Flood														
1200 W HMI PAR	WF														
800 W Joker-Bug	SWF Frosted		1,81,000												
4k HMI SE Par	Fres														
2k Mighty Mole	spot														
		2,00,000		f-8 ⅔		8000	2000	889	500	320	222	125	80	56	41
2500 W HMI SE Par	WF														
400 W Dedo 400D	Spot		2,01,852												
		2,40,000		f-11	f-2.8	9600	2400	1067	600	384	267	150	96	67	49
4k HMI SE Par	SWF														
800 W Joker-Bug	MF		3,15,000												
		3,20,000		f-11 ⅓		12,800	3,200	1422	800	512	356	200	128	89	65
6k HMI Fresnel	Flood														
	Frosted														
6k SE HMI Par	Fres														
1k PAR 64	NSP														
6k Par LTM	FF		3,80,000												
		4,00,000		f-11 ⅔		16,000	4,000	1778	1000	640	444	250	160	111	82
20k Fresnel	Flood														
		4,80,000		f-16	f-4	19,200	4,800	2133	1200	768	533	300	192	133	98

Continued

Table A.3 Continued

						Distance (ft)									
						10	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**80**	**100**
		4,80,000		f-16	f-4	4800	2133	1200	768	533	300	192	133	75	48
12k HMI Fresnel	Flood														
200 W Joker-Bug	S		5,91,800												
4k HMI SE Par	WF														
1k PAR 64	VNSP														
		6,40,000		f-16 ⅓		6400	2844	1600	1024	711	400	256	178	100	64
18k HMI Fresnel	Flood														
12k Par LTM	FF		6,60,000												
6k Par LTM	SWF		7,30,000												
		8,00,000		f-16 ⅔		8000	3556	2000	1280	889	500	320	222	125	80
1200 W HMI Par	MF														
2500 W HMI SE Par	MF														
		9,60,000		f-22	f-5.6	9600	4267	2400	1536	1067	600	384	267	150	96
4k HMI SE Par	MF														
50k SoftSun	Flood		10,50,000												
12k Par LTM	SWF		10,90,000												
6k Par LTM	W		12,60,000												
		12,80,000		f-22 ⅓		12,800	5689	3200	2048	1422	800	512	356	200	128
1200 W HMI PAR	NSP														
400 W Joker-Bug	NSP		15,44,000												
		16,00,000		f-22 ⅔		16,000	7111	4000	2560	1778	1000	640	444	250	160
12k Par LTM	W		17,90,000												
		19,20,000		f-32	f-8	19,200	8533	4800	3072	2133	1200	768	533	300	192
1200 W HMI par	VNSP														
50k SoftSun	Spot		23,75,000												
800 W Joker-Bug	NSP		20,94,000												
6k Par LTM	M		24,80,000												
		25,60,000		f-32 ⅓		25,600	11,378	6400	4096	2844	1600	1024	711	400	256
2500 W HMI SE par	NSP														
		32,00,000		f-32 ⅔		32,000	14,222	8000	5120	3556	2000	1280	889	500	320
12k Par LTM	M		36,00,000												
		38,40,000		f-44	f-11	38,400	17,067	9600	6144	4267	2400	1536	1067	600	384

						Distance (ft)									
						15	**20**	**25**	**30**	**40**	**50**	**60**	**80**	**100**	**150**
		38,40,000		f-44	f-11	17,067	9600	6144	4267	2400	1536	1067	600	384	171
		51,20,000		f-44 ⅓		22,756	12,800	8192	5689	3200	2048	1422	800	512	228
2500 W HMI	VNSP														
SE Par															
		64,00,000		f-44 ⅔		28,444	16,000	10,240	7111	4000	2560	1778	1000	640	284
		76,80,000		f-64	f-16	34,133	19,200	12,288	8533	4800	3072	2133	1200	768	341
12k HMI Fresnel	Spot														
		1,02,40,000		f-64 ⅓		45,511	25,600	16,384	11,378	6400	4096	2844	1600	1024	455
4k HMI SE	VNSP														
PAR															
		1,28,00,000		f-64 ⅔		56,889	32,000	20,480	14,222	8000	5120	3556	2000	1280	569
6k HMI SE	S		1,71,20,000												
Par LTM															
		1,53,60,000		f-88	f-22	68,267	38,400	24,576	17,067	9600	6144	4267	2400	1536	683
12k Par	S		1,96,80,000												
LTM															
		2,04,80,000		f-88 ⅔		91,022	51,200	32,768	22,756	12,800	8192	5689	3200	2048	910

Direct sun, 11 a.m., clear day, January, in Los Angeles = 8400 FC.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

APPENDIX

Lamp tables

B

Table B.1 Photo Floods, Mushroom Floods, MR-16s: Medium Screw Base Lamps					
Type	**Lamp and Base Type**	**Volts**	**Watts**	**Kelvin Color**	**Life (h)**
Standard and Pear-Shaped (PS) Photofloods					
PH-211	A-21 Medium	120	75	3200	100
PH-212	A-21 Medium	120	150	3050	100
PH-213	A-21 Medium	120	250	3400	3
BBA (No 1)	A-21 Medium	120	250	3400	3
BCA (B-1)	A-21 Medium	120	250	4800	3
ECA	A-23 Medium	120	250	3200	20
BAH	A-21 Medium	120	300	3200	20
EBV (No 2)	PS-25 Medium	120	500	3400	6
EBW (B-2)	PS-25 Medium	120	500	4800	6
ECT	PS25/5 Medium	120	500	3200	60
Mushroom Lamps					
DAN (R-20)	R-20 Meduim	118	200	3400	4
BEP (R-30)	R-30 Medium	118	300	3400	4
EBR (R-30)	R-30 Medium	118	375	3400	4
DXH (PH/RFL-2)	R-40 Medium	118	375	3200	15
BFA (R-34)	R-40 Medium	118	375	3400	4
DXC (PH/RFL-2)	R-40 Medium	118	500	3400	6
EAL	R-40 Medium	120	500	3300	15
FAE	R-40 Medium	118	550	3400	10
MR-16 Lamps Medium Screw Base					
FSA (NSP) or JDR120V75W NSP	MR-16, Medium	120	75	3000	–
FSB (MFL) or JDR120V75W MFL	MR-16, Medium	120	75	3000	–
FSD (WFL) or JDR120V75W WFL	MR-16, Medium	120	75	3000	–
FSC (NSP) or JDR120V100W NSP	MR-16, Medium	120	100	3000	–

Continued

Table B.1 Photo Floods, Mushroom Floods, MR-16s: Medium Screw Base Lamps—cont'd.

Type	Lamp and Base Type	Volts	Watts	Kelvin Color	Life (h)
FSE (MFL) or JDR120V75W MFL	MR-16, Medium	120	100	3000	–
FSF (WFL) or JDR120V75W WFL	MR-16, Medium	120	100	3000	–

The lamp type designation indicates type and size (in eighths of inches). For example, R-40 indicates a reflector lamp with a 5-in. diameter (40/8 ¼ 5). An R-30 lamp is 3–6/8 in. diameter, an MR-16 is 2 in. diameter, and so on.
The mushroom floods listed here are all 3000 K or more. Mushroom floods also come in a wide variety of wattages that have lower color temperature, flood, and spot. R-40s, for example, come in 75, 150, and 300 W. The MR-16s listed are 120 V medium screw base. MR-16 and MR-11 lamps also come in a wide variety of other configurations. The 6 and 12 V versions with a small two-pin base are the most common type.

Table B.2 Fluorescent Lamps

Watts	Lamp	Diameter	Length	Description	Kelvin	Base
KF55 (Daylight) Lamps						
6	T5	5/8″	9″	F6T5/KF55	5500	Mini Bipin
14	T12	1-1/2″	15″	FI4T12/KF55 SFC	5500	Med. Bipin
20	T12	1-1/2″	24″	F20T12/KF55 SFC	5500	Med. Bipin
30	T12	1-1/2″	36″	F30T12/KF55 SFC	5500	Med. Bipin
40	T12	1-1/2″	48″	F40T12/KF5S SFC	5500	Med. Bipin
55	T12	1-1/2″	72″	F72T12/KF55/SL SFC	5500	Single Pin
85	T12	1-1/2″	72″	F72T12/KF55/HO SFC	5500	Med. Bipin
75	T12	1-1/2″	96″	F96T12/KF55/SL SFC	5500	Single Pin
110	T12	1-1/2″	96″	F96T12/KF55/HO SFC	5500	Med. Bipin
KF32 (Tungsten) Lamps						
6	T5	5/8″	9″	F6T5/KF32	3200	Mini Bipin
14	T12	1-1/2″	15″	F14T12/KF32 SFC	3200	Med. Bipin
20	T12	1-1/2″	24″	F20T12/KF32 SFC	3200	Med. Bipin
30	T12	1-1/2″	36″	F30T12/KF32 SFC	3200	Med. Bipin
40	T12	1-1/2″	48″	F40T12/KF32 SFC	3200	Med. Bipin
55	T12	1-1/2″	72″	F72T12/KF32/SL SFC	3200	Single Pin
85	T12	1-1/2″	72″	F72T12/KF32/HO SFC	3200	Med. Bipin
75	T12	1-1/2″	96″	F96T12/KF32/SL SFC	3200	Single Pin
110	T12	1-1/2″	96″	F96T12/KF32/HO SFC	3200	Med. Bipin

Other Fluorescent Lamps			
Make and Name	**Color Temp (K)**	**Color Rendering Index**	**Minus-Green Correction Required**
Movie-Tone	3200	–	–
Movie-Tone	5500	–	–
GE Chroma50	5000	90	$\frac{1}{2}$
GE IF 27	3000	–	–
GTE Sylvania Design 50	5000	91	$\frac{1}{2}$
Warm White (WW)	3000	52	Full
Deluxe Warm White (WWX)	3000	77	Full
Cool White (CW)	4500	62	Full

Colored Fluorescent Lamps	
Lamp	**Description**
Super Blue	420 nm blue spike for blue screen opticals
Green	560 nm green spike for green screen opticals
Black Light	UV A stimulates luminescent materials
Red	Party colors
Pink	Party colors
Yellow	Party colors

Table B.3 Tungsten Lamp Specifications and Substitutions

Bi-Pin Single-Ended Tungsten Halogen Lamps							
Watts	**ANSI Code**	**Color Temp (K)**	**LCL**	**Finish**	**Volts**	**LampLife (h)**	**Amps**
100 and 200 W Fresnels: Peppers, Midget, Tiny Mole, Mini Mole, etc.							
Base: Double-contact bayonet candelabra RX7. Lamps: B-12, G-16$\frac{1}{2}$, T-4 and T-8							
Burn within 30 of vertical, base down							
250	ESS	2950	$1\frac{3}{8}''$	C	120	2000	2.1
200	**FEV**	**3200**	$1\frac{3}{8}''$	**C**	**120**	**50**	**1.7**
200	BDJ	3200	$1\frac{3}{8}''$	C	120	20	1.7
200	CCM	3075	$1\frac{3}{8}''$	C	115-125	25	1.7
150	CGP	3075	$1\frac{3}{8}''$	C	115-120	25	1.3
150	ETF	3000	$1\frac{3}{8}''$	F	120	2000	1.3
150	ESP	2900	$1\frac{3}{8}''$	C	120	1000	1.3
150	ETC	3000	$1\frac{3}{8}''$	C	120	2000	1.3

Continued

Table B.3 Tungsten Lamp Specifications and Substitutions—cont'd.

Bi-Pin Single-Ended Tungsten Halogen Lamps							
Watts	**ANSI Code**	**Color Temp (K)**	**LCL**	**Finish**	**Volts**	**LampLife (h)**	**Amps**
100	**ESR**	**2850**	$1\frac{3}{8}''$	**C**	**120**	**750**	**0.5**
100	100Q/CL/DC	3000	$1\frac{3}{8}''$	C	120	1000	0.8
100	CEB	2975	$1\frac{3}{8}''$	C	115-125	50	0.8
75	CBX	2925	$1\frac{3}{8}''$	C	115-125	50	0.6
50	CAX	2875	$1\frac{3}{8}''$	C	115-125	50	0.4
100 W and 150 W Dedo							
Base: Small 2-pin: 2 PM = G 5.3 Lamp: T-3 ½, T-4. Burn base down to horizontal							
150	**FCS**	**3400**	**1.181″**	**C**	**24**	**100**	**6.25**
100	**FCR**	**3300**	**1.181″**	**C**	**12**	**50**	**8.3**
50	BRL	3300	1.181″	C	12	50	4.2
300 W, 650 W Fresnels: Tweenie II, Betweenie, 300 W Pepper, etc.							
Base: Small 2-pin prefocus: 2 PP = GY 9.5. GZ 9.5. Lamp: T-6. Burn with coil horizontal							
650	**FRK**	**3200**	$1\frac{13}{16}^{2}$	**C**	**120**	**200**	**5.4**
500	FRB	3200	$1\frac{13}{16}''$	C	120	200	4.2
300	**FKW**	**3200**	$1\frac{13}{16}^{2}$	**C**	**120**	**200**	**2.5**
Small 1k Fresnels (special high-seal-temp lamp made for specially designed high-temp heads–Sachtler, Desisti)							
Base: Small 2-pin prefocus GY9.5. Lamp: Philips							
1000	Blue Pinch	3200	$1\frac{13}{16}''$	C	120	250	8.3
Old Style Tweenie, 420 Pepper, Teenie Weenie Open Face							
Base: 2-pin prefocus: 2 PP = GY 9.5. GZ 9.5. T-6 or T-7 lamp. Burn with coil horizontal							
650	**EKD-Q650/3CL2PP**	**3400**	$1\frac{7}{16}''$	**C**	**120**	**25**	**5.4**
600	**DYS/DYV/BHC**	**3200**	$1\frac{7}{16}''$	**C**	**120**	**75**	**50**
420	**EKB-Q420/4CL/2PP**	**3200**	$1\frac{7}{16}''$	**C**	**120**	**75**	**2.5**
250	**DYG-Q250/4CL/2PP**	**3400**	$1\frac{7}{16}''$	**C**	**30**	**15**	**5.3**
100	EYL	3300	$1\frac{7}{16}''$	C	12	50	63

1k Fresnels							
Base: Medium bipost, G22. Lamp: T-6, T-7, T-20, or T-24. Burn within 45 of vertical base-down							
1000	**EGT-Q1000T7/4CL**	**3200**	$2\frac{1}{2}''$	**C**	**120**	**250**	**8.3**
1000	EGT	3200	$2\frac{1}{2}''$	C	120	250	8.3
1000	EBB-1M24/13	3350	$2\frac{1}{2}''$	C	120	12	8.3
750	EGR-Q750T7/4CL	3200	$2\frac{1}{2}''$	C	120	200	6.3
750	EGR	3200	$2\frac{1}{2}''$	C	120	200	6.3
750	DVH-750T24/16	3200	$2\frac{1}{2}''$	C	120	50	6.3
500	EGN	3200	$2\frac{1}{2}''$	C	120	100	4.2
500	DVG-500T20/63	3200	$2\frac{1}{2}''$	C	120	50	4.2
Small 2k Fresnels (special high-seal-temp lamp made for specially designed high-temp heads – Sachtler, Desisti)							
Base: Medium bipost, G22. Lamp: T-8 Philips							
2000	Blue Pinch	3200	$2\frac{1}{2}''$	C	120	500	16.7
2k Fresnels							
Base: Mogul bipost, G38. Lamp: T-7, T-8, T-9 ½, and T-48. Burn within 45° of vertical base down							
2000	**CYX-Q2000T10/4**	**3200**	**5″**	**C**	**120**	**250**	**16.7**
1500	CXZ-Q1500T10/4CL	3200	5″	C	120	300	12.5
1000	CYV-Q1000T7/4CL/BP	3200	5″	C	120	200	5.3
5k Fresnel							
Base: Mogul bipost, G38. Lamp: T-17 and T-20. Burn base-down to horizontal							
5000	**DPY-Q5000T20/4CL**	**3200**	$6\frac{1}{2}''$	**C**	**120**	**500**	**41.6**
5000	DPY	3200	$6\frac{1}{2}''$	C	120	500	41.6
10k and 12kTungsten Fresnel							
Base: Mogul bipost, G38. Lamp: T-24. Burn within 45° of vertical base-down							
10,000	**DTY**	**3200**	**10″**	**C**	**120**	**300**	**83.3**
12,000	**Koto 12k**	**3200**	**10″**	**C**	**120**	**-**	**100**
Base: Mogul bipost, G38. Lamp: T32. Burn within 45° of vertical base-down							
20,000	KP200 208V	3200	13.937″	C	208	300	83.3
20,000	KP200 220V	3200	13.937″	C	220	300	83.3
20,000	**KP200 240V**	**3200**	**13.937″**	**C**	**240**	**300**	**83.3**

Continued

Table B.3 Tungsten Lamp Specifications and Substitutions—cont'd.

Watts	**ANSI Code**	**Color Temp (K)**	**LCL**	**Finish**	**Volts**	**LampLife (h)**	**Amps**
Bi-Pin Single-Ended Tungsten Halogen Lamps							
1k Molipso							
Base: Medium prefocus, P28. Lamp: T-5 or T-6. Burn any position							
1000	**EGJ-Q1000/4CL/P**	**3200**	$3\frac{1}{2}''$	**C**	**120**	**500**	**8.3**
1000	EGM-Q1000/CL/P	3000	$3\frac{1}{2}''$	C	120	2000	8.3
1000	EGJ	3200	$3\frac{1}{2}''$	C	120	400	8.3
750	EGF-Q750/4CL/P	3200	$3\frac{1}{2}''$	C	120	500	8.3
750	EGG-Q750/CL/P	3000	$3\frac{1}{2}''$	C	120	2000	6.3
750	EGF	3200	$3\frac{1}{2}''$	C	120	250	6.3
750	EGG	3000	$3\frac{1}{2}''$	C	120	2000	6.3
2k Molipso							
Base: Mogul bipost, G38. T-8 lamp. Burn any position							
2000	**BWA-Q2000/4CL/**	**3200**	**5″**	**C**	**120**	**750**	**16.7**
2000	BWA	3200	5″	C	120	500	16.7
1k Molette, Ellipsoidal Spotlights							
Base: Medium 2-pin. Lamp: G9.5. T-4 or T-6. Burn any position							
1000	**FFL-Q1000/4CL**	**3200**	$2\frac{3}{8}''$	**C**	**120**	**500**	**8.3**
1000	**FCV-Q1000/4**	**3200**	$2\frac{3}{8}''$	**F**	**120**	**500**	**8.3**
1000	FEL	3200	$2\frac{3}{8}''$	C	120	300	8.3
1000	FCV	3200	$2\frac{3}{8}''$	F	120	300	8.3
750	EHF-Q750/4CL	3200	$2\frac{3}{8}''$	C	122	300	6.3
750	EHF	3200	$2\frac{3}{8}''$	C	120	300	6.3
750	EHG	3000	$2\frac{3}{8}''$	C	120	2000	6.3
500	FHC/EHB	3200	$2\frac{3}{8}''$	C	120	200	4.2
500	EHC/EHB-Q500/5CL	3150	$2\frac{3}{8}''$	C	120	300	4.2
500	**EHD-Q500CL/TP**	**3000**	$2\frac{3}{8}''$	**C**	**120**	**2000**	**4.2**
500	EHD	3000	$2\frac{3}{8}''$	C	120	2000	4.2
2k Molette							
Base: Mogul screw. T-8 lamp. Burn any position							
2000	BWF-Q2000/4CL	3200	$5\frac{1}{4}''$	C	120	750	16.7

2000	BWF	3200	$5\frac{1}{4}''$	C	120	400	16.7
2000	**BWG**	**3200**	$5\frac{1}{4}''$	**F**	**120**	**400**	**16.7**
Double-Ended Tungsten Lamps							
Watts	**ANSI Code**	**Color Temp (K)**	**MOL**	**Finish**	**Volts**	**LampLife (h)**	**Amps**
400 and 650 W Soft Lights and Open-Face Lights							
Base: Recessed single-contact R7S. $3\frac{1}{8}''$ double-ended T-4 lamp. Burn any position							
650	**FAD**	**3200**	$3\frac{1}{8}''$	**C**	**120**	**100**	**5.4**
650	FBX	3200	$3\frac{1}{8}''$	F	120	100	5.4
650	DWY	3400	$3\frac{1}{8}''$	C	120	25	5.4
420	FFM	3200	$3\frac{1}{8}''$	C	120	75	3.5
400	**FDA (400T4Q/4CL)**	**3200**	$3\frac{1}{8}^{2}$	**C**	**120**	**250**	**3.3**
400	EHR (400T4Q/CL)	2900	$3\frac{1}{8}''$	C	120	2000	3.3
300	EHP (300T4Q/CL)	2900	$3\frac{1}{8}''$	C	120	2000	2.5
1k Open-Face, Mickey, 1k Arrilite							
Base: Recessed single-contact R7s. Lamp $3\frac{3}{4}''$ double-ended T-3. Burn any position							
1000	**DXW**	**3200**	$3\frac{3}{4}''$	**C**	**120**	**150**	**8.3**
1000	FBY	3200	$3\frac{3}{4}''$	F	120	150	8.3
1000	BRH	3350	$3\frac{3}{4}''$	C	120	75	8.3
1000	DXN	3400	$3\frac{3}{4}''$	C	120	75	5
600	FCB	3250	$3\frac{3}{4}''$	C	120	75	5
500	FGD	3200	$3\frac{3}{4}''$	C	120	100	4.2
Watts	**ANSI Code**	**Color Temp (K)**	**LCL**	**Finish**	**Volts**	**LampLife (h)**	**Amps**
1k Nook, 1k, 2k, 4k, and 8k Soft Lights							
Base: Recessed single-contact R7Ss. Lamp: $4\frac{11}{16}''$ double-ended T-3. Burn horizontal							
1000	**FCM-Q1000T3/4CL**	**3200**	$4\frac{11}{16}''$	**C**	**120**	**500**	**8.3**
1000	FCM-Q1000T3/4	3200	$4\frac{11}{16}''$	F	120	500	8.3
1000	FCM	3200	$4\frac{11}{16}''$	C	120	300	8.3
1000	**FHM**	**3200**	$4\frac{11}{16}''$	**F**	**120**	**300**	**8.3**
750	EJG-Q750T3/4CL	3200	$4\frac{11}{16}''$	C	120	400	8.3
750	EMD-Q750T3/4	3200	$4\frac{11}{16}''$	F	120	400	6.3
750	**EJG**	**3200**	$4\frac{11}{16}''$	**C**	**120**	**400**	**6.3**

Continued

Table B.3 Tungsten Lamp Specifications and Substitutions—cont'd.

Watts	ANSI Code	Color Temp (K)	LCL	Finish	Volts	LampLife (h)	Amps
Bi-Pin Single-Ended Tungsten Halogen Lamps							
500	FDF-Q500T3/ 4CL	3200	$4\frac{11}{16}''$	C	120	400	4.2
500	FDN-Q500T3/4	3200	$4\frac{11}{16}''$	F	120	400	4.2
500	EDF	3200	$4\frac{11}{16}''$	C	120	400	4.2
500	EDN	3200	$4\frac{11}{16}''$	F	120	400	4.2
500	Q500T3/CL	3000	$4\frac{11}{16}''$	C	120	2000	4.2
500	Q500T3	3000	$4\frac{11}{16}''$	F	120	2000	4.2
500	FCL	3000	$4\frac{11}{16}''$	C	120	2600	4.2
500	FCZ	3000	$4\frac{11}{16}''$	F	120	2600	4.2
300	EHM-Q300T2 1/2/CL	2980	$4\frac{11}{16}''$	C	120	2000	2.5
300	EHZ-Q300T2 1/2	2950	$4\frac{11}{16}''$	F	120	2000	2.5
2k Nook							
Base: Recessed single-contact R7s. Lamp: $5\frac{5}{8}''$ double-ended T-6 or T-8. Burn any position							
2000	**FEY-Q2000T8/4CL**	**3200**	$5\frac{5}{8}''$	**C**	**120**	**500**	**16.7**
2000	FEY (2MT8Q/4CL)	3200	$5\frac{5}{8}''$	C	120	400	16.7
1000	FER/EHS-Q1000T4/6CL	3200	$5\frac{5}{8}''$	C	120	500	8.3
1000	FER-(1000T6Q/4CL)	3200	$5\frac{5}{8}''$	C	120	500	8.3
1000	DWT-Q1000T6/ CL	3000	$5\frac{5}{8}''$	C	120	2550	8.3
1000	DWT-(1000T6Q/CL)	3000	$5\frac{5}{8}''$	C	120	2000	8.3
Cyc Strips							
Base: Recessed single-contact R7s. Lamp: $6\frac{9}{16}''$ double-ended T-3 or T-4. Burn horizontal ±4°							
1500	**FDB-Q1500T4/ 4CL**	**3200**	$6\frac{9}{16}''$	**C**	**120**	**400**	**12.5**
1500	FGT-Q1500T4/4	3200	$6\frac{9}{16}''$	F	120	400	12.5

1000	**FFT-Q1000T3/ 1CL**	**3200**	$6\frac{9}{16}''$	**C**	**120**	**400**	**8.3**
1000	FGV-Q1000T3/1	3200	$6\frac{9}{16}''$	C	120	400	8.3

LCL, light center length, the distance from the center of the lamp's filament to the bottom of its base. If the wrong LCL is used, the filament will not be centered on the reflector and fixture performance will be greatly reduced.
MOL, maximum overall length, the distance from the top of the lamp to the tip of the pins on the base or from end to end for double-ended lamps. For double-ended lamps, MOL is necessary to match lamp to fixture size.
Interchangeability, lamps within each grouping in this table are interchangeable—they have the same base (type and dimensions) and the same LCL (or MOL, in the case of double-ended lamps).
The most commonly used lamps for motion picture work are highlighted in bold print.
C, clear finish; F, frosted finish.

Table B.4 PAR 64 Lamps, 120 V, EMEP Base (Extended Mogul End Prong)

		1000 W			
Beam	**500 W 2800 K (2000 h)**	**3000 K (4000 h)**	**3200 K (800 h)**	**5200 K (200 h)**	**1200 W 3200 K**
Very narrow spot	–	–	FFN (VNSP)	–	GFC
			Q1000PAR64/1)		(VNSP
Narrow spot	500PAR64NSP	1000PAR64QNSP	FFP (NSP)	FGM (NSP)	GFB (NSP)
			Q1000PAR64/2	Q1000PAR64/3D	
Medium flood	500PAR64MFL	1000PAR64QMFL	FFR (MFL)	FGN (MFL)	GFA (MFL)
			Q1000PAR64/5	Q1000PAR64/7D	
Wide flood	500PAR64MFL	1000PAR64QMFL	FFR (MFL)	–	GFE (WFL)
			Q1000PAR64/6		
Extra-wide flood	–	–	GFF (XWFL)	–	GFD (XWFL)

Table B.5 PAR 64 Lamp Performance Data for PAR 64 and Aircraft Landing Lights

ANSI Code	Volts	Watts	Base	Color Temp	Avg. Life (h)	Beam	Beam Angle (degrees)	Candle Power
FFN	120	1000	EMEP	3200	800	VNSP	12 × 6	400,000
FFP	120	1000	EMEP	3200	800	NSP	14 × 7	330,000
FFR	120	1000	EMEP	3200	800	MFL	28 × 12	125,000
FFS	120	1000	EMEP	3200	800	WFL	48 × 24	40,000
GFF	120	1000	EMEP	3200	800	XWFL	–	–
GFC	120	1200	EMEP	3200	400	VNSP	10 × 8	540,000
GFB	120	1200	EMEP	3200	400	NSP	10 × 8	450,000
GFA	120	1200	EMEP	3200	400	MFL	24 × 13	160,000
GFE	120	1200	EMEP	3200	400	WFL	58 × 25	45,000
GFD	120	1200	EMEP	3200	400	XWFL	–	–
ACL (Aircraft Landing Light) Lamps in PAR 64 Size								
4559	28	600	Screw Terminal	–	25	VNSP	12 × 11	600,000
Q4559	28	600	Screw Terminal	–	100	VNSP	12 × 8	600,000
Q4559X	28	600	Screw Terminal	–	100	VNSP	11 × 7½	600,000

Table B.6 PAR 36 Lamps, 650 W, 120 V, Ferrule Base

Beam	Lamps, 650 W,	3400 K (30 h)	3400 K (30 h)
Spot	–	FBJ	–
		Q650PAR36/3–	
Medium	FAY	DXK	FCX Q650PAR36/7
	Q650PAR36/3D	Q650PAR36/2	
Wide	–	–	FCW Q650PAR36/6

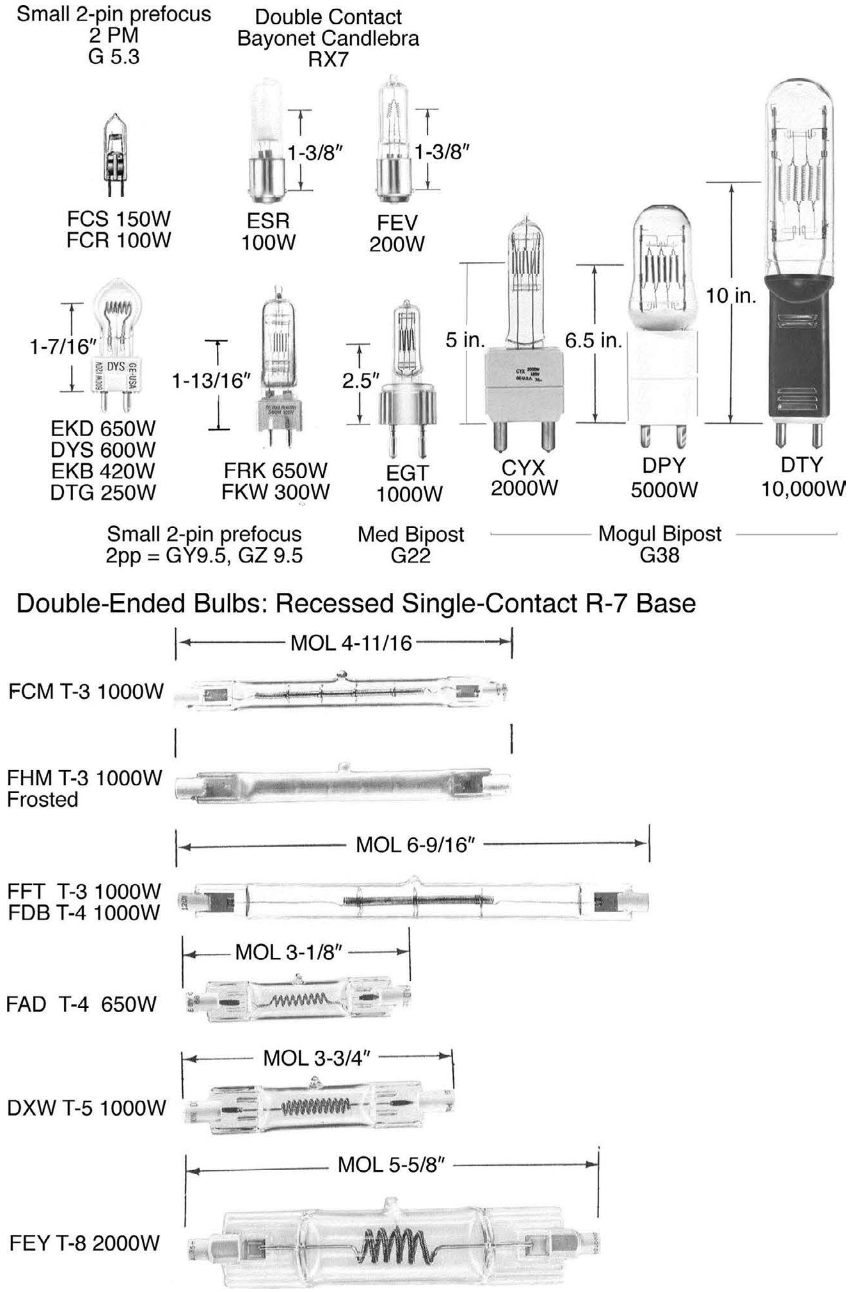


FIGURE B.1

Tungsten halogen lamps.

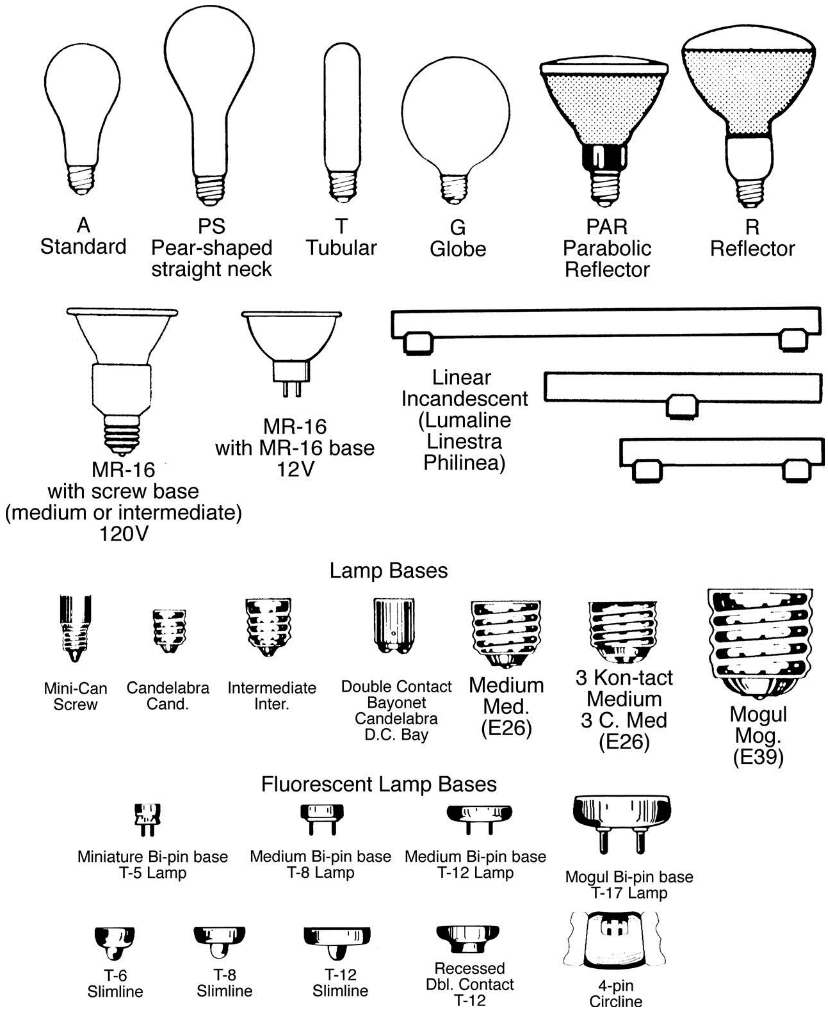


FIGURE B.2

Various types of practical lamps and lamp bases.

APPENDIX

C

Flicker-free frame rates

Table C.1 HMI flicker-free frame rates at any shutter angle: **60 Hz power**

Frames/s	Optimal Shutter Angle
120.000	180
60.000	180
40.000	120
30.000	180
24.000	144
20.000	180
17.143	
15.000	
13.333	
12.000	180
10.909	
10.000	
9.231	
8.000	198
7.058	
6.000	
5.000	
4.000	
3.000	
2.000	
1.000	

Table C.2 Additional flicker-free frame rates at specific shutter angles: **60 Hz power**

Frames/s	Shutter Angle
57.6	172.8
50	144
48	144
45	135
36	108
35	105
32	92 or 96
28	168
26	156
25	150
22	198 or 132
18	162
16	192 or 144

Table C.3 Flicker-free frame rates at any shutter angle: **50 Hz power**

Frames/s	Optimal Shutter Angle
100.000	180
50.000	180
33.333	
25.000	180
20.000	144
16.666	
14.285	
12.500	
11.111	
10.000	
9.090	
8.333	
7.692	
7.142	
6.666	
5.000	
4.000	
3.125	
2.500	
2.000	
1.000	

Table C.4 Additional flicker-free frame rates at specific shutter angles: **50 Hz power**

Frames/s	Shutter Angle
48	172.8
40	144
36	129.6
32	115.2
30	108
28	108.8
26	187.2or93.6
24	172.8
22	158.4
18	194.4or129.6
16	172.8or115.2
12	172.8or129.6
8	172.8or144

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

APPENDIX

Electrical tables

D

Table D.1 Ampacity of Cables: Type W and Entertainment Industry Stage Cable (EISC) Types SC, SCE, and SCT[a] (NEC Table 400–5(B))

	No. of Current-Carrying Wires in Cable		
Size of Cable	**1**	**2[b]**	**3[c]**
Cable Rated at 90 and 105 °C			
4/0	405	361	316
3/0	350	313	274
2/0	300	271	237
1/0	260	234	205
2 AWG	190	174	152
4 AWG	140	130	114
6 AWG	105	99	87
8 AWG	80	74	65
Cable Rated at 75 oC			
4/0	360	317	277
3/0	310	275	241
2/0	265	238	208
1/0	230	207	181
2 AWG	170	152	133
4 AWG	125	115	101
6 AWG	95	88	77
8 AWG	70	65	57
Cable Rated at 60 oC			
4/0	300	265	232
3/0	260	230	201
2/0	225	199	174
1/0	195	173	151
2 AWG	140	128	112
4 AWG	105	96	84

Continued

Table D.1 Ampacity of Cables: Type W and Entertainment Industry Stage Cable (EISC) Types SC, SCE, and SCT[a] (NEC Table 400–5(B))—cont'd.

	No. of Current-Carrying Wires in Cable		
Size of Cable	**1**	**2[b]**	**3[c]**
6 AWG	80	72	63
8 AWG	60	*55*	48

Source: *Reprinted with permission from NFPA 70–1993, The National Electrical Code®, Copyright © 1992, National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association on the referenced subject, which is represented only by the standard in its entirety.*
[a] *These amperage capacities are based on an ambient temperature of 30 °C (86 °F). They are allowable only where the individual conductors are not installed in raceways and are not in physical contact with one another, except in lengths not to exceed 24 in. where passing through the wall of an enclosure.*
[b] *See footnote* b *in Table D.2.*
[c] *See footnote* c *in Table D.2.*

Table D.2 Amperage Capacities for Flexible Cords, Stingers, and Zip Cord[a] (NEC Table 400–5(A))

	No. of Current-Carrying Wires		
AWG Size	**2[b]**	**3[c]**	**Asbestos[d]**
18	10	7	6
16	13	10	8
14	18	15	17
12	25	20	23
10	30	25	28
8	40	35	–
6	55	45	–
4	70	60	–
2	95	80	–

Source: *Reprinted with permission from NFPA 70–1993. The National Electrical Code®, Copyright © 1992, National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association on the referenced subject, which is represented only by the standard in its entirety.*
a *These amperage capacities apply to the following types of cord: thermoset types C, E, EO, PD, S SJ, SJO, SJOO, SO, SOO, SP-1, SP-2, SP-3, SRD, SV, SVO, and SVOO and thermoplastic types ET, ETT, ETLB, SE, SEO, SJE, SJEO, SJT, SJTO, SJTOO, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT3, ST, STO, STOO, SRDE, SRDT, SVE, SVEO, SVT, SVTO, and SVTOO.*
b *The amperage capacities in this column apply to multiconductor cable in which two of the wires are current-carrying (such as a hot wire and a neutral wire, or two hot wires of a 240 V single-phase circuit). The neutral wire of a balanced 240/120 V single-phase circuit is not considered a current-carrying wire for the purpose of this table, with one exception: if the major portion of the load consists of electronic ballasts, electronic dimmers, or similar equipment, there are harmonic currents present in the neutral conductor and it shall be considered to be a current-carrying conductor. The green grounding wire is never considered to be a current-carrying wire.*
c *The amperage capacities in this column apply to multiconductor cable in which three of the wires are current-carrying wires (such as a three-wire three-phase-circuit, a balanced four-wire three-phase circuit, or a single-phase three-wire circuit derived from the neutral and two-phased legs of a wye-connected three-phase system). The neutral wire of a balanced four- wire three-phase circuit is considered a current-carrying wire only when there are harmonic currents present. A cord or cable with four or more current-carrying wires must be derated in accordance with NEC Section 400–5. Cords and cables in which four to six of the conductors are carrying current must be derated to 80% of the ampacities given in this table.*
d *This column gives the amperage capacities of asbestos cords (types AFC, AFPD, and AFPO), which are often used inside fixtures.*

Table D.3 Minimum Size of Grounding Wires (NEC Table 250–95)		
Rating of Overcurrent	**Gauge of Grounding Conductor Aluminum and Copper-Clad**	
Protection of Circuit (A)	**Copper Wire No.**	**Aluminum Wire No.**
15	14 AWG	12 AWG
20	12 AWG	10 AWG
30	10 AWG	8 AWG
40	10 AWG	8 AWG
60	10 AWG	8 AWG
100	8 AWG	6 AWG
200	6 AWG	4 AWG
300	4 AWG	2 AWG
400	3 AWG	1 AWG
500	2 AWG	1/0
600	1 AWG	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250 kcmil
1600	4/0	350 kcmil

Source: *Reprinted with permission from NFPA 70–1993, The National Electrical Code®, Copyright © 1992, National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association on the referenced subject, which is represented in its entirety only by the standard.*

Table D.4 Resistance, Weight, and Cross-Sectional Area of Copper Wire					
Size	**Approx OD inches**	**Cross-Sectional Area (cmil)**	**Lb. per M/100 ft.**	**Ohms per M/100 ft.**	**ft./Ohm**
4/0	0.528	21,1600	65.3	0.00509	19,646
2/0	0.418	133,100	41.1	0.00811	12,330
2 AWG	0.292	66,360	20.5	0.0162	6173
4 AWG	0.232	41,740	12.9	0.0259	3861
6 AWG	0.184	26,240	8.0	0.0410	2439
8 AWG	0.1285	16,510	5.1	0.0640	1529
10 AWG	0.1019	10,380	3.1	0.1018	981.9
12 AWG	0.0808	6530	20.0	0.1619	617.0
14 AWG	0.0641	4110	1.2	0.2575	389.0
16 AWG	0.0508	2580	.8	0.4094	244.0
18 AWG	0.0403	1620	.5	0.6510	154.0

Note*: Weights listed are of the copper itself, not the total weight of an insulated cable. Resistance at 25 °C.*

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

APPENDIX

IP and NEMA equipment ratings

E

INTERNATIONAL PROTECTION RATINGS

Lights and equipment that may be exposed to the elements, such as dew, rain, splashing water, mist, and so on, require an enclosure that prevents water from getting inside. This is known as ingress protection. The International Electrotechnical Commission (IEC), the body responsible for international electrical standards, created an International Protection (IP) rating standard in 1989. The IP rating sig- nifies the degree to which a light enclosure can protect against ingress of water and particulates. The IP rating can usually be found next to the UL listing stamp on the fixture. It begins with the letters “IP,” followed by two numbers. The first is a number from 0 to 6, which refers to the ingress size in milli- meters (as shown below). This is the rating of protection against foreign objects such as fingers, leaves, feathers, and dust. The second is a number from 0 to 8, which refers to the ingress of water:

First number—Objects

0	not protected
1	≥50 mm diameter
2	≥12.5 mm diameter
3	≥2.5 mm diameter
4	≥1.0 mm diameter
5	dust protection
6	dust tight

Second number—Water

0	not protected
1	protection against vertically dripping water
2	protection against dripping water at up to 60° angle from the vertical
3	protection against water spray at up to 60° angle from the vertical
4	protection against splashing water from all directions
5	protection against low-pressure jetting water from all directions
6	protection against a powerful jet of water from all directions
7	protection against temporary immersion in water less than 1 m deep
8	protection against continuous immersion in water at a specified depth

Optional letters may follow the IP numbers:

A	Protection against contact with back of hand
B	Protection against contact with finger
C	Protection against contact with a tool such as a screwdriver
D	Protection against contact with wire
H	Protection against high-voltage apparatus
M	Enclosure was in motion during water testing
S	Enclosure was stationary during water testing
W	Protection against weather

NEMA RATINGS

The *National Electrical Manufacturers Association (NEMA Enclosures Section)* specifies equipment enclosure types, which may be followed by modifying letters: Type 1, Type 2, Type 3, Type 3R, Type 3S, Type 3X, Type 3SX, Type 4, and Type 4X.

In nonhazardous locations, the specific enclosure types, their applications, and the environmental conditions they are designed to protect against, *when completely and properly installed*, are as follows:

Type 1	Enclosures constructed for *indoor use* to provide a degree of protection to personnel against access to *hazardous parts*. Provides a degree of protection of the equipment inside the enclosure against *ingress of solid foreign objects (falling dirt)*
Type 2	All the conditions of Type 1, plus provides a degree of protection with respect to harmful effects due to the *ingress of water (dripping and light splashing)*
Type 3	All the conditions of Type 2, plus enclosures constructed for indoor or *outdoor use*, and provides a degree of protection from *ingress of windblown dust*, and is undamaged by the external *formation of ice* on the enclosure
Type 4	All the conditions of Type 3, plus a degree of protection with respect to harmful effects on the equipment due to the ingress of water (*rain, sleet, snow, splashing water, and hose-directed water*)

Modifying letters

R	Does not provide protection from ingress of windblown dust
S	*External mechanism(s) remain operable when ice-laden*
X	Additional level of protection against corrosion

Equipment suppliers and manufacturers

F

AAdynTech. LED light heads and waterproof LED light heads. Aadyntech.com

AC Power Distribution, Burbank, CA. Distribution boxes. http://actlighting.com/acpower

Airstar. Lenix helium balloon lights. http://www.airstar-light.us

Aladdin. Flexible light-weight LED. https://aladdin-lights.com

Altman Stage Lighting Company, Yonkers, NY. Tungsten and HMI fixtures, ellipsoidal and theatrical fixtures. LED fixtures. http://www.altmanltg.com

American Grip Inc., Sun Valley, CA. Studio and grip equipment. http://www.americangrip.com

Amphenol Socapex. Interconnect systems. http://www.amphenol-socapex.com

Anton Bauer. Brick and block batteries. Vitecgroup.com

Apollo Design Technology, Inc. Gels and lighting accessories. http://www.apollodesign.net

ARRI, Burbank, CA. Tungsten, HMI, Fluorescent, LED lights, remote yoke for large HMIs, stands and grip equipment. http://www.arri.com

Astera. Titan tubes, AX pars. Portable, battery-powered, wireless LED and pixel tubes. https://astera-led.com

Automated Entertainment, Burbank, CA. Range of dichroic filters, blacklights, fully stocked theatrical rental house. http://www.automatedhd.com

Avenger Grip. See Bogen Imaging.

Backstage Studio Equipment, North Hollywood, CA. Studio equipment. http://www.backstageweb.com

Bardwell McAlister Inc. (B&M), Sun Valley, CA. Lights, HLP spacelights, Mac Tech HPL Maxi and HPL Space Light, Fresnel and soft lights. http://bmlighting.com/site/

Barger Light, Venice, CA. Soft light bags and heads. http://www.barger-baglite.com

Baxter Controls, Inc., Driftwood, TX. Pocket console (DMX512). http://dmx2go.com

Bebob. Brick and block batteries, charger and accessories. https://bebob.de

Bender, Coatesville, PA. GFCI distribution equipment. http://www.bender.org

Benjamin Electric Co., Los Angeles, CA. Distribution boxes, deuce boards, studio distribution equipment. http://www.benjaminelectric.com

Blackout. Lighting control app. Blackout-app.com

Blender Lights. LED lens lights. http://blenderlights.com/tech.html

Block Battery. Block batteries, brick batteries, inverters. https://blockbattery.com
Blueshape USA. Brick batteries, power stations, and accessories. Blueshapeusa.com
Bogen Imaging. Lighting stands, clamps, and grip hardware. Now called Manfrotto Distribution. http://www.bogenimaging.us/Jahia/home_page
Bron. Specialty tapes and adhesives. Brontapes.com
Carol Cable Co., Inc., Pawtucket, RI. Cable. http://www.generalcable.com/GeneralCable/
Chimera Photographic Lighting, Boulder, CO. Soft boxes. http://www.chimeralighting.com
Chroma-Q. LED space lights, cyc lights. https://chroma-q.com
Cinemills Corp., Burbank, CA. Tungsten and HMI lights, gel. http://www.cinemills.com
Cineo Lighting. LED lights and remote phosphor LED. Cineolighting.com
City Theatrical. Unique aftermarket lighting accessories, especially for theatrical and touring fixtures, SHoW DMX wireless DMX systems, mounting clamps, LED power supplies, etc. http://www.citytheatrical.com
Clay Paky. Moving lights. www.claypaky.it/en/home/
CORE SWX. Brick batteries, chargers, accessories. https://www.coreswx.com
Creamsource. LED heads. Creamsource.com
Dadco LLC, Sun Valley, CA. Portable Power Distribution Systems, tungsten and HMI lights. http://www.dadcopowerandlights.com
Desisti. Tungsten and HMI lights. http://www.desistilighting.com
Digital Sputnik. LED light heads and tubes. https://digitalsputnik.com
DMG Lumière by Rosco. See Rosco.
Dop Choice. Light banks and soft light control, adaptors. Dopchoice.com
Doug Fleenor Enterprises, Arroyo Grande, CA. DMX testers, opto-splitters, isolators, converters. http://www.dfd.com
Elation Professional. Theatrical, venue lighting, including moving lights and LED lights. http://www.elationlighting.com
Electronic Theatre Controls (ETC), Middleton, WI. Control consoles, dimmer systems, ellipsoidal and PAR fixtures, LED systems. http://www.etcconnect.com
Element Labs. Versa tubes and other LED pixel-mapping applications, Kelvin Tile. LED set pieces. http://www.elementlabs.com
Entertainment Technology (Philips). Reverse phase control (GFCI) dimmer systems. http://www.etdimming.com
ESP Vision. Lighting previsualization software. http://www.espvision.com
ExCel Wire and Cable Co. Cable.
Fiilex. LED, LED Fresnel. https://www.fiilex.com
Filmtools, Burbank, CA. Retailer of all manner of production supplies and lighting gear. http://www.filmtools.com
Firefly. Lighted cable protectors. http://www.fireflycableprotector.com/Distributors.html
Fisher Lights, North Hollywood, CA. Large softboxes for car photography, soft light crane light. Rep for other lights. http://www.fisherlight.com
Flanders Scientific. Monitors. Flandersscientific.com
Fluke Electronics, Everett, WA. Electrical meters and test equipment. http://us.fluke.com
General Electric, Cleveland, OH. Tungsten and HMI bulbs. http://gelighting.com
GenErgy. Cable assemblies. Genergypowerusa.com

Genie Industries USA, Redmond, WA. Man lift. http://www.genielift.com
Giddings Pace, Inc., Sun Valley, CA. Underwater HMI lights. http://www.pacetech.com
Goddard Design Co. RDM and DMX512 testing equipment. http://www.goddarddesign.com
GAM (Great American Market). Stickup lights, flicker boxes, GAM gels, color changers. http://www.gamonline.com/
Grip Trix. Camera cars and portable battery systems. Griptrix.com
Group 5 Bates Connectors (Marinco Electrical Group). Bates connectors. High-power flashlights. http://www.marinco.com
High End Systems, Austin, TX. Control consoles, automated lights. http://www.highend.com
Hive Lighting, Inc. LED and plasma light heads. Hivelighting.com
Honda Generators. http://www.hondapowerequipment.com
HydroFlex, Inc., Los Angeles, CA. Underwater lights. Splash housings for lights and cameras. http://www.hydroflex.com
IDX System Technology, Inc. Brick batteries. Idxtek.com
ILC Technology Inc., Sunnyvale, CA. HMI bulbs. http://www.photonics.com
Illumination Dynamics. Lighting equipment rental, generators. http://www.illuminationdynamics.com
Jem Studio Lighting Inc., Van Nuys, CA. China lantern kits. http://jemlighting.com
K 5600, North Hollywood, CA. HMI Joker fixtures and 200 W Bug light and 200 W inverter. http://www.k5600.com
Kino Flo, Inc., Burbank, CA. LED softlights, fluorescent systems for motion picture production. http://www.kinoflo.com
Komet. LED fixture. http://kometled.com
Koto, Di-Lite Taito-ku, Tokyo, Japan. HMI bulbs.
Lanternlock. Paper lantern holders. http://www.lanternlock.com
LEDStorm. LED light fixtures. http://ledstorm.com/ledstorm/
LED-Z LLC. LED brute lights. http://www.led-z.com
Lee Filters USA, Burbank, CA. Lee filters and gels. http://www.leefilters.com
Leelium Balloons Ltd., London UB5 5QQ England. Helium balloons. http://www.leeliumballoons.com
LEX. Distribution equipment, dimmers. http://www.lexProducts.com
Liberty Pak. Lithium-ion battery packs. http://www.libertypak.com
Light Control Concepts. Control grids for Litepanels lights. http://www.lightcontrolconcepts.com
Lightning Strikes!/Luminys, Hollywood, CA. Lightning effects lights. http://www.luminyscorp.com
LiteGear. LED LightRibbon, LiteMat, LiteTile, and power supplies. http://www.litegear.com
Litepanels. LED light fixtures. http://www.litepanels.com
Lowel-Light Manufacturing, Inc., Hauppauge, NY. Tungsten fixtures. http://www.lowel.com
LRX. Large automated remote HMI lights. http://www.dwightcrane.com
LTM Corp. of America, Sun Valley, CA. Tungsten and HMI fixtures. http://www.ltmlighting.com
Luma Panels. See T8 Technologies.
LumenRadio. Wireless systems. https://lumenradio.com
Luminys Lightning Strikes! SoftSun. http://www.luminyscorp.com/
Magic Gadgets/William A. McIntire Enterprises, Portland, OR. Dimmers, flicker effects boxes, dimmers various gadgets. http://www.magicgadgets.com
Manfrotto Distribution. See Bogen Imaging.

Martin Professional, Moving Lights, LED cycs, and set pieces. http://www.martin.com
Matthews Studio Equipment, Inc., Burbank, CA. Studio equipment. http://www.msegrip.com
Minolta (Konic Minolta). Light meters. http://kmbs.konicaminolta.com
Mole-Richardson Co., Hollywood, CA. Tungsten and HMI fixtures, studio equipment, distribution equipment, carbon arc lights. http://www.mole.com
Movie-Tone Lighting. Color corrected fluorescent lamps. http://www.movie-tone.com/
Multiquip. Studio generators and portable generators. Multiquip.com
Musco Mobile Lighting, Ltd., Oskaloosa, IA. Mobile lighting trucks. http://www.musco.com
Nila Lights. New York. LED light system. http://www.nila.tv
Norms, North Hollywood, CA. Studio grip equipment. http://normsgrip.com/
Osram Corp. Tungsten and HMI lamps.
Peterson Systems International, Duarte, CA. Cable crossovers. http://www.petersonsystems.com
Philips Color Kinetics. LED light fixtures. http://www.colorkinetics.com
Philips Lighting Co., Somerset, NJ. Bulbs. http://www.lighting.philips.com
Philips Lumileds. LED emitters. http://www.philipslumileds.com
Phoebus Manufacturing, San Francisco, CA. Xenon follow spots and searchlights, electronic shutters, xenon projectors, and other specialty items. http://www.phoebus.com
Portable Electric. VoltStack 120 V and 208 V battery power packs. https://www.portable-electric.com
Power Gems Corporation. Electronic HMI ballasts, DMX-controlled HMI ballasts. http://www.cleararc.com
Power To Light. Electronic HMI ballasts. http://www.powertolight.com
PRG. Moving lights, control consoles, event design. http://www.prg.com
Quasar Science. LED tubes, practicals. Quasarscience.com
RatPac. Cintenna wireless transmitters and receivers, dimmers, silent dimmers, power/distribution boxes, Unity Ethernet node. https://www.ratpacdimmers.com
Rosco Laboratories, Inc. Gels. DMG Lumière distributor in the US. http://www.rosco.com
Royal Electric, Inc., Philadelphia, PA. Cable. http://www.royalelectric.com
Sachtler. Tungsten, HMI, fluorescent fixtures, LED lens light fixtures. http://www.sachtler.com
Saunders Electric. Generators and transformers. http://www.saunderselectric.com
Sekonic. Light measurement meters. http://www.sekonic.com
Shock Block (Littelfuse). K-tec circuit/safety protection for wet locations, ground fault relays. http://www.littelfuse.com/ktec/
Shotmaker. Custom tow vehicles. http://www.shotmaker.com
Show DMX. Wireless DMX system. http://www.citytheatrical.com/ShowDMX1.htm
Skylight Balloon Lighting. Lighting balloons. http://skylightballoon.com
Snorkelift. Telescoping boom platforms. http://www.snorkellift.com/AerialWorkPlatforms.aspx
SpectraCine, Inc., Burbank, CA. Light meters. http://www.spectracine.com
Strand Lighting, Inc., Philips Strand Lighting. Tungsten and HMI fixtures, ellipsoidal and theatrical fixtures, dimmer packs. http://www.strandlighting.com/
Strong International, Inc., Omaha, NE. Xenon, HMI, and tungsten follow spots. Xenon lights. http://www.strong-cinema.com
Swisson. DMX testing device. http://www.swisson.com
Sylvania. Tungsten and HMI bulbs. http://www.sylvania.com

T8 Technologies. Lumapanels large fluorescent Sofbanks. http://www.lumapanel.com
Teatronics. Dimmers. http://www.teatronics.com
The Light Source. Clamps, claws, and couplers. http://www.thelightsource.com
TMB. Distributor. Control Data, dimming, connectors, testers, etc. tmb.com
The Rag Place. Fabrics, frames and rigging, gaffer's control, snapgrid. http://trpworldwide.com
Union Connector, Roosevelt, NY. Distribution boxes, electrical connectors. http://www.unionconnector.com/
Ushio America, Inc. Tungsten bulbs, HPL lamps. http://www.ushio.com
Vari*lite, Philips/Vari-Lite. Moving lights and moving light control consoles. http://www.vari-lite.com
VEAM (a division of Litton Systems, Inc.), Watertown, CT. Electrical connectors.
Vectorworks Spotlight. Professional CAD Lighting Plot drafting software. http://www.nemetschek.net/spotlight
W-DMX. Wireless DMX systems. http://www.wirelessdmx.com
Westcott. Flexible LED and softboxes. https://www.fjwestcott.com
Wildfire Inc., Los Angeles, CA. Ultraviolet light technology. Black light Fresnel and theatrical fixtures, paints, and accessories. http://www.wildfirefx.com
Wolfram, Scotts Valley, CA. HMI lamps. http://www.wolframlights.com/
Xenotech, Inc. Strong Xenon lights. http://www.strong-cinema.com
Yellow Jacket. Cable protectors. http://www.yjams.com
Zylight. Small LED, camera-mounted lights and flexible LED. https://www.zylight.com

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

APPENDIX

Gels and diffusions

G

Table G.1 Kelvin Scale/MIRED Scale Conversion Table

Kelvin	0	100	200	300	400	500	600	700	800	900
2000	500	476	455	435	417	400	385	370	357	345
3000	333	323	313	303	294	286	278	270	263	256
4000	250	244	238	233	227	222	217	213	208	204
5000	200	196	192	189	185	182	179	175	172	169
6000	167	164	161	159	156	154	152	149	147	145
7000	143	141	139	137	135	133	132	130	128	127
8000	125	123	122	120	119	118	116	115	114	112
9000	111	110	109	108	106	105	104	103	102	101

Example: *To find the MIRED value for a 6500 K source, look across from 6000, and down from 500. The MIRED value is 154.*

Table G.2 Kelvin Conversion: Lee Color-Correction Conversion

	CTO (Orange)				**CTB (Blue)**			
Light Source Color (K)	***Lee 223 Eighth***	***Lee 206 Quarter***	***Lee 205 Half***	***Lee 204 Full***	***Lee 218 Eighth***	***Lee 203 Quarter***	***Lee 205 Half***	***Lee 201 Full***
2000	1901	1773	1642	1517	2075	2151	2370	2755
2300	1786	1672	1555	1443	1938	2004	2193	2519
2600	2433	2227	2024	1838	2725	2857	3257	4032
2900	2695	2445	2203	1984	3058	3226	3745	4808
3200	2959	2660	2375	2123	3401	3610	4274	5714
3500	3205	2857	2532	2247	3731	3984	4808	6711
3800	3460	3058	2688	2370	4082	4386	5405	7937
4400	3953	3436	2976	2591	4785	5208	6711	11,111
5000	4425	3788	3236	2786	5495	6061	8197	15,873

Continued

Table G.2 Kelvin Conversion: Lee Color-Correction Conversion—cont'd.

	CTO (Orange)				**CTB (Blue)**			
Light Source Color (K)	***Lee 223 Eighth***	***Lee 206 Quarter***	***Lee 205 Half***	***Lee 204 Full***	***Lee 218 Eighth***	***Lee 203 Quarter***	***Lee 205 Half***	***Lee 201 Full***
5600	4878	4115	3472	2959	6211	6944	9901	23,810
6200	5348	4444	3704	3125	6993	7937	12,048	41,667
6800	5780	4739	3906	3268	7752	8929	14,493	1,00,000
7400	6211	5025	4098	3401	8547	10,000	17,544	
8000	6623	5291	4274	3521	9346	11,111	21,277	
9000	7299	5714	4545	3704	10,753	13,158	30,303	

Table G.3 Kelvin Conversion: Rosco Color-Correction Conversion

	CTO (Orange)						CTB (Blue)						
Light Source Color (K)	***R-3410 Eighth***	***R-3409 Quarter***	***R-3408 Half***	***R-3411 ¾***	***R-3401 Sun 85***	***R-3407 Full***	***R-3216 Eighth***	***R-3208 Quarter***	***R-3206 Third***	***R-3204 Half***	***R-3203 ¾***	***R-3202 Full***	***R-3220 2 × CTB***
2000	1923	1845	1721	1585	1585	1499	2049	2128	2217	2315	2500	2710	4115
2300	2203	2101	1942	1770	1770	1664	2370	2475	2597	2732	2994	3300	5650
2600	2469	2342	2146	1938	1938	1812	2681	2817	2976	3155	3509	3937	7813
2900	2740	2584	2347	2101	2101	1953	3003	3175	3378	3610	4082	4673	11,364
3200	3012	2825	2545	2257	2257	2088	3333	3546	3802	4098	4717	5525	18,182
3500	3268	3049	2725	2398	2398	2208	3650	3906	4219	4587	5376	6452	34,483
3800	3534	3279	2907	2538	2538	2326	3984	4292	4673	5128	6135	7576	1,66,667
4400	4049	3717	3247	2793	2793	2538	4651	5076	5618	6289	7874	10,417	
5000	4545	4132	3559	3021	3021	2725	5319	5882	6623	7576	10,000	14,493	
5600	5025	4525	3846	3226	3226	2890	5988	6711	7692	9009	12,658	20,833	
6200	5525	4926	4132	3425	3425	3049	6711	7634	8929	10,753	16,393	33,333	
6800	5988	5291	4386	3597	3597	3185	7407	8547	10,204	12,658	21,277	62,500	
7400	6452	5650	4630	3759	3759	3311	8130	9524	11,628	14,925	28,571		
8000	6897	5988	4854	3906	3906	3425	8850	10,526	13,158	17,544	40,000		
9000	7634	6536	5208	4132	4132	3597	10,101	12,346	16,129	23,256	90,909		

Table G.4 Kelvin Conversion: GAM Color-Correction Conversion

Light Source Color (K)	CTO (Orange)						CTB (Blue)					
	1555 Eighth	***1552 Quarter***	***1549 Half***	***1546 ¾ CTO***	***1543 Full***	***1540 Extra CTO***	***1535 Eighth***	***1532 Quarter***	***1529 Half***	***1526 ¾ Blue***	***1523 Full***	***1520 Extra CTB***
2000	1916	1852	1721	1585	1520	1294	2037	2110	2315	2577	2703	2817
2300	2193	2110	1942	1770	1689	1414	2353	2451	2732	3106	3289	3460
2600	2457	2353	2146	1938	1842	1520	2660	2786	3155	3663	3922	4167
2900	2725	2597	2347	2101	1988	1618	2976	3135	3610	4292	4651	5000
3200	2994	2841	2545	2257	2128	1709	3300	3497	4098	5000	5495	5988
3500	3247	3067	2725	2398	2252	1789	3610	3846	4587	5747	6410	7092
3800	3509	3300	2907	2538	2375	1866	3937	4219	5128	6623	7519	8475
4400	4016	3745	3247	2793	2597	2000	4587	4975	6289	8696	10,309	12,195
5000	4505	4167	3559	3021	2793	2114	5236	5747	7576	11,364	14,286	18,182
5600	4975	4566	3846	3226	2967	2212	5882	6536	9009	14,925	20,408	29,412
6200	5464	4975	4132	3425	3135	2304	6579	7407	10,753	20,408	32,258	62,500
6800	5917	5348	4386	3597	3279	2381	7246	8264	12,658	28,571	58,824	5,00,000
7400	6369	5714	4630	3759	3413	2451	7937	9174	14,925	43,478	2,00,000	
8000	6803	6061	4854	3906	3534	2513	8621	10,101	17,544	76,923		
9000	7519	6623	5208	4132	3717	2604	9804	11,765	23,256			

Table G.5 Daylight Color Correction (CTO Gels)

Name	Rosco Cinegel	MIRED Shift	Lee	MIRED Shift	GAM	MIRED Shift	K Shift	Light Reduction (Stops)
Extra CTO	–	–	–	–	1540	+273	20,000–3200	1
							5500–2200	
Full CTO	3407	+167	204[a]	+159	1543	+163	6500–3200	
Full Straw	3441		441				5500–2900	⅔
Sun 85	3401	+131	–	–	–	–	5500–3200	⅔
85 Acrylic	3761							
¾ CTO	3411	+130	285	–	1546	130	5500–3200	⅔
½ CTO	3408	+81	205[a]	+109	1549	+81	5500–3800	⅓
½ Straw	3442		441					
½ CTO Acrylic	3751							
¼ CTO	3409	+42	206[a]	+64	1552	+40	5500–4500	⅓
¼ Straw	3443		441					
⅛ CTO	3410	+20	223[a]	+26	1555	+22	5500–4900	¼
⅛ Straw	3444		441					

[a] *Also available in 60-in. rolls.*

Table G.6 Neutral Density and ND/Daylight Correction Gels

Gel	Rosco Cinegel	MIRED Shift	Lee	MIRED Shift	GAM	K Shift	Reduction (Stops)
0.15 ND	3415	0	298	0	1514	0	½
0.3 ND	3402	0	209[a]	0	1515	0	1
Acrylic							
	3762						
0.6 ND	3403	0	210[a]	0	1516	0	2
Acrylic							
	3763						
0.9 ND	3404	0	211[a]	0	1517	0	3
Acrylic							
	3764						
1.2 ND	–	–	299	0	1518	0	4
CTO 0.3 ND	3405	+131	207	+159	1556	5500–3200	1
CTO 0.6 ND	3406	+131	208	+159	1557	5500–3200	2
CTO 0.9 ND	–	–	–	–	1558	5500–3200	3

Cinemills Corporation makes gels that share the same product numbers as Lee.
[a]*Also available in 60-in. rolls.*

Table G.7 Tungsten Color Correction (CTB Gels)

Name	Rosco Cinegel	MIRED Shift	Lee	MIRED Shift	GAM	Kelvin Shift (K)	Light Reduction (Stops)
Double Blue	3220	–257	200	–	–	2800–10,000	4
Extra CTB	–	–150	–	–	1520	3200–6200	1 ¾
Full CTB	3202	–131	201	–137	1523	3200–5700	1⅓
¾ CTB	3203	–	281	–	1526		1¼
½ CTB	3204	–68	205	–78	1529	3200–4300	1
⅓ CTB	3206	–49	–	–	–	3200–3800	⅔
¼ CTB	3208	–30	203	–35	1532	3200–3600	⅔
⅛ CTB	3216	–12	218	–18	1535	3200–3400	⅓

Cinemills Corporation makes gels that share the same product numbers as Lee.

Table G.8 Blue/Orange Correction: Colormeter LB Index (MIREDs)

Colormeter LB Reading (MIREDs)	Kodak Wratten Filter		Light Loss Due to Filter	Approximate Equivalent Gel	Kelvin Shift	
	Amber	Blue			From	To
–257	–	–	4	Double CTB	3200	10,000
–133	–	80A	2	Full CTB	3200	5500
–112	–	80B	1⅔	–	3400	5500
–100	–	80C + 82A	–	¾ CTB	3200	4700
–90	–	82C + 82C	1⅓	–	2490	3200
–81	–	80C	1	½ CTB	3800	5500
–77	–	82C + 82B	1⅓	–	2570	3200
–66	–	82C + 82A	1	–	2650	3200
–56	–	80D	⅓	–	4200	5500
–55	–	82C + 82	1	⅓ CTB	2720	3200
–45	–	82C	⅔	–	2800	3200
–32	–	82B	⅔	¼ CTB	2900	3200
–21	–	82A	⅓	⅛ CTB	3000	3200
–10	–	82	⅓	–	3100	3200
+9	81	–	⅓	–	3300	3200
+18	81A	–	⅓	–	3400	3200
+27	81B	–	⅓	⅛ CTO	3500	3200
+35	81C	–	⅓	–	3600	3200
+42	81D	–	⅔	¼ CTO	3700	3200
+52	81EF	–	⅔	–	3850	3200
+81	85C	–	⅓	½ CTO	5500	3800
+112	85	–	⅔	–	5500	3400
+133	85B	–	⅔	¾ CTO or Sun 85	5500	3200
+167	85B + 81C	–	⅔	Full CTO	5600	2900

Table G.9 Green/Magenta Correction: Colormeter CC Index

Colormeter II Color Compensation	Colormeter III		Gel Source with Gel Name	Rosco Cinegel No.	Lee Gel No.	GAM Gel No.	Compensation in f-Stops	Conversion
	CC Filter Magenta	CC Filter Green						
+18	40M	–	–	–			⅔	Removes green
+13	30M	–	Full Minus Green	3308	247	1580	⅔	Removes green
+8	20M	–	–	–			⅓	Removes green
+6	15M	–	Flalf Minus Green	3313	248	1582	⅓	Removes green
+4	10M	–	–	–	–	–	⅓	Removes green
+3	7.5M	–	¼ Minus Green	3314	249	1583	⅓	Removes green
+2	5M	–	–	–	–	–	⅓	Removes green
+1	3.5M	–	⅛ Minus Green	3318	279	1584	¼	Removes green
–1	–	3.5G	⅛ Plus Green	3317	278	–	¼	Adds green
–2	–	7.5G	¼ Plus Green	3316	246	–	⅓	Adds green
–4	–	10G	–	–	–	–	⅓	Adds green
–5	–	15G	½ Plus Green	3315	245	1587	⅓	Adds green
–7	–	20G	–	–	–	–	⅓	Adds green
–10	–	30G	Full Plus Green	3304	244	1585	⅔	Adds green
–13	–	40G	–	–	–	–	⅔	Adds green
–	30M	–	Fluoro-Filter	3310	–	1590	1⅔	Converts cool whites to 3200 K
–	–	30G	Plus-green 50	3306	–	–	1¼	Converts 3200 K source to match cool whites
–	–	30G	Fluorescent 5700	–	241	–	1⅔	Converts 3200 K source to 5700 K (cool white fluorescents)
–	–	30G	Fluorescent 4300	–	242	–	1½	Converts 3200 K source to 4300 K (white fluorescents)
–	–	30G	Fluorescent 3600	–	243	–	1¼	Converts 3200 K source to 3600 K (warm white fluorescents)

Minolta Colormeter II and earlier read out + or color compensation index number (first column). Newer models read out in CC filter numbers (second and third columns)

Table G.10 Diffusion Materials

Types of Diffusion	Product No.	Light Reduction	Notes
Lee			
Full Tough Spun	214	2½	Slight softening of field and beam edge
Half Tough Spun	215	1½	Slight softening of field and beam edge
Quarter Tough Spun	229	¾	Slight softening of field and beam edge
Full Tough Spun	261	2	Flame retardant. Slight softening of field and beam edge
¾ Tough Spun	262	1⅔	Flame-retardant
½ Tough Spun	263	1⅓	Flame-retardant
⅛ Tough Spun	264	1	Flame-retardant
¼ Tough Spun	265	¾	Flame-retardant
216 White Diffusion	216	1½	Very popular moderate/heavy diffusion. Available in 60″ width
½ 216	250	¾	Moderate beam spread and softening
¼ 216	251	⅓	Moderate beam spread and softening
⅛ 216	252	⅛	Moderate beam spread and softening
Blue Diffusion	217	1½	Increases color temperature very slightly
Daylight Blue Frost	224	2¼	CTB frost
Neutral Density Frost	225	2	ND 0.6 frost
Brushed Silk	228	¾	Diffuses light in one direction only
Hampshire Frost	253	¼	Very light frost
New Hampshire Frost	254	–	High-temperature polycarbonate base
Hollywood Frost	255	–	–
Half Hampshire	256	–	–
Quarter Hampshire	257	–	–
Heavy Frost	129	1⅓	Flame-retardant
White Frost	220	1⅓	Flame-retardant
Blue Frost	221	1⅓	Flame-retardant. Increases color temperature very slightly
Grid Cloth	430	–	Heavy white fabric in 52-in. width
Light Grid Cloth	432	–	Lighter white fabric in 52-in. width
Rosco			
Tough Spun	3006	2½	Slight softening of field and beam edge
Light Tough Spun	3007	½	Slight softening of field and beam edge

Continued

Table G.10 Diffusion Materials

Types of Diffusion	Product No.	Light Reduction	Notes
¼ Tough Spun	3022	1	Slight softening of field and beam edge
Tough Frost	3008	2	Slight to moderate softening, moderate beam
			Spread but with discernible beam center
Light Tough Frost	3009	1½	Slight to moderate softening, moderate beam spread but with discernible beam center
Opal Tough Frost	3010	1	Popular light diffusion with slight to moderate softening, moderate beam spread but with discernible beam center
Light Opal	3020	½	Slight to moderate softening, moderate beam spread but with discernible beam center
Tough White Diffusion	3026	3½	Like Lee 216. Dense diffusion with wide beam spread creating even field of shadowless light
½ White Diffusion	3027	2½	Like Lee 250. Moderately dense diffusion with wide beam spread
¼ White Diffusion	3028	1½	Like Lee 251. Moderate diffusion with wide beam spread
Tough Rolux	3000	2½	Moderately dense diffusion with wide beam spread
Light Tough Rolux	3001	–	Moderate diffusion with wide beam spread
Grid Cloth	3030	5	Comes in 54-in. rolls. Very dense diffusion with very wide beam spread, which creates soft shadowless light. Ideal for large area diffusion. Not tolerant of high heat
Light Grid Cloth	3032	3½	Smaller weave than grid cloth. Considerable softening. Comes in 54-in. rolls
¼ Grid Cloth	3034	2½	Considerable softening. Comes in 54-in. rolls
Silent Frost	3029	3	Diffusion made of a rubbery plastic that does not crinkle and rattle in the wind
Hilite	3014	1	Quiet like silent frost. Comes in 54-in. rolls
Soft Frost	3002	2	Quite like silent frost, denser than Hilite
Wide Soft Fros	3023	2	In 72-in. width
½ Soft Frost	3004	½	Quiet, light diffuser
Tough Silk	3011	1½	Considerable softening in one direction only
Light Tough Silk	3015	1	Considerable softening in one direction only
Tough Booster Silk	3012	–	Raises color temperature from 3200 to 3500 K with silk softening characteristics
Tough Booster Frost	3013	–	Raises color temperature from 3200 to 3800 K with frost softening characteristics
Full Blue Frost	3017	–	Raises color temperature from 3200 K to daylight with frost softening characteristics

Table G.10 Diffusion Materials

Types of Diffusion	Product No.	Light Reduction	Notes
GAM–The Great American Market			
Medium GAM Frost	10	–	Soft light, warm center, diffuse edge
Light GAM Frost	15	–	Soft light, warm center, diffuse edge
Full GAM Spun	32	2½	Textural, warm center, defined edge
Medium GAM Spun	35	1⅔	Textural, warm center, defined edge
Light GAM Spun	38	1	Textural, warm center, defined edge
Gamvel	45	3	Soft light with diffuse shadow line
216 GAM White	55	–	Shadowless, white light. Heavy diffusion with no center or edge visible
Medium GAM Silk	65	–	Spreads light predominantly in one direction
Light GAM Silk	68	–	Spreads light predominantly in one direction
Gam Fusion	10–10	¼	Almost clear with no color shift
Gam Fusion	10–20	¼	Very light diffusion with no color shift
Gam Fusion	10–30	½	Light diffusion with no color shift
Gam Fusion	10–40	½	Medium-light diffusion with no color shift
Gam Fusion	10–50	1	Medium diffusion with no color shift
Gam Fusion	10–60	2	Medium-heavy diffusion with no color shift
Gam Fusion	10–70	5	Heavy diffusion with no color shift
Gam Fusion	10–75	5	Heavy diffusion with no color shift
Gam Fusion	10–80	6	Very heavy diffusion with no color shift
Gam Fusion	10–90	6	Fully diffuse with no color shift

Light reduction values given here are manufacturers' approximate figures. The actual transmission will depend on the beam angle of the light and the distance from the diffusion.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

APPENDIX

H

LED lights

This appendix is a sample of some LEDs, available at this writing, that are finding use in motion pictures and television. One cannot hope to maintain a list like this that is completely accurate or comprehensive. New products are constantly coming to market, others are retired, new versions of lights with improved features are constantly being developed, and firmware is constantly being updated. Please check with manufacturers for the most recent information.

Table H.1 Single-color phosphor-based LEDs (panels, punchy, Fresnels)

	Aperture Dimension (in.)	Max Watts	CCT	Battery (V DC)	Control	Notes
Panels						
Litepanels, Astra 6X	12 × 12	105	D	13–24	1, 5	
Litepanels, Astra 3X	12 × 12	55	D	13–24	1, 5	
Litepanels, Lykos	10 × 6	23	D or B	9	5	
Nila, Arina	18 × 18	800	D or T		1	RJ 45
Nila, Boxer	10 × 10	200	D or T	20–30	1	RJ 45 connector
Outsight Cream-source, Mini+	12.5 × 13.4	150	D or B	23–32	1, 8	
Outsight Cream-source, Doppio+	26.5 × 13.5	350	D or B	24–32	1, 8	
Punchy						
AAdynTech JAB Cinema	12.9	212	D, T, B	48	1	

Continued

Table H.1 Continued Single-color phosphor-based LEDs (panels, punchy, Fresnels)

	Aperture Dimension (in.)	Max Watts	CCT	Battery (V DC)	Control	Notes
AAdynTech JAB Hurricane	12.9	212	D	48	1, 8	IP 65
AAdynTech Punch	18.5	584	D		1, 7	
Luminys SunBlast	2.4 × 4.8	600	D	√		Highspeed
Luminys SunBlast	4.2 × 5.3	1200	D	√		Highspeed
Nila, Varsa	6	75	D	10–18	1, 7	RJ 45 connector, IP65
Nila, Zaila	5	45	D or B	10–18	1, 7	RJ 45 connector
Fresnels						
Litepanels Sola 12C	12	346	D		1	RJ 45 connector
Litepanels Sola 9C	9	190	D		1	RJ 45 connector
Litepanels Sola 6C	6	104	D	14–28	1	RJ 45 connector
Litepanels Sola 4C	4	53	D	14–28	1	RJ 45 connector
Litepanels Inca 12	12	346	T		1	RJ 45 connector
Litepanels Inca 9	9	190	T		1	RJ 45 connector
Litepanes Inca 6	6	104	T	14–28	1	RJ 45 connector
Litepanels Inca 4	4	39	T	14–28	1	RJ 45 connector
Mole Pro 100 W Fresnel		100	D	24	1	
24″ 20k LED	24	3000	D or T		1	
Mole 1600 W Tener	14	1600	D or T	60	1	
Mole 900 W Senior	10	900	D or T		1	
Mole 400 W Junior	10	400	D or T		1	
Mole 200 W Junior	8	200	D or T		1	
Mole 150 W Baby	6	150	D or T		1	
Mole 100 W Tweenie	4.5	100	D or T		1	
Zylight F8–100	8	100	D, T or Black	14.4	3, 6	IP54
Zylight F8–200	8	200	D, T or Black	14.9	3, 6	IP54

Notes: 1 Wired DMX 5-pin XLR, 2 LumenRadio, 3 LumenRadio option, 4 Wi-Fi to smartphone, 5 Bluetooth, 6 Wired DMX option, 7 RDM. B Bi-color, 8 wired remote.

D daylight, T tungsten, B bi-color, Black black light.

Table H.2 Remote phosphor panels

	Aperture Dimension (in.)	Max Watts	CCT	Battery (V DC)	Control
ARRI, SkyPanel S30-RP	14 × 11.8	190	A	28.8, 48	1, 7
ARRI, SkyPanel S60-RP	24.5 × 11.8	410	A	28.8, 48	1, 7
Cineo, Maverick	9.4 × 7.3	135	B	10.5–28	1, 7
Cineo, HS2 Wave	21 × 12	500	B		1, 7, 8

Notes: CCT A: 2700 K, 3200 K, 4300 K, 5600 K, 6500 K, 10,000 K, Chroma Green

CCT B: 2700 K, 3200 K, 4300 K, 5600 K, 6500 K, Chroma Blue and Green

Control: 1 Wired DMX 5-pin XLR, 2 LumenRadio, 3 LumenRadio option, 4 Wi-Fi to smartphone, 5 Bluetooth, 6 Wired DMX option, 7 RDM. B bi-color, 8 wired remote.

Table H.3 Bi-color and tunable white panels (rigid)

	Aperture Dimension (in.)	Max Watts	CCT Range (K/100)	Battery (V DC)	Control	Notes
AAdynTech JAB Duo	18.3 × 12.6	650	28–60	—	1, 2	IP 65
AAdynTech JAB Quad Variable	24.3 × 18.7	1,300	28–60	—	1, 3, 7	IP 65
Aladdin Base Lite 100	16.9 × 11.8	100	29–63	12–30	1	
Aladdin Base Lite 200	19.7 × 15.75	200	29–63	12–30	1	
Cineo, Mav X	9.5 × 8.5	135	27–65	10.5–28	1, 2	Weather resistant
DMG Lumière Mini Switch	23 × 7.8 × 0.75	85	30–56	10–36	1, 2, 4	
DMG Lumière SL1 Switch	45 × 7.8 × 0.75	170	30–56	10–36	1, 2, 4	
DMG Lumière Maxi Switch	48 × 30 × 0.75	520	30–56	10–36	1, 2, 4	
Fiilex Matrix II TW	12.2 × 16.5	340	28–65	48	1	IP 24
Litepanels, Astra 6X Bi-Color	12 × 12	105	31–60	13–24	1, 5	
Litepanels, Astra 3X Bi-Color	12 × 12	55	31–60	13–24	1, 5	
Litepanels, Astra Soft Bi-Color	12 × 12	105	31–60	13–24	1, 5	
Litepanels, Brick	8 × 2.8	19	29–53	12–17 P-tap	—	IP 65
Nila, Zaila	5 × 5	45	26–64	10–18	7	RJ 45 connector
Outsight Creamsource Micro	8.7 × 8.1	80	27–65	10–32	1, 8	IP 65, high fps
Outsight Creamsource, Mini+	12.5 × 13.4	150	27–65	24–32	1, 8	high fps

Continued

Table H.3 Bi-color and tunable white panels (rigid) Continued

	Aperture Dimension (in.)	Max Watts	CCT Range (K/100)	Battery (V DC)	Control	Notes
Outsight Creamsource, Doppio+	26.5 × 13.5	350	27–65	24–32	1, 8	high fps
Zylight, Pro-Panel	24 × 12	100	27–65	20–30	1, 8	
Zylight, Pro-Panel V2 2×2	24 × 24	100	27–65	20–30	1, 8	

Notes: CCT is given in Kelvin/100. For example, 20–60 means 2000 K to 6000 K.

Control: 1 Wired DMX 5-pin XLR, 2 LumenRadio, 3 LumenRadio option, 4 Wi-Fi to smartphone, 5 Bluetooth, 6 Wired DMX option, 7 RDM, 8 wired remote.

Table H.4 Bi-color light weight and fabrics

	Aperture Dimension (in.)	Watts	CCT Range (K/100)	Battery (V DC)	Control	Notes
Aladdin All-In 1 (bi-color)	12 × 24	50	29–63	1224	5, 6	
Aladdin All-In 1 (bi-color)	12 × 24	100	29–63	12–24	5, 6	
Aladdin, Bi-Felx M3	5 × 12	30	29–56	12–30	1	
Aladdin, Bi-Felx M7	12 × 12	70	29–56	12–30	1	
Aladdin, Bi-Felx1	12 × 12	50	30–60	12–15	1	
Aladdin, Bi-Felx2	24 × 12	100	29–60	12–30	1	
Aladdin, Bi-Felx4	42.5 × 12	200	29–60	12–30	1	
Aladdin, Bi-Felx4x4	42.5 × 48	800	29–60	12–30	1	
Aladdin, Fabric-Lite 200	36 × 36	200	29–63	12–30	1, 2	
Aladdin, Fabric-Lite 350	36 × 36	350	29–63	48	1, 2	
LiteGear, LiteMat Plus 1	21 × 11	50	26–62	24	1, 3, 6	
LiteGear, LiteMat Plus 2	21 × 21	100	26–62	24	1, 3, 6	
LiteGear, LiteMat Plus 2L	40 × 11	100	26–62	24	1, 3, 6	
LiteGear, LiteMat Plus 3	30.5 × 21	150	26–62	24	1, 3, 6	
LiteGear, LiteMat Plus 4	40 × 21	200	26–62	24	1, 3, 6	
LiteGear, LiteTile Plus 4	46.5 × 24	200	26–62	24	1, 3, 6	
LiteGear, LiteTile Plus 8	92 × 24	400	26–62		1, 3, 6	

Notes: CCT is given in Kelvin/100. For example, 20–60 means 2000 K to 6000 K.

Control: 1 Wired DMX 5-pin XLR, 2 LumenRadio, 3 LumenRadio option, 4 Wi-Fi to smartphone, 5 Bluetooth, 6 Wired DMX option, 7 DMX/RDM.

Table H.5 Bi-color and tunable white tubes, punch lights, Fresnels

	Aperture Dimension	Max Watts	CCT Range (K/100)	Battery (V DC)	Control	Notes
Tubes						
Quasar Science Q-LED X-Crossfade linear	1′, 2′, 4′, 6′, 8′	15, 25, 50, 75, 100	20–60 B	12	1	
Punch Lights						
AAdynTech JAB Variable	12.9″	212	28–65 B	30	1	
Velvet Power 1	15″ × 12″	100	27–65 B	12–35	1, 7	IP 54
Velvet Power 2	27″ × 12″	190	27–65 B	24–35	1, 7	IP 54
Velvet Power 2×2	27″ × 24.5″	340	27–65 B	24–35	1, 7	IP 54
Fresnels						
ARRI L7-TT	7″	160	26–36 TT		1	IP 20
ARRI L7-DT	7″	160	50–65 DT		1	IP 20
ARRI L10-TT	10.8″	400	26–36 TT		1	IP 20
ARRI L10-DT	10.8″	400	50–65 DT		1	IP 20
Fiilex Q8 Junior	8″	170	28–65 TB	48	1	IP 24
Fiilex Q8 travel	8″	340	28–65 TB	48	1	IP 24
Fiilex Q1000	8″	340	28–65 TB	48	1	IP 24
Fiilex Q500	8″	185	28–65 TB		1	IP 24

Notes: CCT is given in Kelvin/100. For example, 20–60 means 2000 K to 6000 K. B Bi-color, TB Tunable Bi-color, TT Tungsten tunable, DT Daylight tunable.

Control: 1 Wired DMX 5-pin XLR, 2 LumenRadio, 3 LumenRadio option, 4 Wi-Fi to smartphone, 5 Bluetooth, 6 Wired DMX option, 7 DMX/RDM.

Table H.6 Full-color panels

	Aperture Dimension (in.)	Watts	CCT Range (K/100) and emitter colors	Battery (V DC)	Control	Notes
Aladdin All-In 1	12 × 12	70	29–60 +RGB	12–24	1	
Aladdin All-In 2	12 × 24	40	29–60 +RGB	12–24	1	
ARRI, SkyPanel S30-C	14 × 11.8	200	28–100 RGBW	28, 48	1, 8, 9	
ARRI, SkyPanel S60-C	24.5 × 11.8	420	28–100 RGBW	28, 48	1, 8, 9	
ARRI, SkyPanel S120-C	50.8 × 11.8	400	28–100 RGBW	28, 48	1, 8, 9	

Continued

Table H.6 Full-color panels Continued

	Aperture Dimension (in.)	Watts	CCT Range (K/100) and emitter colors	Battery (V DC)	Control	Notes
ARRI, SkyPanel S360-C	50.8 × 34.4	1500	28–100 RGBW	28, 48	1, 2, 8, 9	
Cineo, Standard 410	24 × 12	410	27–65	AC	1, 2, 7	
Cineo, LB800	48 × 24	900	27–65	AC	1 2, 7	
Outsight Creamsource, Sky	37 round	1200	32–150	AC	1, 2	IP 65
Outsight Creamsource, SpaceX	23 round	1200	22–150	AC	1, 2	IP 20
Outsight Creamsource, Micro Colour	8.6 × 8	80	22–150 RGBW	10–32	1, 8	IP 65
Fiilex Matrix	12.2 × 16.5	320	28–100 RGBW	48	1	
Kino Flo, Celeb 250	24 × 14	150	25–100 RGB,WW,CW	24	1, 2	
Kino Flo, Celeb 401	30 × 26	210	25–100 RGB,WW,CW	—	1, 2	
Kino Flo, Celeb 450	45 × 14	255	25–100 RGB,WW,CW	—	1, 2	
Kino Flo, Celeb 450Q	30 × 26	270	25–100 RGB,WW,CW	—	1, 2	
Kino Flo, Celeb 850	45 × 26	575	25–100 RGB,WW,CW	—	1, 2	
Kino Flo, Diva 20	25 × 13	150	25–100 RGB,WW,CW	24	1, 2	
Kino Flo, Diva 30, 31	39 × 10.5	150	25–100 RGB,WW,CW	24	1, 2	
Kino Flo, FreeStyle 21, 31, 41	2′, 3′, 4′	150	25–100 RGB,WW,CW	24	1, 2	
LiteMat Spectrum 1	11.5 × 21 × 0.9	50	20–111	48	1 ,2	
LiteMat Spectrum 2	21 × 21 × 0.9	100	20–111	48	1 ,2	
LiteMat Spectrum 2L	11.5 × 40 × 0.9	100	20–111	48	1 ,2	
LiteMat Spectrum 3	21 × 30.5 × 0.9	150	20–111	48	1 ,2	
LiteMat Spectrum 4	21 × 40 × 0.9	200	20–111	48	1 ,2	
Litepanels, Gemini 2×1	24 × 12	325	27–65 RGBWW	28	1, 3, 5	
Zylight, IS3c	18.5 × 10.75	220	25–100 RGBA	48	1, 2	

Notes: CCT is given in Kelvin/100. For example, 20–60 means 2000 K to 6000 K.

Control: 1 Wired DMX 5-pin XLR, 2 LumenRadio, 3 LumenRadio option, 4 Wi-Fi to smartphone, 5 Bluetooth/App, 6 Wired DMX option, 7 RDM, 8 Wired remote, 9 Ethernet.

Emitter colors: RGB (red, green, blue), WW (warm white), CW (cool white), A (amber), L (lime), S (sapphire), C (cyan), X (not disclosed).

Table H.7 Full-color tubes, pixel tubes, spots, and Fresnels

	Aperture Dimension (in.)	Power draw (Watts)	CCT (K/100) and emitter colors	Pixels	Battery (V DC)	Control	Notes
Tubes							
Astera AX1	40.7	28	RGBW	16	Int	2	IP 65
Astera Titan Tube	40.7	72	17–200 RGBMA	16	Int	1, 2, 9	IP 65
Astera Helios	22.7	36	17–200 RGBMA	8	Int	1, 2, 9	IP 65
Astera Hyperion	66.4	144	17–200 RGBMA	32	Int	1, 2, 9	IP 65
Digital Sputnik, Voyager 2′	24	20	RGBW	42	Int	1, 2, 5	IP 68
Digital Sputnik, Voyager 4′	44	40	RGBW	83	Int	1, 2, 5	IP 68
Kino Flo, 4 × FS48 Tubes	48	150	25–100 RGB, WW, CW	1	24	1, 2	
Quasar Science, Rainbow 2′	23.1 × 1.75	25	20–60 RGBX	1	10–26	1, 2	
Quasar Science, Rainbow 4′	47 × 1.75	50	20–60 RGBX	1	10–26	1, 2	
Quasar Science, Rainbow 8′	94.5 × 1.75	100	20–60 RGBX	1	10–26	1, 2	
Spots							
ARRI Orbiter	1.1	400	20–200 RG-BACL	—	48	1, 2, 7, 8, 9	IP 65
Astera AX3	3.7	15	RGBW	—	Int	1, 2	IP 65
Astera AX5	5.7	45	RGBW	—	Int	1, 2	IP 65
Astera AX7	10	60	RGBW	—	Int	1, 2	IP 65
Astera AX10	10	135	RGBW	—	Int	1, 2	IP 65
Hive Bumble Bee 25-C	4	25	16–80 RGLCS	—	12	1, 5	
Hive Bee 50-C	4	40	16–80 RGLCS	—	12–18	1, 5	
Hive Wasp 100-C	4	75	16–80 RGLCS	—	12–20	1, 2, 5	
Hive Hornet 200-C	4	150	16–80 RGLCS	—	24–36	1, 2, 5	
Super Hornet 575-C	4	550	16–80 RGLCS	—	—	1, 2, 5	
Digital Sputnik, DS series	4 × 4	140	RGBW	—	—	1, 4, 9	
Fresnels							
ARRI L5-C	5.4	115	28–100 RGBW	—	—	1, 7, 8, 9	

Continued

Table H.7 Full-color tubes, pixel tubes, spots, and Fresnels Continued

	Aperture Dimension (in.)	Power draw (Watts)	CCT (K/100) and emitter colors	Pixels	Battery (V DC)	Control	Notes
ARRI L7-C	7	160	28–100 RGBW	—	—	1, 7, 8, 9	
ARRI L10-C	10.8	400	28–100 RGBW	—	—	1, 7, 8, 9	

Notes: CCT is given in Kelvin/100. For example, 20–60 means 2000 K to 6000 K.

Int = internal battery.

Control: 1 Wired DMX 5-pin XLR, 2 LumenRadio, 3 LumenRadio option, 4 Wi-Fi to smartphone, 5 Bluetooth/App, 6 Wired DMX option, 7 RDM, 8 Wired remote, 9 Ethernet.

Emitter colors: RGB (red, green, blue), WW (warm white), CW (cool white), A (amber), L (lime), S (sapphire), C (cyan), X (not disclosed).

Glossary*

Φ phase.
Ω resistance (ohms).
18% gray medium gray used to determine exposure.
216 a popular, relatively heavy diffusion.
4-by cart a cart for moving and storing 4 × 4-ft. frames, flags, nets, bounce boards, and so on.
4-by floppy a 4 × 4-ft. flag with an additional flap that folds out to make a 4 × 8-ft. flag.
A ampere.
Abbott a manufacturer of single-conductor connectors sometimes used on feeder cable.
Abby Singer the second-to-last shot of the day. The shot before the *martini.*
Above-the-line costs production costs of the producer, director, writer, and principal actors.
AC (1) Alternating current. (2) Camera assistant.
Ace a 1k Fresnel light.
AD *see* assistant director.
Adapter a device used to convert from one type of connector to another.
Aerial lift one of a variety of different lifts or telescoping boom arm vehicles commonly used as a high lighting platform for large exterior shots. Commonly called a Condor or Snorkelift, which are trade names.
AFHSS adaptive frequency hopping spread spectrum. A method used by wireless DMX systems to increase signal reliability and reduce interference with other transmissions. A matched transmitter and receiver simultaneously hop in a quasi-random way between frequencies in a given range.
Alternate start code a feature of the DMX512-A standard that expands the protocol to allow the DMX512-A signal to be used for communications other than just DMX values, including two-way communications.
Ammeter a test meter for measuring amperage.
Ampacity of cable, the amperage capacity that the cable can carry continuously (as defined by the NEC).
Amperage (*I*) a unit of current. One ampere will flow through a resistance of 1 **Ω** under a pressure of 1 V.
Ampere-hour a quantity of electricity equal to the number of amperes times the number of hours of charge that a battery can deliver.
AMPTP alliance of motion picture and television producers.
Anode a negative electrode.
ANSI American National Standards Institute. Three-letter ANSI codes are used to identify lightbulbs (e.g., EGT is a 1k bulb). Specifications for lighting control networks such as DMX512-A are also ANSI standards.
Apple box a reinforced plywood box used on the set for many purposes, including to raise an actor who is too short or to raise furniture. Apple boxes come in four sizes: full, half, quarter, and *pancake.*
Arc light any light that makes light by forming an arc, including arc discharge lights such as HMIs. On the set, *arc light* is normally understood to mean a carbon arc light.
ASA (1) American Standards Association (now the ANSI). (2) The exposure index (EI) rating of a film emulsion, also referred to as ISO.
Aspect ratio the ratio of the width to the height of the film frame. The standard aspect ratios are 1.33:1 (NTSC television, commonly referred to as 4 × 3), 1.66:1 (European theatrical film standard), 1.78:1 (high-definition television, commonly referred to as 16 × 9), 1.85:1 (American theatrical film standard), and 2.36:1 (Anamorphic 35 mm).
Assistant director (AD) the person who runs the set. The AD is responsible for coordinating the actions of the many departments so that everyone is ready when the time comes to roll cameras.

---

*Entries that have an asterisk are taken from *Practical Electrical Wiring* by Herbert P. Richter and W. Creighton Schwann. New York: McGraw-Hill, 1990.

AVR automatic voltage regulator.
AWG American Wire Gauge.
Baby a 1k Fresnel lighting fixture manufactured by the Mole-Richardson Co.
Baby pin a ⅝-in. mounting pin that mates with a ⅝-in. receptacle.
Baby stand a stand with a ⅝-in. pin.
Backdrop a scenic painting or enlarged photograph transparency used outside set windows and doors when filming in a studio.
Bail U-shaped part of a lighting fixture that attaches the fixture to the stand.
Ballast a power supply required to operate any discharge light, such as HMI, fluorescents, and xenon lights. The ballast provides the ignition charge and then acts as a choke, regulating the power to maintain the arc.
Banded cable several single-conductor cables banded together at intervals, forming one bundle.
Barn doors metal shields on a ring that mounts to the front of a lighting fixture. Barn doors are used to shape and control the beam of light.
Base (1) The basket on the underside of a fixture. (2) The base of a bulb is the porcelain part. (3) The lamp socket is also sometimes called the *base.*
Bates a common name for Stage Pin connectors—three-pin connectors in sizes from 20 to 100 A.
Batten usually refers to 1 × 3-in. lumber. May also refer to pipe on which lights, scenery, curtains, blacks, and borders can be hung.
Battery belt a battery pack, usually containing rechargeable batteries, mounted in a belt that can be worn around the waist during mobile shooting.
Bead board styrofoam used to make soft bounce light.
Beam angle the diameter of the beam angle is defined as the area of the light field that is 50% or more of the peak intensity of the beam.
Beam projector a type of lighting fixture that employs a large parabolic mirror reflector to create relatively strong, parallel rays of light.
Beaver board a nail-on plate mounted to a *pancake.*
Below-the-line costs the production costs of all members of the crew but not the producer, director, writer, and principal actors.
Best boy the assistant chief lighting technician. The best boy is the gaffer's administrative assistant.
Big eye a 10k incandescent fixture with an extra large lens (Mole-Richardson).
Black body locus the curved line of points on a chromaticity diagram, defined by the color points of a black body radiator when heated at a range of temperatures. The locus represents different color temperatures (shades of white light) from orange to blue.
Black body radiator a theoretical continuous spectrum light source used in defining the concept of color temperature. In order to give us a fixed reference point, the color makeup of any source can be compared to that of a theoretical "perfect black body radiator" when it is heated.
Black wrap a thick, durable black foil used on hot lights to control spill and to shape the beam.
Blonde an Ianero 2k open-face fixture.
Boom operator the sound person who operates the microphone boom and affixes microphones to the talent.
Branch circuit as defined by the NEC, circuits that are downstream of the last overcurrent protection.
Branchaloris a branch of a tree or bush held in front of a light to create a moving or stationary foliage pattern.
Broad a nonfocusing, wide-angle lighting fixture, typically using a double-ended bulb, installed in a rectangular fixture with a silver reflector.
Brute a 250 A carbon arc light manufactured by Mole-Richardson Co.
Bull switch a main switch used on the main feeder or on subfeeder lines.
Bump a feature on a dimmer console—an instantaneous change in stage levels from one set of intensities ("look") to another.

Buss bar copper bars in distribution equipment, such as spider boxes, to which lug connectors are attached. Buss bars more generally are the copper bars within any piece of electrical equipment, especially distribution equipment, that provide a junction point.
Butterfly set a frame used to support a net or silk over the top of the action. The silk reduces and softens direct sunlight.
C Celsius (temperature scale).
C-47 a common, wooden spring-type clothespin.
Cable crossover a special ramp used to protect cable from being damaged by being run over and to protect pedestrians from tripping over cable.
CAD computer aided design, a type of computer software used for drafting scale drawings. The lighting department uses this software for drafting light plots.
Call sheet a sheet distributed by the production department before the end of each day that indicates the scenes to be shot on the following day, the call time of all cast and crew members, special travel instructions, special equipment that will be used, and general notices to the cast and crew.
CamLok a type of single-conductor connector used for feeder cable.
Can a permanently installed panelboard bus bar in a soundstage.
Candela (cd) a unit of light intensity derived from brightness and distance. $cd = fc \times ft^2$ or, in Europe, $cd = lux \times m^2$.
Carbon arc light a very bright DC lighting fixture that creates light by igniting an arc flame between two carbon electrodes.
CAT 5 or CAT 6 cable high-speed digital communication cable commonly used for computer networks; also sometimes used for DMX512 networks.
Cathode a positive electrode.
Catwalk a metal or wooden walkway above a soundstage or entertainment venue.
CC *see* color compensation.
C-clamp a large C-shaped clamp with a baby stud or junior receptacle welded to it that is used to mount lights to beams.
CCT correlated color temperature. The equivalent color temperature of a light source that does not have a continuous spectrum (such as HMI, fluorescent or LED).
Celo cuke a wire mesh painted with a random pattern and placed in front of a light to throw a subtle pattern.
Chain vice grip a mounting device that uses a bicycle chain and vice grip to create a tight clamp around pipes, poles, or tree limbs.
Channel device controlling a dimmer or group of dimmers. In a simple system, there is a slider for each channel. On most current control systems, channels are numbered, accessed by a numeric keypad. Multiple dimmers may be controlled by a single channel to which they are *patched.*
Chaser lights a linear string of lights similar to those on a theater marquee. The lamps are wired in three, four, or five circuits; equally spaced lights are connected to the same circuit, which can be sequentially energized, creating the effect of light chasing along the line of lights.
Cheater an Edison plug adaptor that allows three-prong grounded plugs to be plugged into a two-prong ungrounded outlet found in older buildings. Also called a *ground lifter, ground plug adaptor,* or *two-to-three adaptor.*
Chiaroscuro a strongly contrasting treatment of light and shade in drawing and painting. Translated from the Italian, the word means “half-revealed.”
Chicken coop an overhead suspended light box that provides general downward ambient or fill light. Also called a *coop.*
Chief lighting technician *see* gaffer.
Chimera a specially designed, lightweight, collapsible soft box manufactured by Chimera Photographic Lighting.

CID *see* compact indium discharge.
CIE chromaticity diagram the CIE 1931 chromaticity diagram is a commonly used model representing every color perceived by the human eye. The International Commission on Illumination (CIE) first defined human perception of color mathematically in a 1931 study. This definition is known as the CIE 1931 XYZ color space.
Cinevator stand a heavy-duty stand used for the largest types of lights. The mechanism that raises and lowers the light is driven by an electric motor.
Circuit (1) When talking about dimmer circuits, refers to everything downstream of the dimmer, from the dimmer's output connector to the lighting fixtures themselves. (2) Generally, an electrical circuit is one that has a continuous path from the power source, through the load and back to the power source.
Circuit breaker an overcurrent protection switch. It trips and disconnects a circuit if the current drawn exceeds the rating of the circuit breaker.
cmil cross-sectional area of cable in circular mil.
Color chart a chart of standard colors filmed at the head of a roll of film as a color reference for the lab.
Color compensation (CC) a reading gained from a color meter indicating the amount of green or magenta gel needed to neutralize off-color hues, such as in fluorescent lights.
Color space in the case of a display or RGB light fixture, the device uses three or more illuminated colors in combination to create an array of colors. If the color points of three illuminants (red, green, and blue, for example) are plotted on a chromaticity diagram, the triangle formed includes all the colors that are achievable by the device. Any colors outside this triangle cannot be achieved. In the case of cameras, the color space is defined by the colors achievable by the three color sensors (video) or emulsion layers (film).
Color temperature a temperature expressed in Kelvin (K) that defines the color makeup of light emitted by a source, such as the sun or a filament lamp, that has a continuous color spectrum.
Combo stand a junior stand with a 1⅛-in. receptacle used to hold reflector boards and larger lights.
Compact indium discharge (CID) a 5500 K gas discharge globe often used in sun guns.
Compact source iodine (CSI) a type of gas discharge bulb similar to an HMI.
Condor a vehicle with a telescoping boom arm used as a platform to position lights 30–120 ft. in the air.
Continuity (1) Electrical continuity: the unbroken flow of electricity through a conductor or lamp filament. (2) Script continuity (the job of the script supervisor): the task of making sure that all the details of the scene remain consistent from take to take and from angle to angle. Shots may be filmed hours and even weeks apart, but they will be cut back to back in the final film.
Continuity tester a device that runs a small amount of voltage through a conductor and lights an indicator or makes a sound if the conductor is continuous.
Continuous load as defined by the NEC, an electrical load that is to be delivered continuously for more than 3 hours.
Continuous spectrum the color makeup of light from a source, such as an incandescent bulb or natural daylight, which includes all the wavelengths of light without spikes or holes anywhere across the spectrum of colors.
Contrast ratio the ratio of the intensity of the key light plus the fill light to the intensity of the fill light alone.
Control console a computerized controller that provides a user interface and generates a control signal to transmit data to devices on a lighting control network, such as a DMX512 or Ethernet network.
Coupler a clamp that closes around pipe commonly used to hold one pipe to another pipe at right angles, or at adjustable angles. Couplers are also commonly used to attach moving light fixtures to pipe or truss.
Crank-up stand a heavy-duty stand that provides a crank to raise and lower heavy lights.
CRI color rendering index.
Cribbing blocks of wood used to level dolly track.
Croney cone a cone-shaped attachment fitted with diffusion that fits on the front of a light to soften and control the beam.
Crossfade a fade that contains both an up-fade and down-fade. Also may refer to any fade where the levels of one cue are replaced by the levels of another cue.

Crowder hanger a fixture mount that fastens to the top of a set wall and provides two studs.
Crystal-controlled a crystal-based circuit that maintains a camera's frame rate very precisely. A wild camera has no crystal control.
CSI *see* compact source iodine. A type of arc lamp.
C-stand a multipurpose stand used for setting flags and nets. Short for *Century stand.*
CTB gel a blue gel that corrects a tungsten source to daylight.
CTO gel an orange gel that corrects a daylight source to tungsten.
Cube tap a device that allows three Edison plugs to plug into one Edison socket.
Cucaloris a wooden cutout pattern placed in front of a light to create a pattern.
Cue the process of recalling *a preset* from its memory location (in a control console) and putting the result on stage.
Cue light a flashing or rotating light positioned outside the set to warn people when the camera is rolling.
Cup blocks wooden blocks with concave indents. Cup blocks are placed under the wheels of light stands to prevent them from rolling.
Current the rate of flow of electricity measured in amperes.
Cutter a long, thin flag used to make cuts in the light.
Cyc strip a strip of open-face fixtures used to light a cyclorama. The lights are often wired in two, three, or four separate circuits to provide individual control of different colors.
Cyclorama a seamless hanging or set piece, usually white, often curved where it meets the floor. It is used to create a limbo background, having no discernible horizon or texture.
Day rate the wage for a day's work.
Daylight light commonly considered to have a color temperature of 5500–6000 K. Daylight-balanced film renders colors naturally when lit with 5600 K light.
DC *see* direct current.
Dead-man pedal a floor pedal that must be pressed by the operator's foot to operate or drive an aerial lift. The dead-man pedal is a safety device to prevent runaways.
Dedolight a small, special light fixture with a wide range of beam angle adjustment.
Delta-connected system a three-phase configuration of coils at the power source (either a generator or transformer). The transformer coils are commonly depicted as a triangle (delta).
Depth of field the depth of the scene that will be in focus on the screen. Depth of field varies with the camera's aperture, focal length, and distance from the subject and the film format.
Deuce board an AC/DC distribution box having high-amperage contactors that can be controlled from remote switches.
Deuce a 2k Fresnel light.
Dichroic filter a coating that can be applied either to a glass filter or a reflector that colors the light by selectively passing wavelengths. Dichroic filters are available in many colors, including color correction.
Die the semiconductor chip of an LED.
Diffusion material used in front of lighting fixtures to soften the light.
Dimmer the device controlling power to a circuit and lighting fixtures. Two lights on one dimmer circuit cannot be separately controlled.
Direct current (DC) current that does not alternate polarity. Batteries create DC.
Director of photography (DP) the cinematographer in charge of the lighting and camera departments. The DP has direct creative control of the image.
Discontinuous spectrum a light source with a discontinuous spectrum, such as a standard fluorescent bulb, that does not emit light evenly across the color spectrum, but instead has spikes at particular wavelengths and emits little or no light at others.
Distant location a location that is far enough from the production's town of origin that the crew must stay overnight.

Distribution box an electrical box with circuit protection, used to step down cable size and connector size and provide a variety of sizes of outlets for subfeeders, extensions, and various sizes of lights.
DMX512 data link the connection point of the DMX512 signal cable to a controller. Each data link supplies one universe (512 slots) of data, refreshed 44 times/second. For DMX512, this is commonly a 5-pin XLR connector, but modern controllers also use RJ-45 connectors for either DMX512 or Ethernet communications.
DMX512 lighting control network protocol.
DMX512 universe a DMX512 universe comprises 512 sequential data slots. A universe is sometimes thought of as a single DMX512 data link, and all devices connected to it.
Dog collar a short length of aircraft cable used to secure lights hung above the set. The collar is fitted with a loop at one end and a leash clip or carabiner at the other.
Doorway dolly a small, steerable flatbed dolly with large inflated tires, frequently used to move cable and large lights.
Dot a very small, circular flag, net, or silk used to alter only a small portion of the beam of light.
Douser the mechanism on a follow spot used to make a quick blackout without the operator having to extinguish the light itself. On a carbon arc follow spot, the douser protects the lens while the arc is struck.
Down-fade the portion of a fade that involves only channels that are decreasing in level.
DP *see* director of photography.
Dress a light to neaten up the light or cable.
Duck bill a vice grip with a baby stud on the handle and two 6 sq. in. plates welded to the jaws. Used to mount foamcore and bead board on a C-stand.
Dummy load *see* ghost load.
Duvetyn thick, black cloth used to block light.
E electromotive force, measured in volts.
Ears the metal brackets on the front of a light that hold the barn doors and scrims.
Edison plug and socket a typical household plug and socket with two parallel blades and a U-shaped grounding pin. Also called a *U-ground parallel-blade plug.*
Egg crate an accessory for a soft light fixture that cuts stray light and narrows the beam angle.
EIA-485 a standard for the electrical specifications of digital signal transmission, which was incorporated into the DMX standard at its genesis.
Electrician common name for a lighting technician.
Electromotive force voltage.
Electronic ballast a solid-state ballast. The term *electronic ballast* is synonymous with flicker-free square-wave ballast (HMI) or high frequency (fluorescent).
Ellipsoidal reflector spotlight (ERS) a spotlight of fixed or adjustable focal length that has framing shutters and a projection gobo slot and produces a long, narrow throw of light. Also called a *Leko.*
Elvis a gold lamé stretched on a frame and used to bounce light.
Emulsion the photochemical substance on a piece of film that captures the image.
Equipment grounding the grounding of noncurrent-carrying parts of equipment via a green grounding wire.
ESTA the Entertainment Services and Technology Association, responsible for many initiatives within the entertainment industry, including developing DMX512-A as an ANSI standard and other forward thinking standards for control networks, as well as publishing technical and safety reports and creating certification testing for entertainment electricians, among other things.
Ethernet a high-speed network protocol designed for communication between computers and devices, also used in lighting control.
Expendables supplies, such as tape, that are used up during the course of a production.
Eye light a light used to create a twinkle of light in the eye of the subject.
F Fahrenheit (temperature scale).

Fade a gradual change in stage levels from one set of intensities ("look") to another.
Fall-off the diminishing intensity of light from one position to another.
FAR a lighting fixture that lights a cyclorama.
FAY an incandescent par light with dichroic coating that creates daylight-colored light.
fc *see* foot-candle.
Feeder cable large single-conductor cable used to run power from the power source to the set.
Field the area that is at least 10% of the maximum candle power of a beam of light.
Field angle the angle from the light fixture to the opposite edges of the field.
Filament the tungsten coil inside a bulb that glows when voltage is applied to it, creating light.
Fill light soft light used to reduce the darkness of the shadow areas.
Finger a very small rectangular flag, net, or silk used to make minute cuts of the beam of light.
First team the director and actors.
Fixture a luminaire, light, lamp, instrument, head, or lantern.
Flag black duvetyn cloth stretched over a metal frame and used to shape and cut light.
FLB filter a filter used on the camera to remove the green hue of fluorescents.
Flex arm a small jointed arm used to hold fingers and dots.
Flicker box an electrical circuit box used to simulate the flickering of a flame or television screen. A flicker box randomly increases and decreases the intensity of the lighting fixtures.
Flicker-free an HMI or fluorescent ballast that provides a square-wave or high-frequency output that eliminates light-level pulsation when filmed at any shutter speed.
Flood the spread of the beam from a fixture that is broad and relatively weak.
Foamcore a white, glossy card laminated to $^1/_4$-in. Styrofoam and used to bounce light.
Focal length the distance from a lens at which an image comes into focus (the focal point). For camera lenses, it is usually expressed in millimeters. A long lens has a very narrow angle of view and a short depth of field. A short lens has a wide angle of view and greater depth of field.
Focal spot an accessory that mounts on a Fresnel fixture, essentially changing the fixture into an ellipsoidal spotlight.
Follow spot a high-power, narrow-beam spotlight suitable for very long throws. It is designed to follow performers on stage.
Foot-candle (fc) an international unit of illumination. One foot-candle equals the intensity of light falling on a sphere placed 1 ft. away from a point source of light of one candela. One foot-candle equals one lumen per square foot. *See also* lux.
Foot-lambert an international unit of brightness. One foot-lambert equals the uniform brightness of a perfectly diffusing surface emitting or reflecting light at a rate of one lumen per square foot.
Forced call when less than the minimum turnaround time is given between wrap on one day and call on the following day.
Format the film or video medium and the aspect ratio of the image.
Forward phase dimmer a dimmer technology that uses an SCR or triac circuit to control the duty cycle within each half-cycle of the AC sinewave, using a pulse-width-modulated signal from the control electronics.
fps frames per second.
Framing shutters in an ellipsoidal spotlight, or on some profile moving lights, shutters that can be adjusted to cut the beam and shape it in geometric shapes.
Frequency the number of cycles/second of alternating current, measured in Hertz.
Fresnel (1) A type of lens that has the same optical effect as a plano-convex lens but has reduced weight and heat retention. (2) The light fixture that uses a Fresnel lens.
f-stop a scale used to set the aperture of the camera.
Furniture clamp an adjustable clamp used for mounting lights.
Furniture pad a packing blanket used to protect floors, deaden sound, soften a fall, and so on.

Fuse an overcurrent device that uses an alloy ribbon with a low melting point. The circuit is broken when the current exceeds the rating of the fuse.

Gaffer the head of the lighting crew. The gaffer works directly under the director of photography.

Gaffer's tape heavy, fabric-based tape that rips cleanly in the direction of the weave. It is used for securing cables and lights on the set.

Gamma a graph line that describes a film emulsion's reaction to tonal gradation and its innate contrast. Also called *D log E curve* or *characteristic curve.*

Gang box an outlet box that provides Edison outlets and plugs into a larger connector, such as a 60 A Bates or a 100 A stage box.

Gator grip a baby stud on a spring-loaded clamp with rubber jaws, used for mounting lightweight fixtures to doors, poles, furniture, and so on.

Gel polyester-based colored gelatin used to color a beam of light.

Generator the power plant used to create power on location. Motion picture generators are sound-baffled and provide bus bars or other common feeder connectors.

Genny *see* generator.

GFCI, GFI *see* ground fault circuit interrupter.

Ghost load a load not used to light the set and placed on a circuit to balance the various legs of power or to bring the load on a resistance-type dimmer up to its minimum operating wattage. Also called *dummy load* and *phantom load.*

Globe a bulb.

Gobo arm the arm of a C-stand.

Gobo head the metal knuckle that attaches the gobo arm to a C-stand.

Golden time premium overtime pay after 12 hours of work (14 hours when on a distant location). Golden time is normally double the regular hourly rate.

Gray scale a chart showing gradations of gray from white to black.

Greens the wooden catwalk suspended above the set in a sound stage.

Grid (1) A transformer unit used with a carbon arc light. (2) The structure of metal pipes suspended above the stage floor for hanging lighting fixtures.

Grid clamp a clamp that attaches to grid pipe.

Grid cloth a white nylon diffusion fabric with a gridlike weave.

Griffolyn nylon-reinforced plastic tarp material. Griffolyns are typically black on one side and white on the other; they are used as a bounce for fill. Also called *griff.*

Grip a crew member responsible for many of the nonelectrical aspects of lighting and rigging and for the camera dolly and other camera platforms.

Grip clip a metal spring clamp.

Grip helper a metal arm that mounts to a junior stand. A gobo head angles down and out from the stand to which a 4-by frame can be attached in front of the fixture.

Grip truck the truck that houses the lights and grip equipment during location shooting.

Grounded wire the grounded, white, current-carrying wire of an AC circuit. Do not confuse this term with the green *grounding wire.*

Ground fault circuit interrupter (GFCI) a special type of circuit protection required around water, pools, and in wet locations, that detects leakage current—current not returning to the power source that could pose a hazard.

Grounding wire the green, noncurrent-carrying equipment grounding wire of an AC circuit.

Ground lifter *see* cheater.

Ground row cyclorama lights placed along the ground at the base of the cyc. A mask normally hides the lights from view.

Halogen cycle the cycle by which halogen in a bulb returns tungsten deposits to the filament, preventing blackening on the inner wall of the bulb.

Head a light fixture.
Head cable the cable running from the ballast of a lighting fixture to the head.
Hi boy an extra tall stand.
HID high-intensity discharge. A type of street lamp.
High key a bright lighting style with low contrast and bright highlights.
High leg the 208 V leg of a delta-connected three-phase system.
High roller an extra tall rolling stand, often used to fly an overhead frame.
HMI *see* mercury (Hg) medium-arc iodide. Trade name of Osram's metal halide arc lamps.
Honey wagon the trailer that houses the lavatories used when shooting on location.
Hot spot (1) The beam center. (2) A shiny spot or glare reflection that is distracting to the eye.
House lights the permanent lighting in the audience area of a theater or sound stage.
Housing the metal casing that surrounds the bulb and reflector of a lighting fixture.
Hz Hertz (cycles/second).
I current, measured in amperes.
IA, IATSE International Alliance of Theatrical Stage Employees.
IBEW International Brotherhood of Electrical Workers.
IGBT insulated gate bipolar transistor. A high-speed switching transistor circuit used to control power in various devices including HMI electronic ballasts, reverse phase dimmers, and sine-wave dimmers.
Impedance (Z) a measure, in ohms, of the opposition to current flow in an AC circuit. Impedance includes resistance, capacitive reactance, and inductive reactance.
Incandescent any type of electric light that creates light by making a metallic filament (usually tungsten for film lights) glow by applying current to it.
Incident light meter a light meter that reads the light falling onto the face of the meter.
Inductance a measure, in henrys, of the opposition to current change in an AC circuit (causing current to lag behind voltage). Inductance is exhibited by turns of wire with or without an iron core.
Infrared (IR) wavelengths above the highest visible wavelength of light, felt as heat.
Ingress Protection, International Protection Rating (IP) the IP rating signifies the degree to which an enclosure can protect against ingress of water, solid objects, and particulates. The International Electrotechnical Commission (IEC), the body responsible for international electrical standards, created an International Protection (IP) rating standard.
Instrument a lighting fixture.
Intermittent duty operation for alternate intervals of load, no load, and rest.
Inverter an electronic device that converts DC power into AC.
IR *see* infrared.
Iris the mechanism on a follow spot that adjusts the diameter of the beam.
ISO the exposure index (EI) rating of a film emulsion.
Jockey boxes metal storage containers on the underside of a truck. Jockey boxes usually store cable, distribution boxes, and so on.
Juicer a set lighting technician.
Junior a 2k Fresnel fixture.
Junior stand a stand with a 1⅛-in. junior receptacle.
Junior stud a 1⅛-in. stud.
K Kelvin (temperature scale). Used to define the color temperature of light.
k one thousand.
Kelvin a unit of measurement of temperature (0 K = —273 °C). In set lighting, the term refers to the color temperature (color makeup) of light and not to its physical temperature.
Key light the main source lighting the subject.
Kicker a side backlight.
Kick-out the accidental unplugging of a light.

Kit rental an additional fee a technician charges for the use of his or her own tools, equipment, and hardware. Also called *box rental.*
Layout board cardboard sheets, 4 x 8 ft., commonly used to protect floors.
LED light emitting diode. A solid-state illumination engine.
Leko a trademark of Strand's ellipsoidal reflector spotlight.
Light plot a drawing depicting the layout of the lights and lighting positions.
Light-balancing (LB) scale scale used in color meters.
Lithium-ion (Li-ion) a type of rechargeable battery chemistry. Characteristics: no "memory" problems, fast charging, high sustained voltage, high cell voltage, very light weight, environmentally friendly.
Louvers thin, parallel strips with a black finish arranged in a grid pattern that is placed in front of a soft light source. Louvers reduce spill light and direct the light in one direction.
Low boy a very short stand.
Low key a dark, shadowy lighting style.
Lug an extremely heavy-duty brass connector that bolts feeder cables to bus bars, deuce boards, and spiders. Also called *sister lugs.*
Lumen a unit of light (flux).
Lumen maintenance the scheme used to define the end of the useful life of an LED, expressed as a percentage of the LED's initial output.
Luminaire a light fixture.
Lux an international unit of light intensity used primarily in Europe. One lux equals one lumen per square meter. One foot-candle equals 10.764 lux. lux = cd/m^2.
MacAdam ellipse defines the distance at which two colors that are very close to one another first become distinguishable to the human eye as different colors. When plotted on a CIE chroma- ticity diagram, this radius is elliptical.
MacBeth a blue glass conversion filter used on some open-face lights. Converts tungsten sources to daylight.
Mafer clamp an all-purpose grip clamp (cam screw tightening) that can receive a number of different mounting attachments, such as a baby stud or a flex arm.
Magic hour the hour of light after sunset, during which the western sky creates a warm-colored soft light.
Make first, break last a rule of thumb when connecting single-conductor cables. The grounding connection must be made first, before any of the other wires. When disconnecting the cables, the grounding wire connection should be broken last.
Martini the last shot of the day.
Matth pole a pole that braces against two opposite walls to provide a structure from which to hang a lightweight fixture.
Meal penalty the fee paid by the production company (on union films) when shooting continues beyond 6 hours without breaking for a meal.
Meat ax an arm mounted to the pipe of a catwalk or to the basket of a boom platform that provides a way to place a flag in front of a fixture.
Media server a computer used to store, manipulate, and play back images and video through a projector or display.
Meltric a five-pin, heavy-duty connector used in some power distribution systems.
Memory on a dimmer console, the storage location for preset information.
Mercury medium-arc iodide (HMI) a type of gas discharge bulb with a color temperature of 5600 K and high efficiency of more than 90 lumens/W.
Mickey a 1k open-face fixture manufactured by Mole-Richardson.
Midget a 200 W wide-beam Fresnel fixture manufactured by Mole-Richardson.
Mini (1) A 100 or 200 W Fresnel fixture manufactured by Mole-Richardson, or a miniature soft light manufactured by LTM. (2) Minnie: Girlfriend of Mickey, manufactured by Walt Disney.

Minusgreen gel a magenta gel used to take the green out of fluorescent light.
MIRED one million times the reciprocal of the Kelvin rating of a given light source. The MIRED scale is used to determine the color shift of a given gel when used with any source. Short for *microreciprocal degree.*
Mole-pin a 0.5-in. slip pin used as a distribution system connector.
MOS a scene filmed without recording sound.
Mountain leg the leg of a three-leg stand that extends to allow the stand to remain upright on uneven ground.
Mover an automated light fixture typically having motorized pan, tilt, beam focus, zoom, color, gobos, shutter, iris, and other features.
Multiline spectrum the spectral energy distribution graph of an HMI light. Instead of a continuous line across the color spectrum, the color makeup is created by numerous single spikes.
Musco Light a very powerful mobile lighting truck.
NABET National Association of Broadcast Employees and Technicians. Trade union.
Nanometer (nm) a unit of length used to measure the wavelengths of the colors of light. One nanometer equals one-billionth of a meter.
ND *see* neutral-density.
NEC National Electrical Code.
NEMA National Electrical Manufacturers Association. Defines such things as standards for connectors and ingress protection for electrical equipment in the United States.
Net a black honeycomb netting material sewn onto a rod frame that is used to reduce the intensity of part or all of a light's beam.
Neutral-density (ND) a gel or filter that reduces light transmission without altering the color of the light.
NFPA National Fire Protection Association.
Ni-Cad Nickel cadmium. A type of rechargeable battery chemistry.
Ni-MH Nickel-metal hydride. A type of rechargeable battery chemistry.
Nook light a small, lightweight open-face fixture that typically uses a double-ended bulb and a V-shaped reflector.
Offset a piece of grip hardware used to hang a light out to the side of a stand.
Ohm (Ω) a unit of electrical resistance equal to the resistance through which 1 V will force 1 A.
Opal a popular, thin diffusion.
Open-face light a fixture that has no lens, only a bulb mounted in front of a reflector.
Opto-isolator an optically isolated signal amplifier that reads and regenerates a DMX512 control signal and outputs it to a single output connector.
Opto-splitter an optically isolated signal amplifier that reads and regenerates a DMX512 control signal and outputs it to multiple output connectors.
OSHA Occupational Safety and Health Administration.
Overcurrent device a circuit breaker or fuse.
Overhead set a large frame with one of several types of material stretched across it, including a solid, single net, double net, silk, or griffolyn.
O-zone the open spaces between the perms, in the rafters of a sound stage. Only rigging grips are typically allowed to work in the O-zone using safety proper fall protection equipment.
PA *see* production assistant.
PAM (pulse amplitude modulation) solid-state electronics used to drive current-driven devices such as fluorescent lights and LEDs. PAM limits the current using high-speed switching. At very high frequency, the current is allowed to rise to a set maximum and is then shut off.
Pancake a ¾-in. piece of plywood matching the dimensions of the large side of an apple box.
Paper method a method of calculating the amperage of 120 V fixtures by dividing the wattage by 100.
Parabolic reflector a reflector shaped like a parabola, giving it a focal point from which all light rays will be reflected outward in a parallel beam.

Parallel circuit the connection of two or more fixtures across the same conductors of a circuit such that current flow through each is independent of the others.
Parallels a small, easy-to-assemble scaffold platform.
PAR can a rugged fixture used often in rock-and-roll concerts. A PAR can is simply a PAR globe mounted in a cylindrical can that provides a slot for colored gel.
Party gel colored gels, also called *effects gel* or *theatrical gel.*
Patch historically, the process of physically connecting circuits to dimmers. Now usually refers to electronic assignment of dimmers to channels. *Patch* does not refer to the assignment of channels to cues or submasters.
Peppers a line of small, lightweight tungsten lights manufactured by LTM in sizes of 100, 200, 300, 420, 500, 650, 1000 W, and 20k.
Perms permanent catwalks near the high ceilings of sound stages.
Phantom load *see* ghost load.
Phase (1) An energized single conductor, usually ungrounded and never the neutral. (2) The positioning of an AC cycle in time, relative to the phases of the other hot legs. Most electrical services are either single-phase or three-phase services.
Photoflood a bulb, typically with a standard medium screw base that has a color temperature of 3200–3400 K.
Piano board originally, a portable dimmer switchboard or road board. This term has come to be used for many types of portable dimmer switchboards.
Pigeon plate a baby nail-on plate.
Pins any of several types of connectors. Mole-pins and *0.515* pins are single-conductor slip pins used on feeder cable. Three-pin connectors, commonly called *Bates connectors,* are also sometimes called *pins.*
Pipe clamp a clamp used to hang a light from an overhead pipe.
Pixel mapping software is used to map a video, graphic or other image onto an array of individual lights (typically RGB LEDs) in order to create a large display or graphic effect.
Plano-convex a lens that is flat on one side and convex on the other. Light comes from the flat side and converges or diverges as it passes though the lens, in proportion to the lamp's distance to the lens.
Plate dimmer a resistance-type dimmer commonly used with DC circuits.
Plusgreen gel a gel used to add green to lights to match their color to that of fluorescent bulbs.
Polarity the orientation of the positive and negative wires of a DC circuit or the hot and neutral wires of an AC circuit. A polarized plug cannot be plugged in with reversed polarity.
Pole cats lighting support equipment consisting of extendible metal tubes that wedge between two walls or between floor and ceiling to which lights can be mounted.
Power the total amount of work, measured in watts. The term is also generally understood as electricity, or juice.
Power/DMX an arrangement used by some accessory devices such as gobo rotators, and also some LEDs, that provides both a DMX512 signal and low-voltage power to the device on the same cable. Power/DMX typically uses a four-pin XLR in which the first three pins are configured to carry a DMX512 signal, and the fourth pin carries low-voltage power (24 V is typical).
Power factor in AC, the ratio of the actual or effective power in watts to the apparent power in volt-amperes, expressed as a percentage. Inductive loads cause the current to lag behind the voltage, resulting in a power factor of less than 100%.
Practical lamp a lamp, sconce, or fixture that is shown in the scene.
Prefocus base the type of lamp base.
Prelight or prerig to rig in advance. During production, the grip and electrical crew may form a second crew or bring in a second crew to work ahead, rigging the sets that are to be shot during the following days.
Preset of a dimmer console, a predefined set of intensities for a set of channels, stored in memory for later replay.
Primary colors for light, red, blue, and green. When the primary colors of light are projected onto a white surface, the area where all three colors intersect theoretically make white light.

Prime fixture a focusable, open-face fixture.
Priscilla a silver lame stretched on a frame and used to bounce light.
Producer the person who oversees the production of the film or television show from the very beginning (obtaining the script, finding the backing to produce the show) to the very end (selling the finished film in domestic and world markets). The producer is the ultimate authority on all money-related decisions and most others. Everyone on the production works for the producer.
Production assistant (PA) the bottom rung entry-level position in film production (although director is also often an entry-level position). A PA performs any number of tasks, including "locking up the set," calling for quiet before each take, distributing scripts and paperwork, running errands, attending to special needs of actors, director and producers, getting coffee, lending a hand with the assistant directors, and so on.
Programmer lighting control programmer. The operator of the lighting control console, especially moving light consoles and other advanced devices.
PSA public service announcement.
PWM (pulse width modulation) method of voltage control used in a vast array of electronic power supplies and dimming equipment. Pulse width modulation controls RMS voltage by altering the duty cycle.
R resistance, measured in ohms. *See* resistance.
Rag the cloth part of an overhead set.
Rain tent a tent to cover lights and electrical equipment in case of precipitation.
RDM remote device management. A control protocol that allows two-way communication between control console and DMX512-A/RDM devices.
Reactance (*X*) a measure, in ohms, of the opposition to AC due to capacitance (X_C) or inductance (X_L).
Receptacle a female connector or female mounting hardware.
Rectifier an electrical unit that converts AC to DC.
Redhead a 1k open-face fixture.
Reflected light meter a light meter that reads the amount of light reflected by the scene into the meter. A standard reflected meter has a relatively wide angle of view and averages the areas of light and dark to give the reading. *See also* spot meter.
Reflectors silver-covered boards typically used to bounce light, usually sunlight. Also called *shiny boards.*
Resistance (*R*) a measure, in ohms, of the opposition to current flow in a conductor, device, or load. In DC, volts ÷ amperes = ohms of resistance. For AC, see impedance.
Reverse phase dimmer a type of electronic dimmer, which employs an IGBT circuit to vary the duty cycle of each half-cycle by varying the point at which the circuit is switched OFF.
RGB LED LED having red, green, and blue emitters. Using additive mixing, a wide array of colors are possible.
Rheostat a resistance dimmer.
Rigging bible a set of diagrams showing the power layout of a studio's sound stages.
Rigging gaffer the gaffer in charge of designing and installing the cabling and electrical distribution for, and prelighting the set.
Rim a backlight that makes a rim around the head and shoulders of the subject from the perspective of the camera.
Ritter fan a large effects fan used to blow snow and rain and to give the appearance of wind or speed.
Safety a wire, chain, cable, or rope looped around the bail of a light to prevent it from falling should it come loose from its mount.
Sandbag a sand-filled bag used to stabilize stands and equipment by adding deadweight or counterweight.
Scale the minimum pay scale set forth by the labor union representing the crew or cast.
Scissor clip a device that provides a means of hanging lights from a dropped ceiling, such as those found in many modern commercial buildings.
Scoop a lighting fixture that consists of a large 1k or 2k bulb mounted in a reflector. Scoops are used for general area light.
Scosh a very small amount, as in "Flood it out a scosh."

SCR silicon controlled rectifier. A type of AC dimmer circuit used by a forward phase control dimmer to vary the duty cycle by switching off the circuit at a (variable) point in each half-cycle.
Scrim a circle of wire mesh, which slides into the ears on the front of a fixture and reduces the intensity of the light. A single dims the light about a half-stop. A double dims it about one stop. A half-single or double affects only half of the beam.
Second team the stand-ins are actors used, in place of the real cast, as models during lighting, to line up shots, and to rehearse camera moves.
Secondary colors the colors formed by combining two primary colors. Also called *complementary colors.*
Senior a 5k incandescent Fresnel fixture manufactured by Mole-Richardson Co.
Series circuit connection of two or more devices or loads in tandem so that the current flowing through one also flows through all the others.
Service electrical service. This term can refer to the types of circuits installed, for example single-phase, three-wire service.
Service entrance the main panel board into which the power lines running to a building terminate.
Shock the sensation or occurrence of an electrical circuit being completed through a person's body.
Short circuit unwanted current flow between conductors.
Show card thick card stock, usually white on one side and black on the other, used to bounce light.
Shutter in a motion picture camera, a butterfly-type device that spins in front of the aperture plate.
Shutters a device that is mounted at the front of a light to douse the light using Venetian blind-like metal slats.
Silicone spray a dry lubricant used on dolly track.
Silk silk fabric used to soften and cut the intensity of light. It is used in all sizes, from very small dots and fingers to very large 20 x 20-ft. overheads.
Silver bullet a 12k or 18k HMI light manufactured by Cinemills Corp.
Sine-wave dimmer a type of electronic dimmer that creates no filament buzz (associated with phase control dimming) by electronically varying the effective voltage of a sinusoidal waveform.
Single-phase a single-phase load is any load that is powered from one phase wire and the neutral, or two phase wires. Almost all lighting loads are single-phase. *See also* three-phase.
Sister lugs *see* lug.
Sky pan a large, soft light fixture used for general fill, comprising a 2k, 5k, or 10k bulb and a large pan-shaped reflector.
Slot the DMX512 control protocol provides 512 data slots in each universe. Each slot supplies a device with an 8-bit value (a number between 0 and 255), which may be used to control a parameter of that device.
Snoot a black metal cylinder or cone mounted on the ears of a fixture to narrow the beam.
Snot tape sticky adhesive substance used to attach gel to a frame.
Socapex commonly used to refer to 19-pin-compatible connectors, sometimes also called a multipin connector. Socapex is a trademarked name owned by Amphenol-Socapex, the original manufacturer. Multiconductor cable is commonly used for dimmer circuits, but may also be used for any function where six circuits are run in one cable.
Soft box a device used to create soft, diffuse light, typically having a diffusion front and solid sides to contain spill light.
Soft light (1) A light fixture with a large, curved, white reflector surface that bounces light onto the scene. (2) Light emitted from a relatively large diffuse surface.
Solid a black "rag" stretched on a frame and used to cut light.
Sound mixer the person who operates the audio recorder machine.
Space light a large silked cylinder that hangs above the set to create soft ambient illumination.
Spark a nickname for set lighting technician.
SPD spectral power distribution (graph).
Specular an adjective used to describe hard light emitted by a point source.

Spider box a cable splicing box used to join feeder cables.
Spot a beam focused into a narrow, relatively strong beam of light.
Spot meter a type of reflected meter having a very narrow angle of acceptance used to determine the light value of a specific point on the set.
Square wave a type of AC created by an electronic ballast that can be used to greatly broaden the window of flicker-free operation of HMIs.
Squeezer a dimmer.
Staging area the area on the sound stage or location selected as a temporary place to keep the lighting equipment and carts.
Start address the DMX512 address set on a signal receiver which is the first DMX512 address a device will respond to. The device responds to the values of subsequent slots in accordance with its personality.
Stickup an extremely small, lightweight fixture that can be taped to the wall.
Stinger an extension cord; officially, a hot extension cord.
Stokes shift phosphors are used in fluorescent lights and LEDs to broaden color spectrum from a more monochromatic pump color. The Stokes shift is the difference between the pump color and the resulting spectrum after light energy bombards the phosphors.
Stop an f-stop or a t-stop.
Strain relief a rope tie used to reduce strain at the point at which a cable attaches to its connector.
Streaks and tips cans of hair color that are often handy for darkening reflective surfaces.
Strike (1) To dismantle a set or to take down and put away a piece of equipment. (2) When referring to an HMI, to *strike* the light can mean to turn it on.
Strobe light a light that creates short, bright, regular flashes of light at an adjustable speed.
Studio zone in California, the area within 30 miles of a specific point in Hollywood. Labor rules are different inside and outside of this zone.
Submaster a controller (usually a linear slider) on a dimmer board that allows manual control of groups, effects, cues, or channels.
Suicide pin an adaptor with two male ends.
System grounding the grounding of the service equipment and the current-carrying, neutral white wire to the transformer and to earth.
Taco cart a special cart that carries grip equipment, such as C-stands, apple boxes, wedges, mounting hardware, and grip expendables.
Tag line a line dropped from aloft and used to hoist equipment into a catwalk, green beds, or Condor.
Talent on-camera people and animals, usually actors, not necessarily talented ones.
T-bone a metal T-shaped base with a junior receptacle, used to place larger lights at ground level.
Termination on a DMX512 network, the last device in the chain of devices must be terminated using a termination plug or via a switch on the last (if so equipped). Termination is necessary to prevent signal reflections that can corrupt the signal data.
Three-fer a connector that provides three female connectors from one male connector.
Three-phase a three-phase power source creates alternating current in three leads—the AC cycle of voltage in each lead is a third of a cycle (120°) apart from the last. A three-phase power source may be used to power single-phase loads of different voltages by using two of the phase wires, or one phase wire and a neutral wire. A three-phase load in one that requires all three phase wires. Examples of three-phase loads used in lighting include some xenon ballasts, chain motors, Luminys SoftSun, and 480 V step-down transformers.
Three-riser a stand that has three extensions.
Throw the distance at which a fixture can effectively light a subject.
Tie-in the connection of distribution cables to a facility's service panel.
Titan a 350 A carbon arc light manufactured by Mole-Richardson.
Tracing paper thin, translucent paper used to white-out windows, also called 1000H.

Transformer a device with no moving parts and two or more insulated windings on a laminated steel core that is used to raise or lower AC voltage by inductive coupling. Volt-amperes into the primary coil and volt-amperes out of the secondary coil are the same, less the small current necessary to magnetize the core.
Tree a tall stand or tower that has horizontal pipes on which lights can be hung. Used a great deal in theater and concert lighting.
Triac a type of solid-state dimmer circuit used in household dimmers, based on PWM control.
Trombone fixture-mounting hardware that hooks over the top of the set, drops down the set wall, is adjustable, and provides a baby or junior stud or receptacle to which a light is mounted.
Truss a metal structure designed to support a horizontal load over an extended span. Truss is used to support lighting fixtures aloft.
T-stop the aperture setting of a zoom lens after compensation for light lost in the numerous optical elements of the lens.
Tungsten color temperature a color temperature of 3200 K.
Tungsten halogen lamp a lamp designed to maintain an almost constant color temperature and a high lumen output throughout its life. The halogen cycle is a regenerative process that prevents the blackening of the inside of the bulb.
Turnaround the time between the time you go off the clock on one day and call time on the next.
Turtle stand a squat junior stand that enables a large light to be positioned at ground level.
Tweenie a 650 W Fresnel light manufactured by Mole-Richardson Co.
Twist-lock a connector for which the plug inserts into the socket and then twists, locking the plug to the socket.
Type W cable cable manufactured to meet the requirements of NEC Articles 520 and 530 regarding portable entertainment cable. It is abrasion-, oil-, solvent-, and ozone-resistant and flame-tested.
U-ground a standard Edison plug with a U-shaped grounding pin.
UL Underwriters Laboratories. An agency that tests electrical equipment. A qualifying piece of equipment is referred to as "UL listed."
Ultraviolet (UV) the wavelengths of light below the shortest visible wavelength. UV-A is black light. UV-B radiation can cause skin burns and eye damage, as well as skin cancer, if not filtered.
Unilux a manufacturer of strobe lighting equipment that can be synchronized to a motion picture camera shutter.
Up-fade the portion of a fade that involves only channels that are increasing in level.
UPS uninterruptable power supply. A power supply used for powering mission-critical equipment, such as a control console, so that if the power supply is interrupted (the power cord accidentally gets pulled out), the UPS will continue to supply power via battery and sound an alarm.
USITT United States Institute for Theatre Technology. The body that created the DMX512 system.
UV *see* ultraviolet.
V *see* volt.
VA *see* volt-ampere.
Variac an AC autotransformer dimmer—a type of variable transformer that can vary voltage below and above line voltage.
VEAM connector VEAM Litton is a manufacturer of connectors, including multipin HMI head feeder connectors and single-conductor feeder cable connectors.
Velum *see* tracing paper.
Visqueen plastic material used to protect equipment from precipitation.
Volt (V) a unit of electrical force. One volt is required to force 1 A of electricity through a resistance of 1 **Ω** (ohm).
Voltage drop the difference in voltage between two points in a circuit due to the intervening impedance or resistance.
Volt-ampere (VA) voltage times amperage. In DC, volts × amps = watts, but in AC, inductance and capacitance in the circuit may introduce reactance, causing a discrepancy (power factor) between watts and volt-amperes.

Voltmeter a meter used to measure voltage potential between two points in a circuit.
W *see* watt.
Wall sled a fixture-mounting device that hangs from the top of the set wall and rests against the wall.
Wall spreader hardware that mounts to either end of a piece of lumber, creating a span from one wall to another from which lights can be hung.
Watt (W) a unit of electrical power, the product of voltage and amperage.
Wedge a triangular wooden block used to level dolly track.
Western dolly a large flatbed camera platform with large inflated tires that steer at one end. A western dolly can be useful for moving lights and cable.
Wiggy a continuity or resistance-testing device.
Wireless DMX a system of transmitters and receivers used to transmit a lighting control signal using radio waves in the 2.4 GHz range.
Wrap the end of the work day. The process of taking down lights and coiling cable that begins after the last shot of the day has been completed successfully.
Wye-connected system a common type of three-phase transformer arrangement. On a 208Y/120 system voltage reads 208 V between any two of the hot legs and l20 V between a hot leg and the neutral white leg.
Xenon lights an extremely bright type of arc discharge light that has a color temperature of 5600 K. Because the arc is very small, the light can be channeled into a very narrow shaft of extremely bright light.
Y-1 a type of gel that converts a white carbon arc to normal daylight color balance.
Yoke *see* bail.
Zip cord two-wire, 18-AWG electric lamp cord.
Zip light a small soft light.
Zone system Ansel Adams's system of 11 gradations of gray from pure black to pure white. The zones are numbered in Roman numerals from 0 to X. There is a one-stop difference from zone to zone.

Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

Index

Note: Page number followed by *f* indicate figures, by *b* indicate boxes, and by *t* indicate tables.

Taylor & Francis Group
an **informa** business

Taylor & Francis eBooks

www.taylorfrancis.com

A single destination for eBooks from Taylor & Francis with increased functionality and an improved user experience to meet the needs of our customers.

90,000+ eBooks of award-winning academic content in Humanities, Social Science, Science, Technology, Engineering, and Medical written by a global network of editors and authors.

TAYLOR & FRANCIS EBOOKS OFFERS:

- A streamlined experience for our library customers
- A single point of discovery for all of our eBook content
- Improved search and discovery of content at both book and chapter level

REQUEST A FREE TRIAL

support@taylorfrancis.com

Routledge
Taylor & Francis Group

CRC Press
Taylor & Francis Group