Mechanics in Agriculture

by Lloyd J. Phipps

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Lloyd J. Phipps

Professor Emeritus
Agriculture Education Division
University of Illinois at Urbana-Champaign

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This third edition of *Mechanics in Agriculture* is dedicated to my daughter, Linda L. Slife, and to my grandchildren, Michael Slife and Abigail Slife.

PREFACE

Mechanics in Agriculture is designed to serve the needs of high school students, post–high school students, and adults preparing for occupations requiring knowledge and skill in agricultural mechanics. Its contents are also designed to serve the needs of persons presently engaged in the many occupations requiring knowledge and skill in agricultural mechanics.

The book emphasizes the basic principles involved in all types of agricultural mechanics activities, from shop work to soil and water management. Throughout the book safety practices are stressed. The contents were selected to supplement and complement both shop and field activities in agricultural mechanics.

Emphasis has been placed on the "why" as well as the "how." Persons may use the contents of the book to obtain an overview and basic understanding of a problem area in agricultural mechanics. This basic overview and understanding will make more meaningful the details learned in the shop and in the field.

The new and broadened objectives of vocational education in agriculture guided the author in the selection and organization of the materials. The materials included should be of value to persons engaged in or preparing to engage in (1) production agriculture and (2) off-farm agricultural occupations.

The contents of the book cover a wide range of problem areas. A basic book such as *Mechanics in Agriculture* has certain advantages for both the teacher and the learner. The chapters in the book have been grouped into the six major areas of content in agricultural mechanics. In addition, because the metric system of measurement is now being used in these major areas, a chapter on the metric system has been included.

Lloyd J. Phipps

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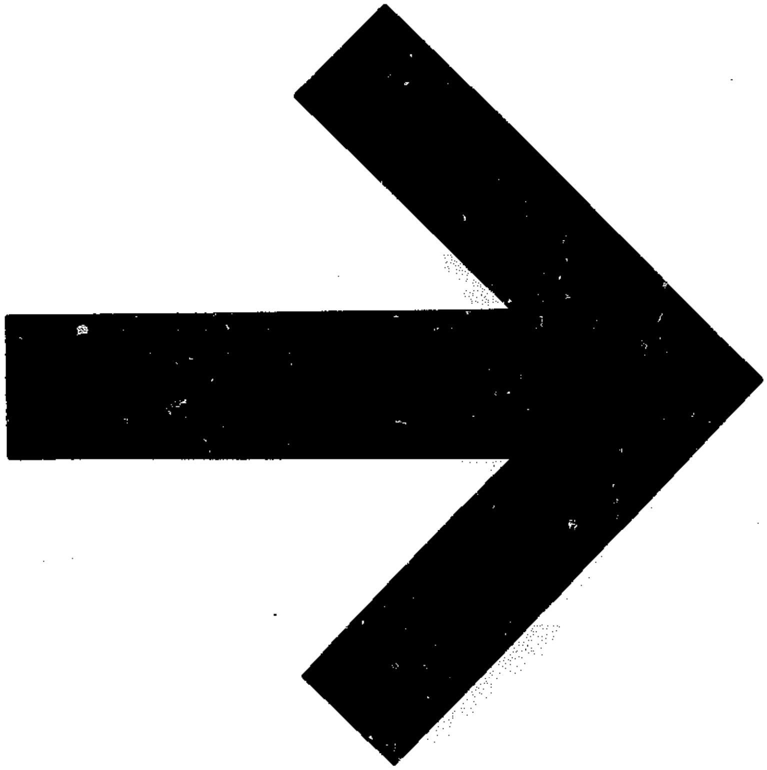

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PART I

Introduction

INTRODUCTION

Student Abilities to Be Developed

1. Ability to appreciate the importance and understand the objectives of agricultural mechanics instruction.
2. Ability to appreciate the value of good quality work and proper housekeeping in a shop.
3. Ability to select suitable and worthwhile agricultural mechanics projects based on individual supervised agriculture experience programs.
4. Ability to understand and follow safety measures in agricultural mechanics.

CHAPTER 1

Understanding and Using Mechanics in Agriculture

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is agricultural mechanics?
2. How important is agricultural mechanics?
3. What are the objectives of agricultural mechanics?
4. What relation does agricultural mechanics have to students' supervised agriculture experience programs?
5. How important is repair work?
6. Why is good housekeeping in agricultural mechanics essential?
7. How should the students dress for agricultural mechanics activities?
8. How important is good quality work?
9. What factors should be considered in selecting projects?
10. What are the essential steps in completing projects?
11. How important are student notebooks in agricultural mechanics?
12. What does the student need to know before starting work on mechanical activities?
13. What kind of projects should be undertaken first?
14. What safety precautions should be followed?

Meaning of Agricultural Mechanics—The term "mechanics" is often used to indicate some mechanical work such as auto mechanics or welding, but as used in the vocational field it has a much broader meaning. The terms "agricultural shop work" and "agricultural mechanics instruction" are often used interchangeably in connection with the program in vocational agriculture. "Agricultural mechanics instruction," however, is a more inclusive term than "agricultural shop work." Agricultural mechanics includes all the unspecialized mechanical activities performed on the farm and in agriculturally oriented businesses and services. The following five areas of instruction usually constitute the content of mechanics in agriculture:

1. *Agricultural Shop Work.* Selection, sharpening, care, and correct use of shop tools and equipment; woodwork and simple carpentry; sheet metal

work; elementary forge work; welding; pipe fitting; simple plumbing repairs; rope work.

2. *Agricultural Power and Machinery*. Selection, management, adjustment, operation, maintenance, and repair (excluding major repairs requiring specialized equipment and services) of gas engines, tractors, trucks, and the principal machines used in farming and agriculturally oriented businesses and services.
3. *Agricultural Electrification*. Utilization of electricity in the home and in the productive enterprises; selection, installation, operation, and maintenance of electrical equipment.
4. *Agricultural Buildings and Conveniences*. Elementary scale drawing and plan reading; farmstead layout; functional requirements of buildings, shelters, and storages; basic construction; concrete; water systems; septic tanks and sewage disposal.
5. *Soil and Water Management*. Elementary leveling, land measurement, and mapping; drainage; irrigation; terracing, contouring, and strip cropping.

Importance of Mechanics in Agriculture—Most of the work in the many and diverse occupations in agriculture involves some type of mechanical activity. With the increasing mechanization of work, people employed or self-employed in agriculture cannot be successful unless they possess considerable mechanical knowledge and skill. Agricultural engineers estimate that approximately 85 per cent of the machinery in operation on farms is more or less out of adjustment. In addition to the adjustment of machinery used in farming and in other agricultural

(Courtesy *Farm Safety Review*, National Safety Council)

Fig. 1.1. Advance planning is essential in agricultural mechanics. With advance planning and doing, difficulties such as this may often be avoided.

businesses and services, there are many mechanical jobs that a worker in an occupation requiring knowledge and skill in agriculture should and can do after receiving training in agricultural mechanics, such as repairing agricultural machinery, constructing buildings, remodeling buildings, maintaining electrical equipment, repairing and maintaining home conveniences, and staking out contours and terraces.

Objectives of Agricultural Mechanics—There are many values which every student should receive from agricultural mechanics instruction. Some of the objectives of the instruction are:

1. To develop desirable work ethics.
2. To discover mechanical aptitudes.
3. To develop dependable judgment in agricultural mechanics activities.
4. To develop basic skills in agricultural mechanics.
5. To develop self-confidence in performing mechanical operations.
6. To understand the underlying principles of mechanical processes.
7. To be able to recognize quality work in agricultural mechanics.
8. To develop interest in and willingness to do agricultural mechanics jobs.
9. To understand and determine which mechanical activities can be done more economically by someone else.
10. To utilize opportunities for learning by doing.
11. To develop abilities necessary for doing the unspecialized mechanical jobs that a worker in an agricultural occupation needs to be able to do.
12. To develop the ability to work cooperatively and effectively with others in a school's agricultural shop.

Relation of Agricultural Mechanics to the Students' Agriculture Experience Programs—The agricultural mechanics instruction should be closely related to the students' agriculture experience programs, including productive and improvement projects, supplementary jobs, and placement for experience.

When students in an agriculture class are receiving supervised agriculture experiences through placement-employment training programs with fertilizer dealers, they will probably need to learn how to operate, adjust, and maintain various fertilizer application machines. They may also need to learn how to operate, adjust, and maintain machinery involved in mixing and handling fertilizer.

When students in an agriculture class are preparing for gainful employment in an ornamental horticulture occupation, they may need to learn how to operate, adjust, and maintain such machines as turf pluggers, turf sweepers, tree injectors, and greenhouse humidifiers.

When students are raising crops such as corn, they will need to learn how to operate, maintain, adjust, and repair the tractors they use. They will also need to learn how to operate, maintain, adjust, and repair the other machines used in producing corn such as the planter, plow, disk, harrow, cultivator, and combine. They may need to learn about some of the mechanical aspects of soil convervation, and they may need to learn about carpentry in order to repair or remodel storage facilities for the corn crop and for the machinery which they use. If they elevate the grain produced into a storage facility with an electric motor, they may need to learn something about wiring and the selection and care of the motor.

When students have sow and litter projects, they will need housing facilities which may necessitate the remodeling or building of hog houses. They may need to construct gates, feeders, troughs, crates, and chutes, all of which make excellent projects. A student with a baby chick project will need feeders, stands, and pens, which may be made in the shop.

The following is a partial list of projects, grouped according to their relation to certain agricultural enterprises, which are commonly included in supervised agriculture experience programs:

CROPS

1. Beet rack
2. Crate for potatoes
3. Ensilage rack
4. Hayrack
5. Hotbed frame
6. Orchard ladder
7. Machinery maintenance
8. Rope splicing
9. Seed potato cutting rack
10. Seed tester
11. Seed treating equipment
12. Vegetable forcing box
13. Wagon box
14. Wheelbarrow

LIVESTOCK

Cattle

1. Calf stanchions
2. Cooling tank for milk
3. Dehorning chute
4. Feed bin
5. Feed bunk for grain
6. Feed bunk for hay
7. Feed or silage cart
8. Loading chute
9. Milk loading platform
10. Rope halter
11. Stanchions
12. Stock shipping crate
13. Water trough

Poultry

1. Automated feeding equipment
2. Automated waterer
3. Brooder house
4. Candling equipment
5. Carrying hook
6. Catching hook
7. Colony poultry house
8. Door and window frames
9. Double-tier wall nest
10. Dropping board
11. Dry mash hopper
12. Dusting box
13. Feed box
14. Feeding trough
15. Grit hopper
16. Hopper for green feed
17. Nest for laying house
18. Oats sprouter
19. Portable chick brooder
20. Self-feeder for chicks
21. Self-feeder for hens
22. Shed roof type house
23. Show crate
24. Stand for drinking fountain
25. Stand for mash hopper
26. Trap nest

Sheep

1. Drinking trough
2. Hay and grain rack
3. Lamb creep
4. Loading chute
5. Panels for lambing pens
6. Portable lamb trough
7. Salt and mineral box
8. Shipping crate

Swine

1. A-type hog house
2. Breeding crate
3. Colony hog house
4. Concrete feeding floor
5. Creep for pigs
6. Farrowing stall
7. Hog hurdles
8. Knock-down hog pen
9. Loading chute
10. Material handling equipment maintenance
11. Portable fence, panels
12. Self-feeder
13. Self-oiler for hogs
14. Shed roof type hog house
15. Shipping crate
16. Smokehouse
17. Summer shelters
18. Trough

There are many other types of agricultural mechanics projects, activities, and jobs which may be a part of a student's supervised agriculture experience program.

(Courtesy National Safety Council)

Fig. 1.2. First-aid supplies should always be available, but proper safety precautions should be utilized in agricultural mechanics to minimize the need for first aid.

Some of these activities are planning a soil conservation system or a strip cropping system, laying out contour lines, laying out terraces, and establishing a drainage system. Construction projects such as the following may also be included in agriculture experience programs.

AGRICULTURAL EQUIPMENT

1. Bag holder
2. Barn medicine cabinet
3. Barnyard stock gate
4. Barrel cart
5. Concrete steps, walks, and feeding floor
6. Electrical controls maintenance
7. Electrical wiring
8. Electric motor maintenance
9. Farm field gate
10. Fork and shovel rack
11. Machinery adjustment
12. Road drag
13. Rope halter
14. Saw buck
15. Scoop endgate
16. Tractor repair
17. Trailer
18. Truck and body rack

HOME CONVENIENCES

1. Basement fruit and vegetable rack
2. Flower trellis
3. Fly trap
4. Folding bench
5. Medicine cabinet
6. Painter's ladder
7. Plant box
8. Step ladder

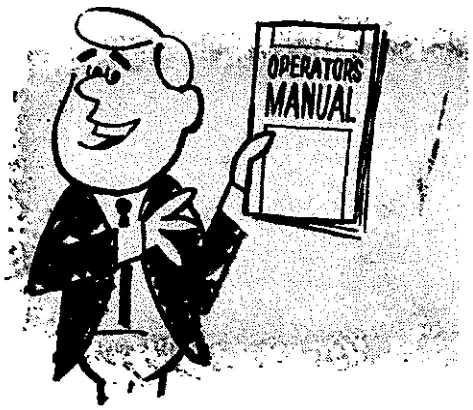
HOME SHOP EQUIPMENT

1. Anvil stand
2. Bench drawer
3. Bench hook
4. Bench stop
5. File handle
6. File rack
7. Lumber rack
8. Miter box
9. Nail box
10. Rack for drills, bits
11. Saw filing clamp
12. Sawhorse with open top
13. Sawhorse with solid sill
14. Saw jointer
15. Storage shelves—nails, screws
16. Tool box
17. Tool cabinet
18. Workbench

Repair Work—It has been found in several states that a large percentage of the work in agricultural mechanics involves repair work such as repairing buildings, machinery, and tractors. Many pieces of machinery are discarded when they might have been repaired at a small cost.

It is true, however, that the construction of new projects is probably more attractive than working on an old, rusty piece of machinery, but students should develop an appreciation of the economy of repair jobs, and they should do repair work that is economically profitable.

Adjustment and Maintenance—A successful employee in a fertilizer plant, a seed house, or an agricultural equipment and machinery shop must know how and be willing to adjust and maintain the machinery being used. Self-employed agricultural workers also must be able to adjust and maintain machinery if they are to make a profit. Inability to adjust and maintain machinery properly often leads to loss of a job or failure of a business.



(Courtesy National Safety Council)

Fig. 1.3. An agricultural mechanics student makes effective use of operator's manuals.

Good Housekeeping Essential—A shop furnishes a very good place for the formation of desirable habits. Many of the habits formed in school are carried throughout life. Keeping the shop neat and tidy should be the ambition of every student. Every piece of equipment should be kept in the correct position and should be properly cleaned. A shop should be carefully swept each day. By a little cooperation on the part of every student, a shop can be kept presentable at all times. Good housekeeping promotes safety and decreases loss of tools and supplies.

Shop Dress—A person cannot accomplish as much in shop work when "dressed up" as when wearing something to protect good clothes. Coveralls afford about the best protection. Many students prefer blue denim coveralls, but they have a tendency to fade on white clothing. For this reason they are not very practical. White coveralls very readily show dirt; khaki seems to be the best color for shop coveralls. Students should place their names in small letters on their coveralls to prevent any argument regarding ownership. A very good place for the name is under the collar. The coveralls should be kept in a special location in the shop when not being worn.

Caps are very inexpensive and are very good protection for students working with welders, on motors, or on any other project of a dirty nature. Black caps are preferred by many workers because they do not show soil as readily as caps of a lighter color.

Work Quality—A student often has the mistaken idea that since much of the carpentry and other work in agricultural mechanics is of a rough nature, little regard needs to be given to work quality. High standards of quality are just as essential in agricultural mechanics work as in other types of shop work. This does not mean that a pen for animals should be finished like a stereo cabinet, but it does mean that all materials in the pen should be squared and fitted together properly. The following partial list of standards is suggested:

1. Use only materials of proper kind and dimension.
2. Stress durability at all times.
3. Complete all jobs started.
4. Finish all projects before allowing them to be taken from the shop; that is, have them completed and well painted.
5. Do not handle tools carelessly.

Employers in agricultural businesses insist that their employers produce good quality work.

Factors to Consider in the Selection of Projects—There are several factors which students should consider in selecting projects, a few of which are as follows:

1. Do I have any need for the project?
2. Will it be of any practical value to me in my supervised agriculture experience program?
3. Can plans be secured or drawn for it?
4. Are suitable materials available?
5. Are tools available to do the job?
6. Is it too expensive? Will it pay to do it?
7. Will it give me a feeling of satisfaction or pride?

Often students select projects merely to have something to do and are not guided by the proper consideration of the preceding points.

Essential Steps in Completing Projects—After students have decided upon agriculture projects, they should conform to a procedure similar to the one that follows:

1. Make a complete drawing or plan for the project.
2. Develop a bill of materials and estimate the cost of the project.
3. Select and secure the proper materials.
4. Label and care for the materials secured.
5. Select the proper tools
6. Begin work on the project.
7. Do a good job.
8. Keep a record of the time spent on the job.
9. Figure the actual cost of the project, including personal labor, after the project is completed.

Student Notebook—The notebook used for agricultural mechanics may be the same as the notebook used for the other instruction received in vocational agriculture. A loose-leaf notebook of the standard 8½ by 11 inch, three-ring type is preferable.

Notebooks in agricultural mechanics, if used correctly, provide records of the problems and questions which students decide, with the assistance of the teacher and classmates, should be solved and answered so that they can conduct their agriculture experience programs more effectively and efficiently. The notebooks should also contain records of the conclusions reached regarding these problems and questions.

The most important part of a notebook, however, is the student's individual plans, sketches, and lists of bills of materials. We learn by doing, but we must first make plans for what we are to do. Any individual plans for specific agricultural mechanics activities should also be recorded on a calendar of activities for the student's supervised agriculture experience program.

Notes which are taken from material read, or during a preliminary class discussion of a problem, should be recorded on sheets for the notes of this type. They should not be placed on the pages in a notebook designed for the recording of the analysis of problems and for the conclusions reached regarding these problems. If reading notes and notes taken during class discussion are placed on the pages where problems are analyzed and where conclusions are recorded, these pages will become so filled with irrelevant material that they will be of little value.

What to Undertake First—Do not attempt projects which are too complicated until some training in using tools has been received. Start with some project which has practical value and which is not too difficult as a means of obtaining experience. It is better to undertake some worthwhile project than it is, for example, to merely square a board that will be thrown in the scrap pile after it is squared. After students have learned how to use tools, they may then begin more complicated projects such as reconditioning a combine, repairing a mower, or constructing agricultural equipment.

Approved Practices in Agricultural Mechanics—If the instruction in agricultural mechanics is to be effective and worthwhile, there are a number of things which should be done. The following is a partial list of desirable practices.:

1. Select projects of a practical nature.
2. Finish projects before taking them home or to the business in which you are employed.
3. Have a plan to follow before beginning work on a project.
4. Attack work which you are capable of doing.
5. Be careful in handling tools.
6. Follow instructions.
7. Work cooperatively with others.
8. Observe all safety precautions.
9. Keep busy at work of practical value.
10. Furnish your own materials.
11. Keep your tools sharp and in good condition.
12. Secure necessary supplies outside of school hours.
13. Do your work to the best of your ability.
14. Keep the quality of your work high.

Safety Measures—There are a number of safety precautions which should be followed in a shop, such as wearing safety glasses while you are using a grinder, wearing a helmet while electric arc welding, and wearing safety glasses while oxyacetylene welding. Other safety measures are suggested in Chapter 2. These should be read and followed.

CHAPTER 2

Using Safety Precautions

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is the most frequent cause of accidents on farms and in nonfarm agricultural jobs?
2. What are some of the precautions that may be taken to prevent accidents in an agricultural shop?
3. What are the safety precautions that should be observed in using power shop tools? Hand tools?
4. How should objects be lifted?
5. What general precautions should be observed when handling and moving objects?
6. How may falls be prevented?
7. How may fires be prevented?
8. How may accidents caused by fumes and carbon monoxide be prevented?
9. What general safety precautions should be observed on farms and in agriculturally oriented businesses and services?
10. What should be done when an accident occurs?

Agricultural mechanics can be dangerous if proper safety precautions are not observed. There are many accidents in agriculture, and agricultural mechanics activities are the source of the majority of these accidents.

At one time the most frequent cause of accidents on farms and in other agricultural businesses was animals. At present the more frequent source of injuries in agriculture is machinery. Most accidents resulting from agricultural mechanics activities may be prevented by the development of safe habits. Many of the safe habits needed in all agricultural activities may be acquired while learning the skills and developing the abilities needed in agricultural mechanics.

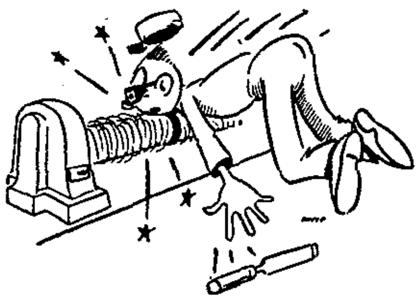
Anyone who does not form the essential habits of safety which should accompany the development of an agricultural mechanics skill or ability is foolish.

SAFETY IN THE AGRICULTURAL SHOP

An agricultural shop may be a safe place to work or it may be a very dangerous place. Whether it is dangerous or safe depends to a great extent on the intelligent actions of those who work there.

Dress—Proper dress is a prerequisite for safety in a shop. Snug fitting clothes with no tears, belts, or ties to become entangled in machines are essential. The clothes worn should be washable so that undue care need not be taken to keep them clean. Working in a shop while wearing dress clothes may cause an accident because of the excess caution that must be exercised to keep the clothes clean.

A necktie or a loose belt strap may become entangled in a machine and be the cause of a serious accident. Coveralls are probably the most sensible type of garment to wear in a shop. Safety glasses should be worn also.



(Courtesy National Commission on Safety Education, NEA)

Fig. 2.1. The wearing of inappropriate clothing can cause a serious accident.

Behavior—"Playing around" and teasing or annoying other workers in an agricultural mechanics shop may result in a serious accident, perhaps the loss of a life. There is a time and place for everything. In a shop the undivided attention of a worker is required for the activity being performed if the shop is to be a safe place to work.

Color Dynamics—Various colors may be used to make a shop a safer place in which to work. Every shop worker should learn the significance of each color and observe the proper safety precautions.

A color code has been developed which should have the same meaning in all shops and factories, and in agriculture. The color yellow means to watch out. Moving objects are painted yellow. Yellow and black parallel bars are used to identify nonmoving objects or parts of machines which create the hazards of being struck against, stumbled over, or fallen into.

The color orange means danger. It says *be on guard*. Machine guards, moving parts, crushing or cutting edges, and the insides of electrical switchboxes are painted orange.

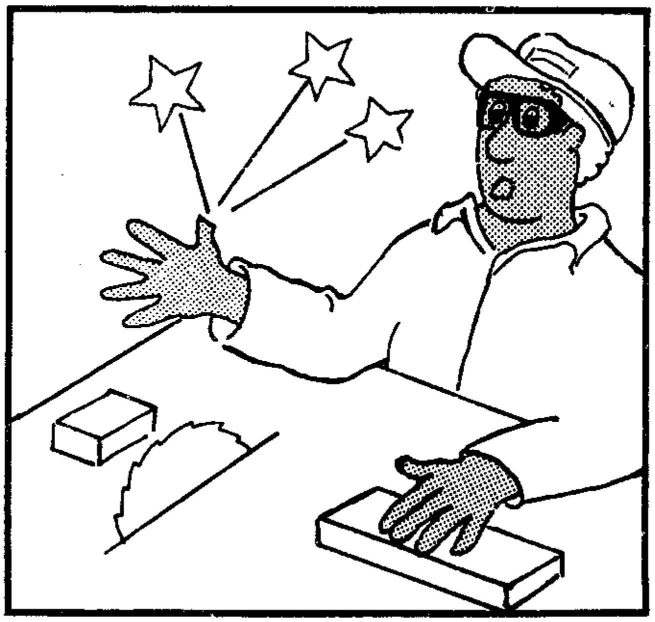
The color red is reserved for firefighting equipment and its location. Green indicates safety equipment and its location. White is used as a guide color. It is used on floors, for example, to mark direction of movement, and location of materials. The bodies of power tools such as table saws, grinders, or drill presses are painted a light green or a gray, and nonmovable edges of power tools are painted ivory.

Safety Instruction—A student should not use tools, especially power tools, before receiving instruction regarding their safe use. Students who use a tool before receiving such instruction not only may injure themselves, but also may develop some habits in using the tool which are dangerous. These unsafe habits are often difficult to eliminate and may sooner or later cause an accident.

Power Tools

Saw—A power saw, either table or radial arm, is a common power tool in a shop on a farm or in an agriculturally oriented business. In addition, many shops have electric hand saws. The first safety precaution in the use of a power saw is to select the type, size, and speed of saw best suited for the type of work to be done. If a saw in a school is not of the type or size required for certain types of jobs, the instructor will probably inform the students of this fact at the time he or she teaches the safe use of the saw.

Before using power saws, students should form the habit of checking the condition of saws, such as whether or not (1) guards are all in place and securely attached, (2) the saw is sharp and the teeth are of uniform height, and (3) the saw is correctly adjusted for the work to be done. The users of power saws should stay alert. Adequate light is essential, and the floor should not be littered. A littered floor may cause an operator of a saw to slip or stumble. In trying to prevent a fall, the student may put a hand into the saw.



(Courtesy Agriculture Education Divison and Vocational Agriculture Service, University of Illinois)

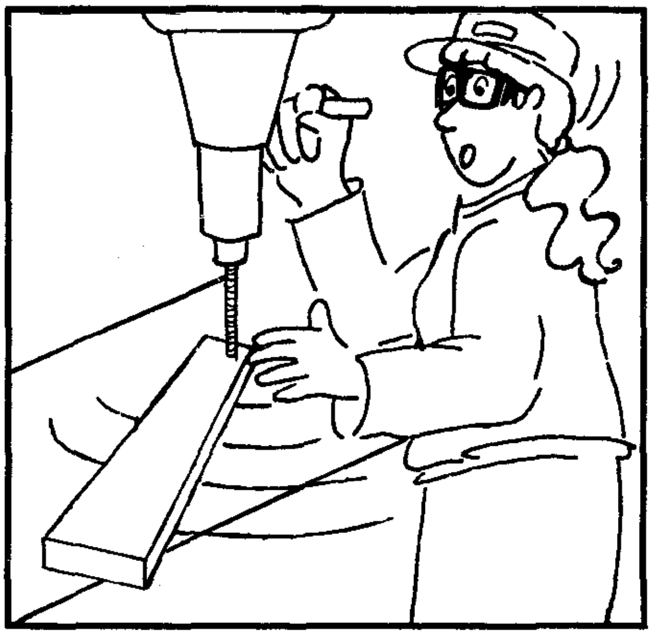
Fig. 2.2. Always use a miter gauge when crosscutting. Also wear safety glasses.

If the blade of a saw is not sharpened and set properly or does not run straight and smooth, the saw should not be used until the difficulty is corrected. If a blade is warped or cracked, it should be discarded at once. The guard on a power saw should always be in place. It does not pay to take chances in the operation of power saws.

While using a saw, the operator should not wear gloves. Before a saw is started, a check should be made to determine whether or not anyone may be injured by it. Removing sawdust frequently from under a saw may prevent the operator from slipping or falling. Scrap material should be removed with a brush at frequent intervals from the table of a saw. The operator should stand to one side of the saw and not in line with the blade.

The most frequent accident with a power saw is getting hands into the blade; therefore, the hands should be kept away from the line of cut. A long stick with a notched end may be used to push narrow pieces between the saw blade and the guide. The power should be shut off immediately if the material being sawed binds or pinches. The saw blade should stop completely before the material is backed away from the blade. If a saw breaks or does not work properly, the power should be shut off and disconnected, and the saw allowed to come to a complete halt before repairs are attempted.

When ripping material, the operator should be certain that the *anti-kickback cogs* are working. After work is finished, the operator should stay at the saw until it has coasted to a *complete stop* as a precaution to prevent others from inadvertently



(Courtesy Agriculture Education Division and Vocational Agriculture Service, University of Illinois)

Fig. 2.3. When using a power drill, be sure to clamp the material being drilled securely to the table of the drill. Also wear safety glasses.

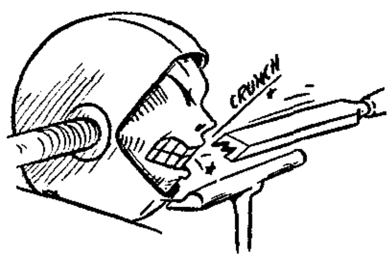
being injured on the saw while it is still running. If a saw is not in safe operating condition, the user should see that it is disconnected until it has been repaired. A blue tag is often put on power tools and other equipment when they are not in working condition. A practice in industry is to padlock the switch so that the machine cannot be operated while it is not in good working order.

The saw blade should be adjusted so that the blade will extend above the table only slightly more than the thickness of the wood being sawed.

Drill Press—The operator of a drill press needs to always check to be sure that the material being drilled is secure so that it will not turn with the drill. It is dangerous to hold materials being drilled.

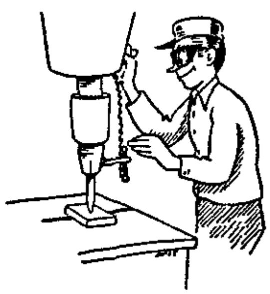
A frequent cause of an accident with a drill press is the failure to remove the chuck wrench before the press is started. A good habit is to check the location of the chuck wrench before starting the press. A safety precaution is to tape the chuck wrench to the lead cord so that the press cannot be connected to the power line without first removing the wrench from the machine. When a portable drill press is used, the operator should check to see whether or not the tool is grounded. The operator should also be careful not to overload the tool.

Grinder—Most shops contain power grinders, and accidents often result from their improper use. An operator of a grinder needs to wear safety glasses. Others working nearby also need to wear safety glasses to be safe. The tool rest on a grinder should be kept adjusted so that it is close to and above the center of the



(Courtesy National Commission on Safety Education, NEA)

Fig. 2.4. An emery wheel that is not round is dangerous and damages tools.



(Courtesy National Commission on Safety Education, NEA)

Fig. 2.5. Always remove the chuck wrench before starting a drill press.

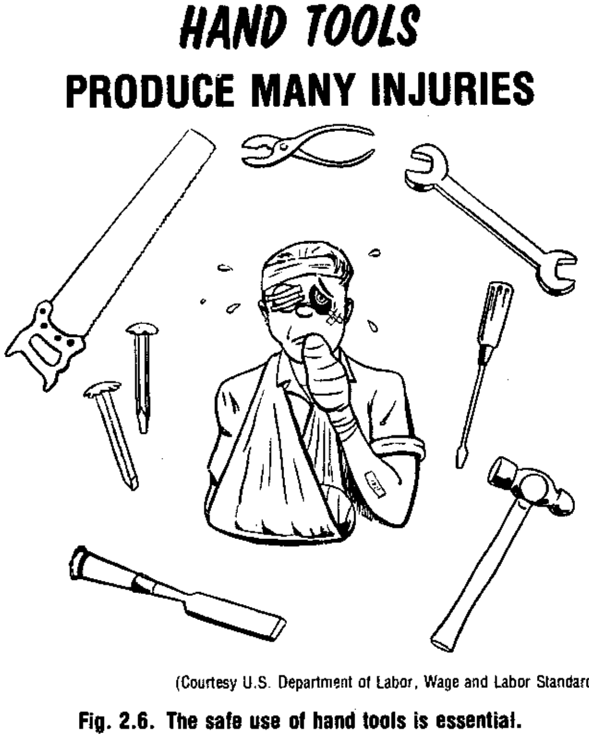
stone. The safe operator develops the habit of checking before grinding regarding whether or not shields, guards, and lights are in position and properly adjusted. The temperature of the grinding wheels should not be below room temperature at the time the machine is being used. The manufacturer's manual for the use of a grinder and its attachments should be studied and followed by all operators of the grinder.

Hand Tools

Most persons are familiar with the use of hand tools, but frequently hand tools are used incorrectly, and they cause a high percentage of the accidents in work on farms and in nonfarm agricultural businesses. Many of the injuries result from the the use of an improper tool for the job. An important ability in agricultural mechanics is to learn the tools best suited for various jobs. A hand tool to be safe must be sharp and otherwise in good working condition. Tools that are not clean can slip from the hands easily.

Sorting tools for the one desired often causes injuries. All hand tools should be kept in tool cabinets or in tool racks where they are accessible without sorting.

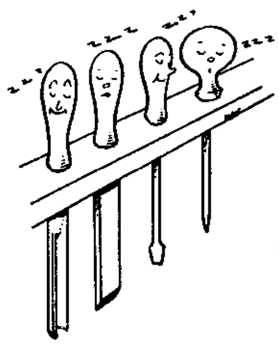
The use of dull tools often results in injuries. Dull tools cause injuries by sticking, slipping, or sliding. Sharp tools used correctly are safer. Slivers from damaged or poor quality handles may cause painful injuries. Heads of hammers, axes, and hatchets not securely fastened to handles are dangerous. Keeping all tools in good condition is an important safety precaution.



(Courtesy U.S. Department of Labor, Wage and Labor Standards Administration)

Fig. 2.6. The safe use of hand tools is essential.

Hammer—A hammer is a simple tool, but its incorrect use may cause an accident. When using a hammer, as when performing any other agricultural mechanics activity, the undivided attention of the worker is required. Keeping the eyes on a nail being hammered may prevent striking the nail at an angle, which may cause chipping or a mashed finger. In driving a nail, hold it between the thumb and finger near the head and give it a few light taps to start it. Make sure before driving a nail that the face of the hammer is clean and free of grease.



(Courtesy National Commission on Safety Education, NEA)

Fig. 2.7. Safely stored.

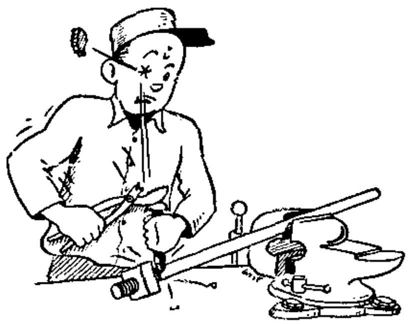
Hatchets, Axes—When using a hatchet or an ax, be careful that no one is standing close enough to be hit by flying chips and that no obstructions are in the line of swing. When the blade of a hatchet or an ax strikes the object, the handle should be as horizontal as possible. Legs are in danger when the handle of the ax is nearly parallel to the body.

(Courtesy U.S. Department of Labor, Wage and Labor Standards Administration)

Fig. 2.8. Chief causes of hand tool injuries.

Hatchets or axes may cause serious injuries if left lying on the floor. When they are carried, they should be placed in leather cases. If a leather case is not used, the blade should be turned away from the carrier.

Pliers—Pliers are not the correct tool to use to loosen or tighten nuts. A wrench of the proper size is better. Pliers slip off a nut more easily than does a wrench of the proper size. Pliers are not hammers and should not be used as such.



(Courtesy National Commision on Safety Education, NEA)

Fig. 2.9. An example of what can happen when the incorrect tool for a job is used. It also shows the importance of wearing safety glasses.

Wire Cutters—When wire is cut, the loose ends may fly into the face or hands, especially when the wire is coiled or when the wire is under tension. Take hold of a wire to be cut close to the point where it is to be cut. Be sure the current is turned off on an electrical circuit before cutting.

Planes—Planes are relatively safe if they are used properly and if the blades are kept sharp. Dull blades may cause injuries by jamming and sticking. To keep a plane sharp, raise it slightly on the back stroke.

Saws—A safe saw is a sharp saw. Injuries may occur when starting a saw cut. The thumb should be used to guide the saw blade until the cut is started. Pull the saw up on the first stroke. Support the piece being sawed on a sawhorse or a bench, or in a vise. A vise should be used when sawing with a hacksaw.

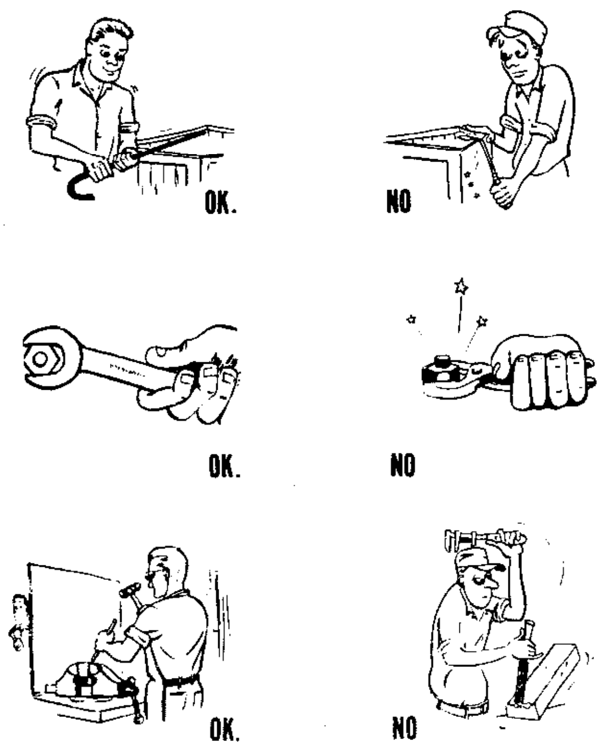
(Courtesy National Commission on Safety Education, NEA)

Fig. 2.10. In agricultural work, select only tools with serviceable handles.

Screwdrivers—Screwdrivers are not made to be used as chisels, pry bars, hammers, or spark testers. Their use as substitutes for these tools may cause injuries because of their breaking or slipping. To avoid injury due to slipping, make sure the blade of the screwdriver used fits the screw and is seated squarely against the bottom of the slot in the screw.

The work should never be held in one hand and the screwdriver in the other because the screwdriver may slip and pierce the hand. When doing electrical work, make sure the screwdrivers used have insulated handles to prevent shocks. All screwdrivers should be kept in good repair. A broken screwdriver is dangerous.

Wrenches—The most frequent cause of accidents with wrenches is the use of a wrench that does not fit the nut being loosened or tightened. Skinned knuckles, mashed fingers, and sprained backs, fingers, and wrists may result when a wrench slips. To avoid injuries when using wrenches, use only those that are in good condition, and obtain solid footing so that slippage or breakage will not throw you off balance. When a hard pull is placed on a wrench, make sure that the wrench fits the nut or bolt squarely and snugly. Don't use a wrench as a hammer. All wrenches should be inspected before they are used. Defective ones should be discarded. When using a wrench, pull if possible. If it is not possible to pull, push the wrench with an open hand.



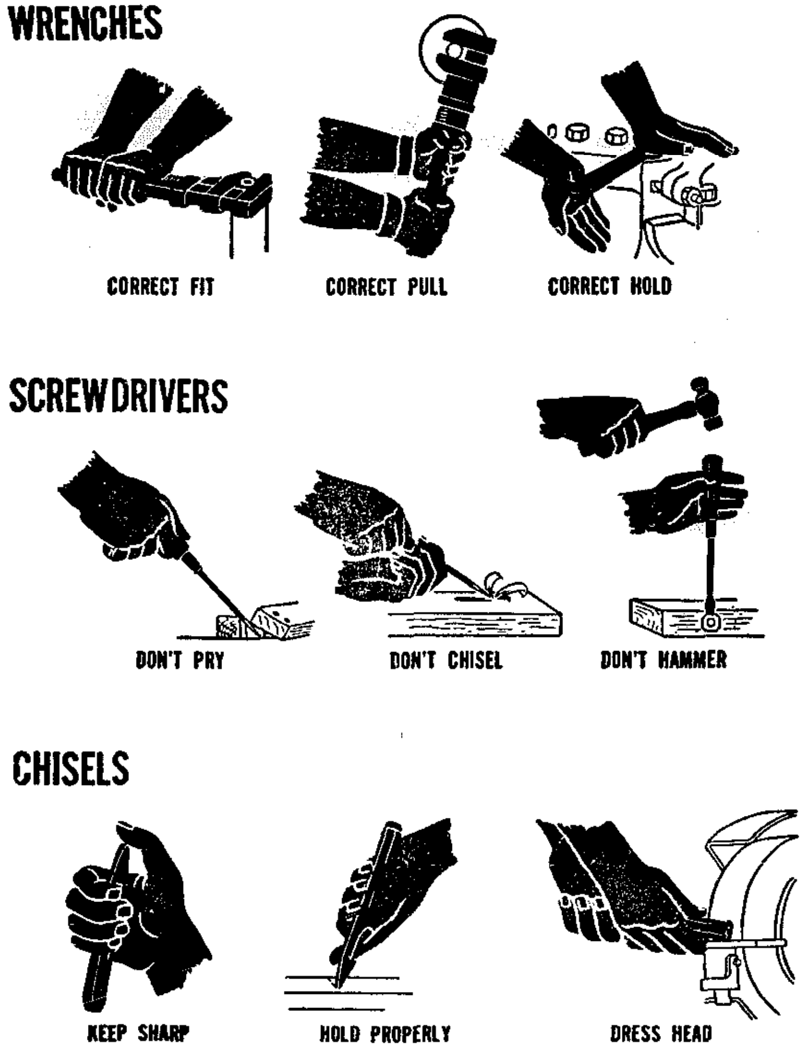
(Courtesy U.S. Department of Labor, Wage and Labor Standard Administration)

Fig. 2.11. Always use the correct tool for the job.

Chisels, Punches—The principal hazard in using chisels, punches, and similar tools is allowing the heads to become mushroomed. Mushroomed heads when struck may break off and injure the worker or someone else. A mushroomed head may be made safe by grinding off the "mushroom."

Pry Bars—Falling is the principal hazard in the use of a pry bar. When a bar slips and causes the worker to fall, it is usually because the point of the bar was not placed securely under the object being moved. Failure to place a bar securely under an object may be caused by the dullness of its point.

Files—Using a file without a handle on the tang end is an invitation for trou-



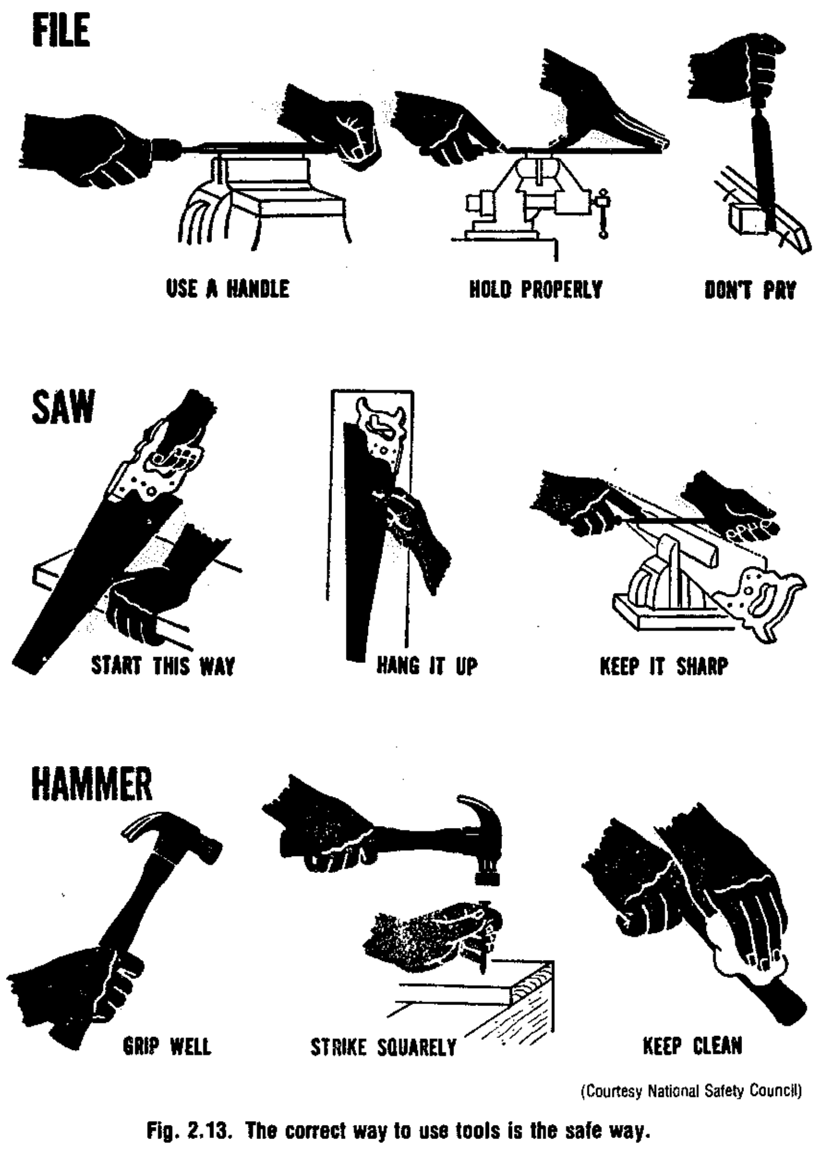
(Courtesy National Safety Council)

Fig. 2.12. There is a correct and incorrect way to use all tools. Be safe. Learn the correct way.

ble. When a file that does not have a handle slips, the sharp point of the tang often pierces the hand of the user. Keeping a file clean will help prevent it from slipping. Since files are made of very brittle steel, they should never be used for hammering.

Knives—Using a knife that is too large or too small for the job may be the cause of an injury. All knives should be kept sharp. A sharp knife is safer than a dull knife, because less pressure is necessary in using a sharp knife.

In using a knife always cut away from the body and the hands. Knives should be used only for cutting. Since knife blades are brittle, they are broken easily when used as substitutes for screwdrivers or punches.

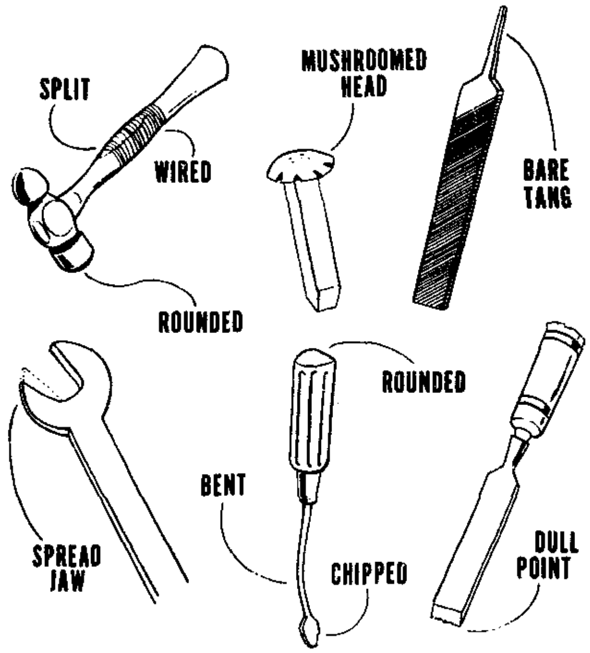


(Courtesy National Safety Council)

Fig. 2.13. The correct way to use tools is the safe way.

(Courtesy National Commission on Safety Education, NEA)

Fig. 2.14. A file is not made for prying. Always select the correct tool for the job.



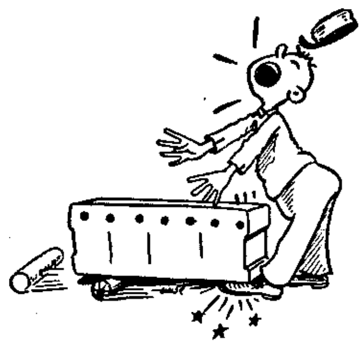
(Courtesy U.S. Department of Labor, Wage and Labor Standards Administration)

Fig. 2.15. Specific tool defects that cause injuries.

Handling Materials

Many injuries may be prevented in handling materials by wearing gloves and hard-toe shoes. However, the most frequent hazard in handling materials is lifting. Proper lifting is a skill. The development of this skill may prevent back injuries, ruptures, and sprains.

Workers should not attempt to lift loads which are too heavy for them. Persons need to develop good judgment regarding what they can lift. Before lifting, a worker should make sure that footing is secure. A good balance should be



(Courtesy National Commission on Safety Education, NEA)

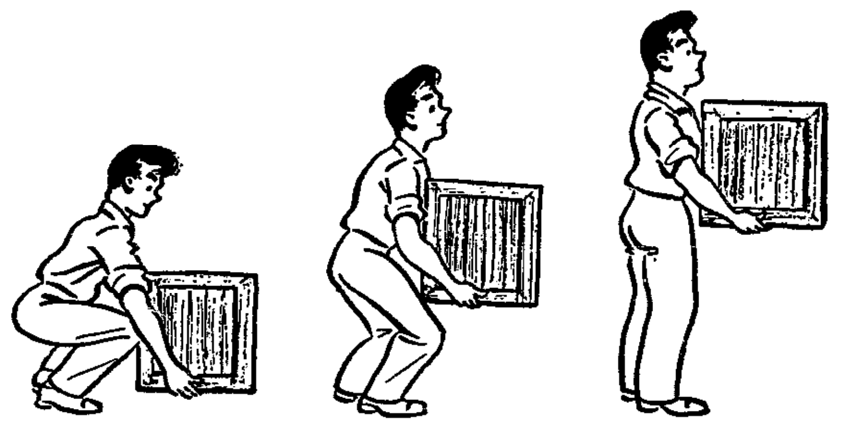
Fig. 2.16. The use of safety blocks prevents accidents such as this.

achieved by placing the feet from 8 to 12 inches apart. The feet should be placed close to the base of the object to be lifted so that the back muscles will not have to lift all the load.

Be sure to bend the knees outward and keep the back straight. Lift the load by pushing up with the legs. The load should be kept close to the body as it is lifted so that full advantage may be taken of the mechanical leverage of the body. In turning with a load, change the direction of the feet instead of twisting the body. When a load is placed on a table, place it on the edge of the table and push it forward. Let the table take part of the load.

When a load is to be placed on the floor, bend the knees, keeping the back straight and the load close to the body. Lower the load with the arm and leg muscles. Before placing a load on a floor make sure that there are blocks to support the load so that the fingers will not be pinched.

Never be afraid to ask for help to carry a load. It is better to obtain help than to sprain your back. If a load interferes with walking, it is safer to obtain help.



(Courtesy Bureau of Labor Standards)

Fig. 2.17. The correct way to lift.

Keep the shop clean to avoid tripping and falling while carrying loads. Use mechanical equipment for lifting and carrying loads whenever possible.

Falls

Falls, stepping on nails, and slipping or stumbling on pieces of lumber may cause painful injuries. Neat working habits and alertness will prevent most accidents of this type. Injuries may be avoided by developing the habits of keeping the working area clean, replacing tools properly when they are not in use, placing loose nails in a suitable container, and clinching or removing nails which are driven through boards.

In a shop, grease should be cleaned from the floor as soon as it is spilled. Slipping on grease may cause a dangerous fall. Another common cause of falls in shops is the use of makeshift ladders. A chair, table, or box makes an unsafe ladder. Reaching from ladders may also cause falls. Always take time to obtain a safe ladder and then use it carefully.

In the category of accidental deaths, the national toll from falls is exceeded only by accidental motor vehicle deaths.

General Safety Precautions

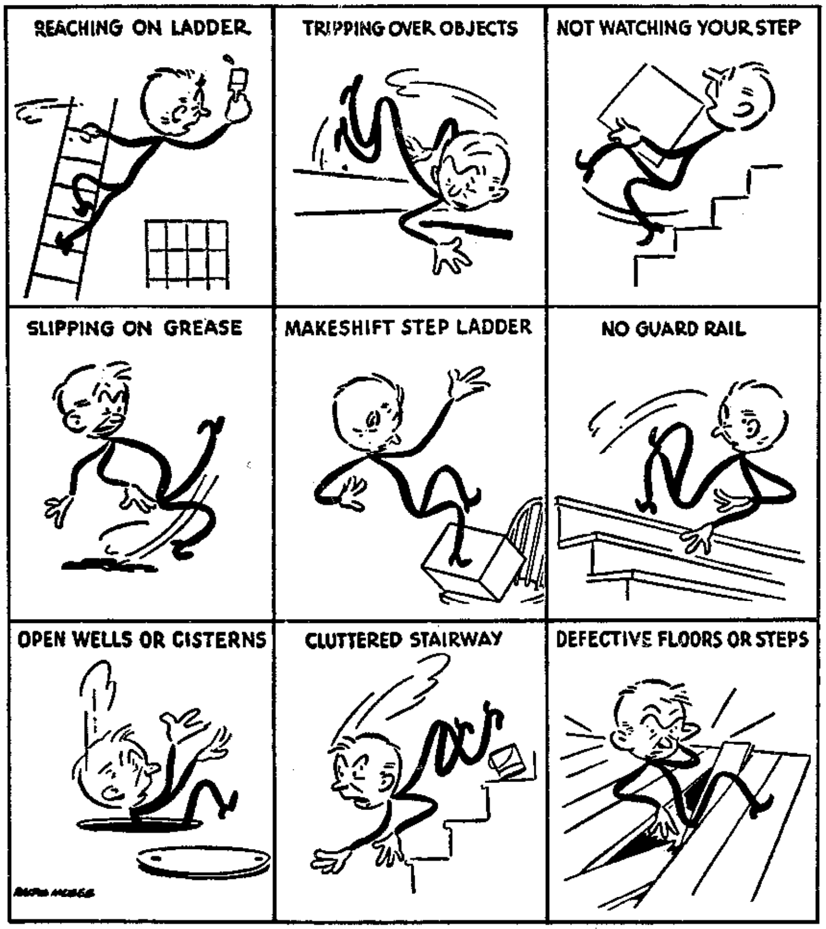
Machinery and Equipment—Tractor wheels that are kept spread whenever possible will reduce tipping hazards. Guards that are kept in place will make the operation of machinery on farms and in agricultural businesses less hazardous. Many accidents may be prevented by turning off the power before adjusting or unclogging machinery. The development of the habit of turning off the power before working on machinery is a prerequisite for the safe operation of equipment. Persons should not be allowed to operate machinery until they have developed this habit.

All equipment should be checked periodically to determine whether or not it is safe. Before a tractor is started, it should be out of gear and the brake should be set.

Power take-off shafts are dangerous, and the habit of not stepping over them should be developed. Loose, torn, or ragged clothing worn around machinery is dangerous. It is very easy to become entangled in gears and moving parts. In fact, avoid climbing over or around machinery when it is operating.

Another frequent cause of deaths and injuries is the operating of a tractor on steep inclines and on treacherous banks. Adjusting and getting in front of mowing machines while they are in gear also causes many serious accidents.

Buildings—The ladders and steps in use on farms and in other agricultural businesses are often in need of repair, and they cause many accidents. Handrails should be placed on stairways, and ladder and hay chute openings need to be protected adequately. These openings and stairways may be made less dangerous by adequate lighting.



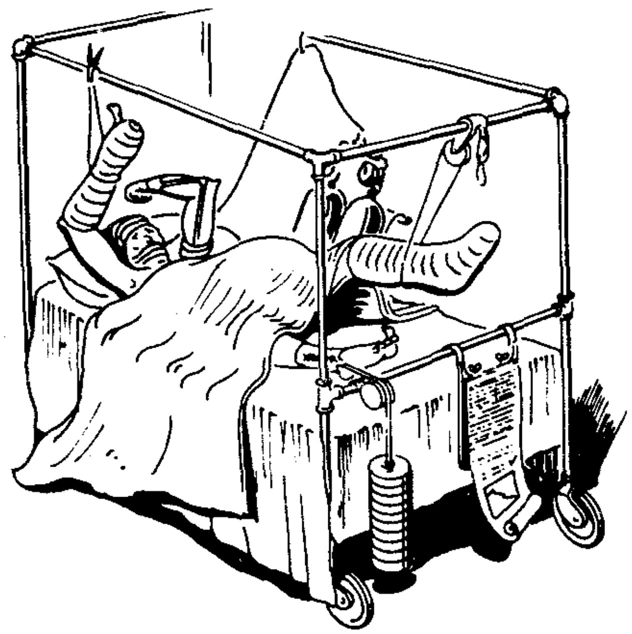
(Courtesy National Safety Council)

Fig. 2.18. Some common causes of accidents on farms and in agricultural businesses.

Loose materials stored overhead may fall and cause injuries. Nails in loose boards are often not pulled and may cause painful injuries. The yard and buildings should be kept clean of tools, forks, rubbish, and waste.

Metal-roofed buildings require proper grounding. Frequent checks should be made to determine whether the lightning rods on buildings are well grounded. Ladders should be quickly accessible in case of fire, and they should be long enough to reach the roof of the highest building on the farm or the nonfarm agricultural business.

Fires—Fires and explosions cause many deaths. Numerous explosions have occurred in agricultural shops because gasoline was used for cleaning. Such an explosion usually results in the death of someone and in the destruction of the shop. The only safe use to be made of gasoline is as motor fuel. The use of gasoline in a shop is especially dangerous. Welding in another part of the shop may



(Courtesy Vocational Agriculture Service, University of Illinois)

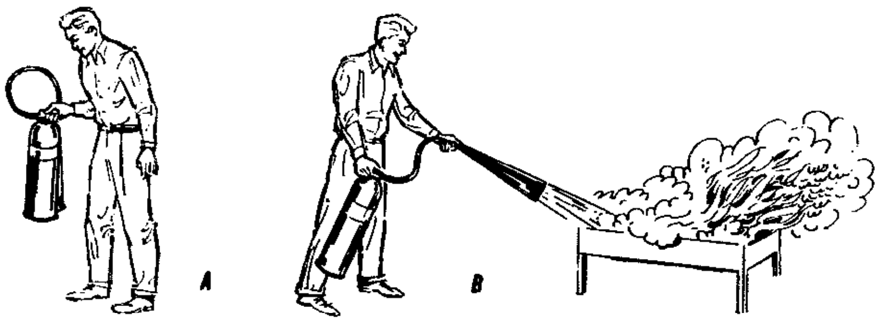
Fig. 2.19. Failure to practice safety precautions can be expensive and painful.

cause an explosion. Only safe cleaning fluids with a high flash point should be used for cleaning.

Paints, varnishes, and lacquers are flammable liquids which produce gases or vapors when exposed to the air or when heated. These gases or vapors are very combustible. Special care must be taken when quick drying paints, varnishes, or lacquers are used inside a building. The proper mixture of air and vapors from these products will produce violent explosions as well as fire. The vapors may be ignited by a lighted pipe, cigar, or cigarette, a static spark, or an open flame. Adequate ventilation will reduce the hazard of painting inside a building. All windows and doors should be kept open while painting. It is not safe to spray paint or use quick drying paint products in a school's agricultural shop or home shop because of the many sources of ignition such as a welder or sparks from a grinder.

Fires may occur because of the improper storage of the waste rags used in painting, or the improper storage of paint. Waste rags used in wiping paint may cause a fire through spontaneous ignition. If waste rags are kept, they should be stored in closed metal containers. Paint that is stored should be kept in closed containers in a metal cabinet which is not located near stairways, combustible materials, or heat.

All shop workers should know where the fire extinguishing equipment is and how to use it. If workers do not know how to use firefighting equipment, it is their responsibility to learn how. Everyone should feel a responsibility for removing and reporting fire hazards. Aisles, fire escapes, and stairways should be kept clean in case a fire occurs. Welding should never be done when flammable vapors, gases, or



(Courtesy U.S.D.A.)

Fig. 2.20. Operation of a carbon dioxide fire extinguisher. Direct the discharge at the near edge and the bottom of the fire, then forward and upward. Continue to use after the fire is out to prevent a reflash of the fire.

liquids are present. Engines should not be filled with gasoline in a shop; nor should gasoline or other fuel be stored in a shop.

Agricultural businesses and farms need emergency water supplies for fires, such as ponds, barrels of water in buildings, or hose attachments to a water system. Water, however, should not be used to fight many types of shop fires. Boxes of sand in buildings are also needed to supplement other equipment in fighting oil or gasoline fires.

The elimination of oil- or paint-saturated rags, weeds, brush, old lumber, and other fire hazards from around buildings will prevent many fires. Gasoline should be stored underground or in an isolated tank at least 40 feet from the buildings of an agricultural business or a farm. An additional safety precaution is painting gasoline containers a bright red.

Tractors filled while running or while hot may cause a fire or an explosion. Cars, tractors, and other motors should be kept in buildings separate from the barns.

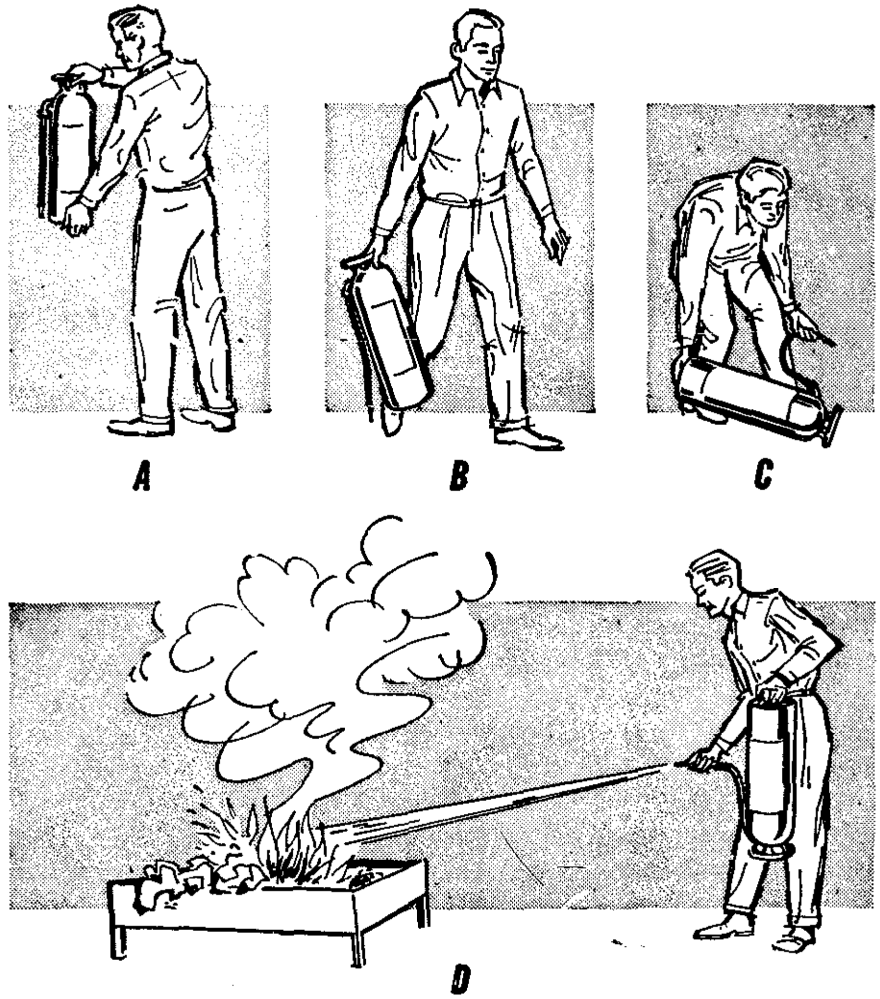
Approved types of fire extinguishers placed at or near the entrances of buildings are a worthwhile fire precaution. These fire extinguishers need regular checks to determine whether or not they are operating correctly.

Brooder houses are frequent sources of fires, so they should be placed at least 100 feet from other buildings and from each other. If there is no rural fire department, it is wise to arrange with neighbors to come with tools and ladders in case of fire.

Newly stored hay often causes fire, so it should be watched closely. Another common source of fires is smoking. Avoid smoking around farm or other agricultural buildings, and do not carry matches loose in pockets.

When starting a fire to burn rubbish, select a day that is not windy. Do not start a fire close to buildings, because it may get windy.

Carbon Monoxide and Fumes—Fumes of various types produced in agricultural shops are often dangerous as well as annoying. Welders and engines frequently produce fumes, so agricultural shops should be adequately ventilated in



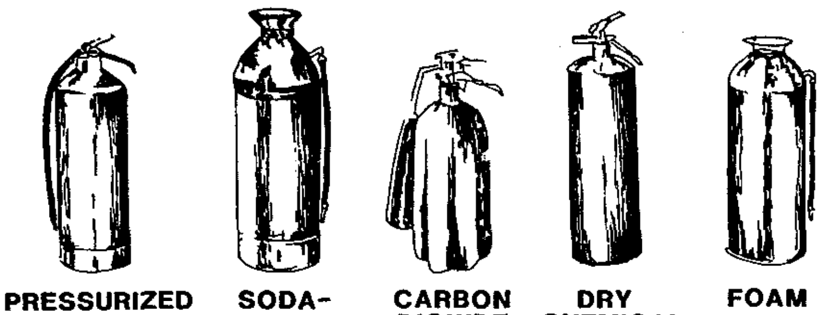
(Courtesy U.S.D.A.)

Fig. 2.21. Operation of a foam extinguisher. Direct the stream above the fire and against the wall if possible. If not, let the foam fall on the fire with as little force as possible. Learn how to operate all types of fire extinguishers and when each type should be used.

order that all fumes may be eliminated quickly. Exhaust fans and hoods are often used to remove fumes. If facilities for doing this are inadequate, a worker may usually avoid danger by performing the activity producing the fumes outside the shop.

Carbon monoxide is a poisonous gas and is produced by gasoline engines, stoves, and furnaces. One or two parts of carbon monoxide in 1,000 parts of air will cause death if breathed continuously for several hours.

If engines are operated in a shop, the shop should have equipment for removing the carbon monoxide produced. Often shops have flexible hoses or pipes that may be attached to the exhausts of engines being operated. These flexible hoses or pipes are connected with an exhaust fan.



(Courtesy Vocational Agriculture Service, University of Illinois)

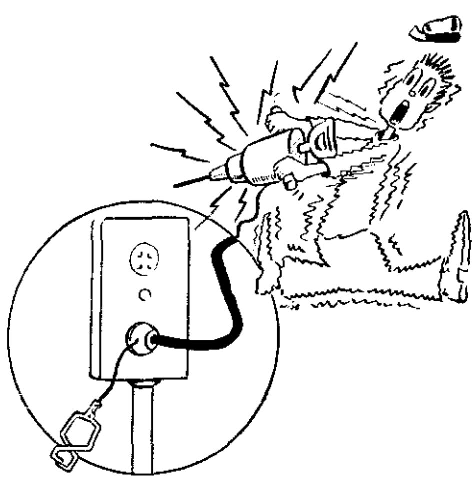
Fig. 2.22. Types of fire extinguishers.

The symptoms of carbon monoxide poisoning are weakness and weariness. These are often followed by dizziness, a headache, and a desire to vomit. If these symptoms are noticed, get to fresh air at once. Often, however, a tractor being operated in a closed shop will produce carbon monoxide so rapidly that none of these indications will be noticed before consciousness is lost.

If anyone is found unconscious in a shop, provide him or her with fresh air at once. If persons overcome by carbon monoxide are given fresh air while still breathing, they will usually recover quickly with no permanent injury.

A slight headache will usually follow the breathing of very small amounts of carbon monoxide. If you experience headaches after working in a shop, suspect carbon monoxide and check possible sources of the gas.

Electricity—Farmers and workers in nonfarm agricultural businesses subject themselves to many dangers in using electricity. Since electricity is being used more and more, it is essential that agricultural workers learn the precautions neces-



(Courtesy National Commission on Safety Education, NEA)

Fig. 2.23. All electrical appliances should be grounded before they are used.

sary for using it safely. A very important safety habit is the disconnecting of the current before any work is done on an electrical conductor. Circuits should not be overloaded. Fuses or circuit breakers that have an amperage rating too high for the conductors they are protecting will permit these conductors to overheat and cause fires.

Portable motors are being used more extensively on farms and in nonfarm agricultural businesses. To obtain the safe operation of these motors, heavy moisture-proof rubber cords are essential. Frequent checks of electrical appliances and cords are important to detect unsafe equipment before it produces a fire or shocks a worker. Special precautions should be observed to make certain that portable electrical equipment is well grounded. The use of ground fault circuit interrupters is recommended. Only approved electric fence controllers should be used. All workers should know the location of the main switch box, and the pathway to it should be free of all obstructions so that the current may be disconnected if trouble occurs. All agricultural workers also need to know how to treat electric shock cases.

Sanitation and Health—Sunlight is beneficial, but excessive exposure of the body to the sun may produce skin troubles and other difficulties. Heat collapse may often be prevented by drinking plenty of water.

Care needs to be exercised to protect drinking water from contamination. Wells should be sealed to prevent contamination by surface water. The natural drainage should be away from wells, and wells need to be located at least 100 feet from septic tanks and other sewage disposal locations.

During electrical storms, agricultural workers increase their danger when they stand under a lone tree or near wire fences.

Farms and nonfarm agricultural businesses need first-aid kits located in strategic positions. These first-aid kits need to be kept well stocked, and agricultural workers need to learn how to use them if they are to be of value.

FIRST AID

When accidents do occur, every agricultural worker needs to know what to do. Knowing how to administer first aid may save a life. The value of first aid must not be overestimated, however, and a physician should be called promptly, especially if the injury is serious or if the nature of the injury is not apparent.

First-aid methods may be considered here only briefly. It is desirable for farmers and other agricultural workers to secure special instruction in first aid. In most communities there are first-aid courses, taught under the sponsorship of the American Red Cross, in which farmers and other agricultural workers may enroll.

Bleeding—The first thing to do after an accident is to determine whether the patient is bleeding. If bleeding is occurring from a large artery, the patient may die in a few minutes unless the bleeding is arrested. Bleeding may be stopped by:

1. Pressure over the wound with dressing.

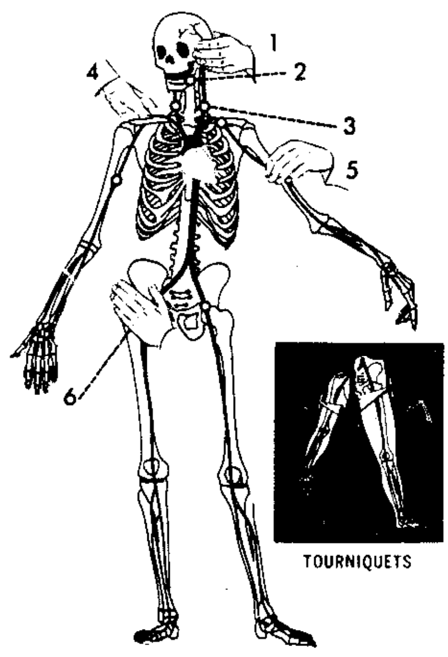
2. Application of pressure at pressure points.
3. A tourniquet.

In most cases a few layers of gauze with pressure over the wound will stop bleeding. If this does not stop the bleeding, apply pressure at the appropriate pressure point. Only use a tourniquet in life-saving situations. Never use a tourniquet unless there is no alternative. For example, if a leg is severed, a tourniquet is necessary to keep the person from bleeding to death. A tourniquet should be a piece of sterile cloth at least 1 inch wide. If nothing else is available, use a handerchief, necktie, belt, or towel. Bleeding in the arm may be arrested by appling a tourniquet a hand's width in front of the armpit. For the leg, place the tourniquet a hand's width below the groin.

Before appling a tourniquet, place several layers of gauze or cloth around the arm or leg to prevent injury at the site of the tourniquet. Often when a tourniquet is used, it is not tight enough, which may increase instead of decrease bleeding. Use a stick, pencil, or ruler to twist the tourniquet tight. Don't twist so tight that the skin is cut, however. Twist the tourniquet rapidly until the bleeding stops.

Never let a tourniquet be hidden so that it may be forgotten. The first-aid instructions of the American Red Cross require that every patient with a tourniquet be marked on the forehead with a red crayon. Pin a note to the person's clothing regarding the tourniquet. Seek medical assistance at once.

A tourniquet should not be used to stop venous bleeding, or bleeding from veins. Blood from arteries is bright red and comes in spurts. Blood from veins is dark blue in color.



(Courtesy National Safety Council)

Fig. 2.24. The pressure points to stop bleeding.

General Care—When an accident occurs, do not become excited and attempt to move the patient immediately, because there may be a bone fracture or other injuries which movement would complicate. Get the patient in a comfortable position. Loosen tight clothing. Examine the mouth and remove any foreign substances. Remove false teeth and bridgework if there is danger that the person may swallow them. Turn the head to one side if the patient is vomiting to prevent the drawing of the contents of the stomach into the lungs.

If a fracture is possible, examine the patient with extreme gentleness. Splints should be applied if a fracture is suspected. Wrap and tie the arm or leg in a pillow if no splint boards are available.

All skin abrasions need treatment because if an infection starts it may lead to blood poisoning. Clean wounds with soap and water and apply an antiseptic such as iodine, merthiolate, metaphin, mercresin, or zephrain.

Shock—Treat for shock first and for injuries later. If the patiene has a weak and rapid pulse; is cold, clammy, and covered with perspiration; is unconscious or semi-conscious; or has rapid, irregular, and shallow breathing, treatment for shock is needed. Lay the patient down with the head low. Keep the body warm by wrapping in blankets and using hot water bottles. Provide plenty of fresh air. Give the person a stimulant such as black coffee. A teaspoonful of spirits of ammonia in a small quantity of water may also be used as a stimulant. Don't try to give a semiconscious or unconscious person liquids, because they may strangle him or her.

Bruises—When the tissues beneath the skin are torn without the skin being torn, it is known as a bruise. Discoloration results because bleeding occurs, but the blood is unable to escape because the skin is not torn. Symptoms are swelling, tenderness, and soreness. A light bandage over a bruise may reduce internal bleeding. Don't open the bruise, but use cold applications except when there is shock or when the patient is old or acutely ill. The cold applications may be a saturated solution of Epsom salts or a 15 per cent solution of alcohol in water.

Scalds and Burns—Pain caused by scalds and burns may be decreased by proper treatment. The danger from a burn is in proportion to the area covered and the depth of the burn. Extensive and deep burns should be treated by a physician immediately.

Minor burns may be treated by submerging the area in cold water until pain subsides. Apply a dry cloth for protection from contamination.

Only sterilized gauze should be used as a dressing, because there is extreme danger of infection. Second-degree burns often blister. For second-degree burns, remove clothing in the vicinity of the burns. Cover with a clean cloth dipped in ice water. Blot dry and apply sterile gauze. If the legs or arms are burned, keep them elevated. Seek medical attention. If the skin is charred or white, it is a third-degree burn. For third-degree burns, do not remove charred clothing. Loosely cover the burns with a clean cloth. Keep burned legs and arms elevated, and do not permit the victim to walk. Arrange for transportation to a hospital.

If an eye is burned, see a doctor or nurse at once. Until medical attention is received, flush the eye with water for 5 to 15 minutes. Then cover it with a protective bandage.

Breathing a flame or steam is serious. Keep the patient quiet, apply an ice bag to the chest, and give the patient milk or cream if he or she can swallow. Acid burns may be treated by washing them with a solution of bicarbonate of soda. For

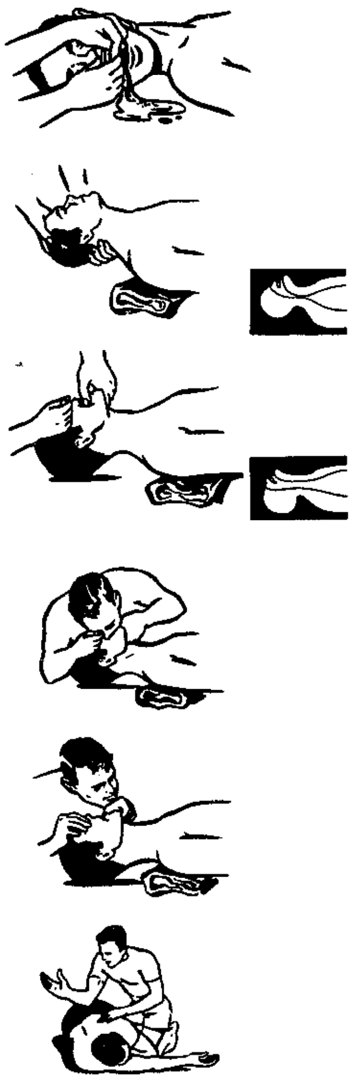


Fig. 2.25. Artificial respiration, mouth-to-mouth method. Turn the victim's head to one side and remove any foreign matter. Then place a folded coat under the shoulders and tilt the head back as far as possible. Pull the chin upward to keep the air passage open. Pinch the nostrils shut, take a deep breath, place your mouth over the victim's mouth and your thumb, creating a tight seal, and blow until the chest rises. Remove your mouth and listen for the air outflow. Inflate the victim's lungs 12 times per minute. If first attempts to inflate the lungs are unsuccessful, turn the victim on one side and administer sharp blows between the shoulders to dislodge any obstructions in the air passage.

alkali burns, wash with an acid solution such as vinegar. If the cause is not known, flood the burned area with large amounts of water. Seek medical attention.

Artificial Respiration—Electrical shock, lack of oxygen, or water submersion may cause breathing to stop. When breathing stops, artifical respiration is needed. Farmers and other agricultural workers who do not know how to give artificial respiration should seek instruction.

While artificial respiration is being given, an assistant should loosen any tight clothing about the neck, chest, and waist. The patient needs to be kept warm and should not be given any liquids until fully conscious. Keep the patient quiet and lying down after he or she revives, to avoid heart strain. If a doctor is not present after the revival of the patient, give him or her a stimulant such as hot tea or coffee. Get a doctor for the patient as soon as possible.

Do not move a patient any more than necessary to give artificial respiration. Watch the patient closely after breathing starts, because frequently the breathing will stop again.

PART II

Agricultural Shop Work

SHOP TOOLS AND EQUIPMENT

Student Abilities to Be Developed

1. Ability to plan a suitable agricultural shop.
2. Ability to establish, equip, and maintain an agricultural shop.
3. Ability to recognize and follow the necessary safety rules in an agricultural shop.
4. Ability to select the correct tools for an agricultural mechanics activity.
5. Ability to use power tools.
6. Ability to use hand tools.
7. Ability to sharpen hand tools.
8. Ability to repair hand tools.

CHAPTER 3

Developing a Home Shop for Agricultural Mechanics

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Why should a farmer or nonfarm agricultural worker have a home shop?
2. How may a home shop be established?
3. What are the essential requirements of a shop for agricultural mechanics?
4. What tools and equipment are needed?
5. How should the equipment be arranged in a shop?
6. What supplies are needed and how should they be stored?
7. How should the shop and equipment be maintained?
8. What safety precautions should be observed?
9. How should fuels and oils be stored?

Why Have a Home Shop—One of the objectives of agricultural mechanics instruction is the establishment of home shops. Agricultural workers should take pride in maintaining properly the equipment they use on farms, in their businesses, and in their homes. It is very important for agricultural workers to keep their machinery and other equipment in satisfactory working condition for efficient operation. It is also important that they keep all buildings and fences in proper repair. Agricultural workers on and off farms also need to construct new buildings, fences, and labor-saving devices occasionally. They may desire to install or assist with the installation of electrical systems, plumbing systems, material handling equipment, or other types of conveniences. *By being proficient in the use of tools and having suitable facilities to perform the needed jobs which they are capable of doing, farmers and nonfarm agricultural workers can save considerable time, inconvenience, and money.*

Agricultural workers should have home shops for the following reasons:

1. To provide a suitable place for storing and using tools and equipment. *Tools are frequently lost when they are not properly stored; keep them in a definite place.*
2. To provide suitable space for working on agricultural equipment.
3. To provide storage space for shop supplies.

4. To provide adequate facilities for performing the shop jobs which should and can be done on the farm, in an agricultural business, and in the home.

Agricultural workers on and off farms cannot hope to be specialists in all the jobs of a mechanical nature they encounter. The specialized jobs such as completely overhauling a tractor, using a welder to build up worn shafts and other worn machinery parts, and repairing complex electrical equipment, in most instances, should be taken to a specialized mechanic. The jobs unspecialized agricultural workers should do will depend on their abilities and the availability of suitable facilities. Unspecialized agricultural workers should endeavor to develop their abilities to perform the unspecialized mechanical jobs needed in connection with the successful performance of their jobs. Farming and other agricultural businesses have become highly mechanized, making it important for all agricultural workers to become proficient in the use of tools and in the maintenance of agricultural equipment.

Establishing a Home Shop—A home shop may be established in a number of different ways:

1. It may be set up in a separate building.
2. It may be constructed as a part of some other building, such as a machine shed, a garage, or a truck and tractor shed.
3. It may be placed in an existing building.

A few good tools with a definite place to keep them may be the beginning of a home shop. Additional equipment and space may be acquired as funds become available. It is important for a student of vocational agriculture to establish a home shop or to improve the existing shop.

Requirements of a Home Shop—A home shop should (1) provide ample space, (2) be of desirable construction, (3) have a suitable floor, (4) have a large main entrance, (5) have adequate lighting and ventilation, (6) have a suitable chimney, and (7) contain a satisfactory heating system.

The *size* of a shop should be based on the kind and amount of work to be done in it. Home shops usually vary in width from 32 to 36 feet and in length from 36 to 40 feet.

A *large doorway* should be provided for moving large equipment in and out of the shop. A door 24 to 27.5 feet wide and 14 to 16 feet high is desirable.

A *concrete floor* and a concrete apron outside the large doorway are desirable. Other types of floors may be used temporarily if necessary. A well packed dirt floor in some cases may be used until a better floor can be made available.

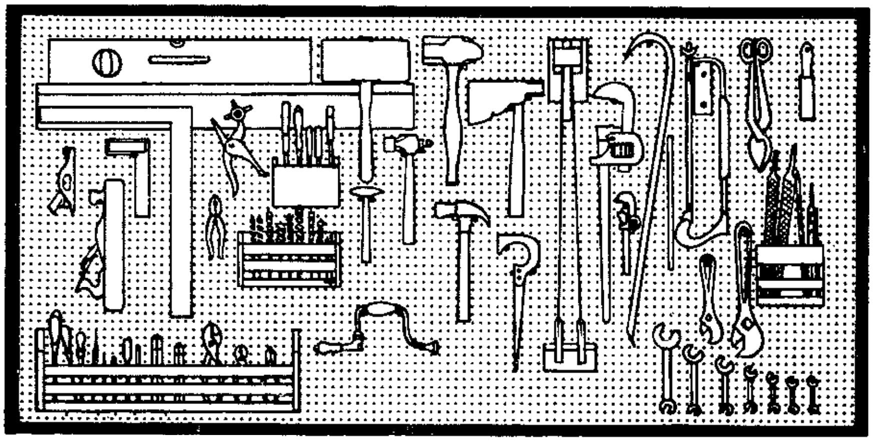
Adequate lighting and ventilation are important. The windows, if possible, should have small panes, and be located on at least two sides of the building to provide for proper ventilation. Windows should not be placed directly above a workbench, since tool cabinets may be hung in this space. The window space should be equal to at least 20 per cent of the floor area.

Electric lights should be provided in a shop. Glare-free lighting should be over each workbench, and over other work areas where there may be a need for supplemental light. Other lights should be placed near the ceiling so as to be out of the way.

Sufficient convenience outlets should be located about the room to provide for the use of electrical equipment. If an electric arc welder or another piece of equipment using 220 volts is to be used, the shop should be properly wired with 220-volt circuits.

A *chimney* of sufficient size should be provided to meet the needs of the heating system. The area around the pipe where it passes through the roof should be insulated properly. It should be extended slightly above the peak of the roof to obtain sufficient draft.

Proper heating facilities should be provided. An old stove may be available, or a new one may be purchased.



(Courtesy Wire Division, Republic Steel Corporation)

Fig. 3.1. A pegboard tool panel for storing hand tools in an agricultural shop.

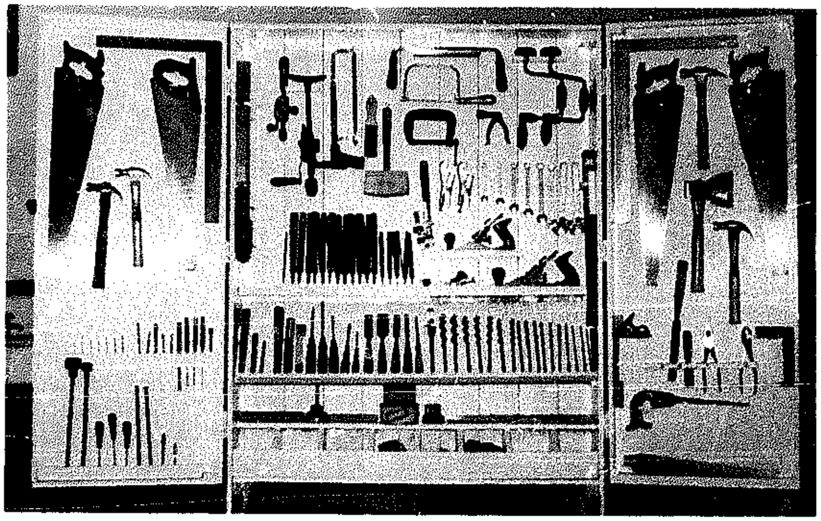


Fig. 3.2. A tool cabinet with doors for use in an agricultural shop.

Providing Tools and Equipment—The following procedure is suggested for selecting and providing tools and equipment:

1. Prepare a list of the items already on hand.
2. Prepare a list of the items needed to perform the shop jobs often encountered in agricultural businesses and on farms.
3. Compare the list of items needed with those on hand to determine which ones to secure.
4. Decide (a) where you are going to obtain space for storing and using the equipment, (b) the kind of shop you will have, and (c) how the tools will be stored.
5. Decide which items are needed most urgently and should be secured first. The amount of money available for the purchase of equipment should also be considered.
6. Decide which items of equipment may be homemade.
7. Select *standard brand* tools of good quality. This does not mean you will have to secure the most expensive tools; neither does it mean that the cheapest tools should be purchased. A medium priced tool is generally satisfactory for a home shop.
8. Purchase and add tools and equipment as the need arises and money becomes available.

SUGGESTED TOOL AND EQUIPMENT LIST FOR A HOME SHOP

Machinery Tools

1 bender, iron, universal, complete with dies
1 bleeder, hydraulic brake
1 chain, log
1 charger, battery
1 cleaner, parts
1 cleaner, washer, high-pressure pump
1 compressor, air
1 creeper, automobile
1 cutter, bolt
1 drill, twist, high-speed
1 gauge, thickness
1 grinder, portable
1 hoist, safety, differential chain
1 impact tool, 1/2", portable electric
1 indicator, speed
1 jack, heavy-duty, hydraulic
1 lamp, trouble, heavy-duty
1 light, neon timing
1 micrometer, 2"– 6" combination
2 oilers, bench, 1/3 pint
1 pr. pliers, long nose
1 pliers, water pump
1 puller, gear, heavy-duty
1 saw, abrasive cutoff
1 saw, metal cutting
2 shears, metal, 3/16" and 1/2"
2 stands, safety, 2 ton
1 tester, spark plug
1 tester, storage battery
1 wrench, air impact
1 wrench, socket, spark plug
1 wrench, stud bolt puller
1 wrench, tension
1 wrench set, Allen
1 wrench set, distributor
2 wrench sets, open end 1/4" to 3/4", and set of metric sizes
2 wrench sets, socket and open end, up to 2 1/4" by 32nds, and metric set
2 wrench sets, special mechanic's 7/16" to 1", and metric set
1 wrench set, tappet

Metalworking

1 anvil, 100–150 lbs.
1 anvil stand (homemade)
1 blacksmith's leg vise, 4 1/2"
1 blacksmith's 32-oz. hammer

1 propane torch
1 bolt cutter
1 center punch, 3/8"
3 cold chisels, 1/2" to 3/4"
4 adjustable wrenches, 6", 8", 10", and 12"
1 electric arc welder, 220 amp., and oxyacetylene outfit
1 electric drill, 1/2" heavy-duty, with stand (desirable)
1 file, flat bastard, 10"
1 file, round bastard, 10"
1 file, mill bastard, 10"
1 hacksaw frame and 1 doz. blades
1 hand drill
1 hardie to fit anvil
1 machinist's hammer, ball-peen, 1 lb.
1 machinist's vise, 4 1/2"
1 machinist's hammer, 24 oz.
2 monkey wrenches, 10" and 24"
1 pr. bolt tongs, 3/8" × 20"
1 pr. straight lip tongs, 20"
1 electric soldering iron, 300 W.
2 pr. pliers
1 drift punch, 3/8"
2 pin punches
1 pr. tinner's snips, 2 1/2" cut
1 pr. winged dividers
1 riveting hammer, 12 oz.
1 rivet set
2 reamers, taper, 1/2" and 1"
1 screw plate, tap and dies—NC and NF—1/4" to 3/4"
1 set S wrenches
1 set bits—stock drills, 1/16" to 5/8"
1 set box end wrenches, 3/8" to 1"
1 set socket wrenches, 12-point, 1/4" to 1" by 16ths with ratchet handle
1 set double end wrenches, 3/8" to 1"
1 vise-grip wrench, 8"
1 set Ezy-outs
1 snips, aviation

Carpentry

1 auger bit file
1 carpenter's framing square, 16" × 24"
1 carpenter's level, 24"
2 chisels, socket firmer, 1/2" and 1"
1 claw hammer, 16 oz.
1 combination carborundum oil stone
1 combination miter and try square, 12"
1 compass saw, 12"
1 crosscut saw, 26"
1 drawknife, 10"
1 expansive bit, 7/8"–3"
1 file card
1 grinding wheel dresser
1 half-round wood file
1 hatchet, 4" broad blade
1 jack plane, 14"
1 block plane, 7"
1 line tape, 50'
1 marking gauge
1 miter box (homemade)
4 nail sets, assorted sizes
1 ratchet brace, 10" sweep
1 round file, 10"
1 ripping bar, gooseneck, 3/4" × 30"
1 ripsaw, 6-point, 26"
1 countersink
1 spiral screwdriver
3 screwdrivers, 6", 8", and 10"
1 screwdriver for Phillips screws
2 screwdriver bits, 1/4" and 3/8"
1 set auger wood bits, 1/4"–1"
1 slim taper file, 6"
1 extra-slim taper file
1 tool cabinet (homemade)
1 tool grinder wheel, 1 1/2" face, 8" or 10" diameter
1 woodworking bench, 24"–30" wide and 6'–10' long (homemade)
1 woodworking vise, metal preferred, 7"
1 wood rasp, 10"
1 rasp plane

Pipe Work

1 pipe cutter, 1/2"–2"
1 pipe reamer, 1/4"–2"
1 pipe vise, 1/8"–2 1/2"
2 pipe wrenches, 14" and 18"
1 set pipe stock and dies, 1/8" to 2"
1 cutter, copper tubing
1 flaring tool, copper tubing

Glazing

1 box glazier's points
1 glass cutter
1 putty knife, $1^1/_4$" blade
1 putty knife, offset

Concrete Work

1 cement edger
1 cement jointer
1 measuring box, 12" × 12" × 12" (homemade)
1 jointing trowel
1 pointing trowel
2 shovels, square point, short handle
1 tamper (homemade)
1 wood float (homemade)
1 set star drills
1 set masonry drills
1 wheelbarrow

Power Tools

1 table saw, 10" with 1-HP motor
1 grinder, 8" × $1^5/_8$" wheels
1 portable saw, 8"
1 sabre saw
1 portable drill press stand and portable drill, $^1/_2$"
1 portable electric drill, $^1/_4$"
1 compressor, 10-gal. tank, 150-lb. capacity
1 portable grinder, 5" wheel

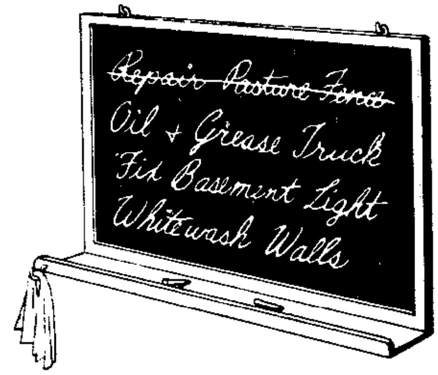
Electric Work

1 pr. lineman's pliers
1 pr. long nose pliers
1 pr. channel lock pliers
1 screwdriver, $^3/_{16}$" blade
1 cable cutter
1 wire stripper and crimper
1 tape measure, retractable
1 meter, volt-ohm
1 cable ripper
1 keyhole saw
1 tape, fish
1 tool pouch, electrician's
1 knife, electrician's

The first pieces of equipment to obtain for a home shop should include items such as essential pieces of woodworking and metalworking equipment, proper storage facilities, and workbenches.

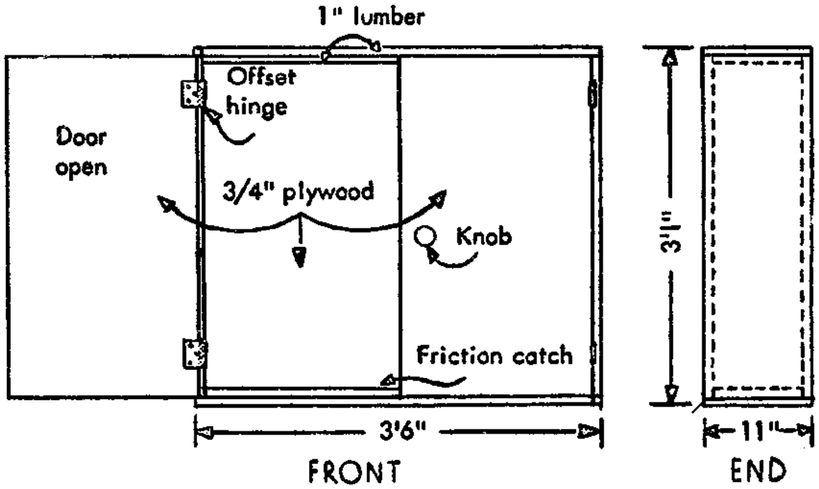
A number of pieces of shop equipment can be homemade. These include workbenches, storage racks, anvil stands, sawhorses, tool cabinets, and miter boxes. The workbenches should be made 24 to 30 inches wide and 6 to 10 feet long, depending on the size of the shop. The heights of benches vary from 30 to 35 inches, depending on the height of the person using them. Tool cabinets should be provided for storing tools. If wall tool cabinets are used, as shown in Fig. 3.4, a panel is formed when the doors of the cabinets are opened, thus making all tools readily accessible. They can be locked when the tools are not in use, and they protect the tools from dust.

Arranging the Equipment—Insofar as possible, the equipment should be arranged along the walls of the shop so that the center floor space is available for repairing and constructing large pieces of equipment. Workbenches should be



(Courtesy Wire Division, Republic Steel Corporation)

Fig. 3.3. A handy chalkboard reminder for a home agricultural shop.



(Courtesy John Matthews, Vocational Agriculture Service, University of Illinois)

Fig. 3.4. A wall tool cabinet. (Plans developed by George Sprau, Illinois.)

placed along the walls with tool cabinets above them. It is desirable to have a woodworking bench on one side of the room with the woodworking and carpentry tools in a cabinet placed directly above the bench. A metalworking bench may be placed on the opposite side of the room, with a wall cabinet containing machinery and metalworking tools hung above it. If only one bench is available, a woodworking vise may be placed on one end and a machinist's vise placed on the opposite end. Tools such as forks, shovels, hoes, corn knives, and spades may be hung on the walls.

Providing and Storing Supplies—The supplies to keep in a shop will depend on the jobs to be done. The following is a suggested list to keep on hand:

Carpentry

1. Assorted pieces of lumber of the more common dimensions
2. Assorted sizes of nails
3. Assorted sizes of wood screws
4. Glue, sandpaper, and steel wool

Painting, Finishing, and Glazing

1. Clean rags or waste
2. Glazier's points
3. Linseed oil
4. Putty or glazing compound
5. Soap
6. Turpentine
7. Wood stain, shellac, and varnish

Metal Work

1. Bar iron, flat, 1/4 to 3/8 inch thick
2. Bar iron, round, 1/4 to 1/2 inch diameter
3. Bolts, carriage, assorted sizes
4. Bolts, machine, assorted sizes
5. Washers, regular and lock, assorted sizes
6. Cotter pins, assorted sizes
7. Hacksaw blades
8. Safe solvent for cleaning machinery parts
9. Nuts, assorted sizes
10. Oil, machine
11. Oil, threading
12. Rivets, iron, assorted sizes
13. Sal ammoniac
14. Soldering flux
15. Solder, 50-50
16. Angle iron
17. Pipe
18. Welding rod and electrodes for electric arc welding
19. Welding rod for oxyacetylene welding

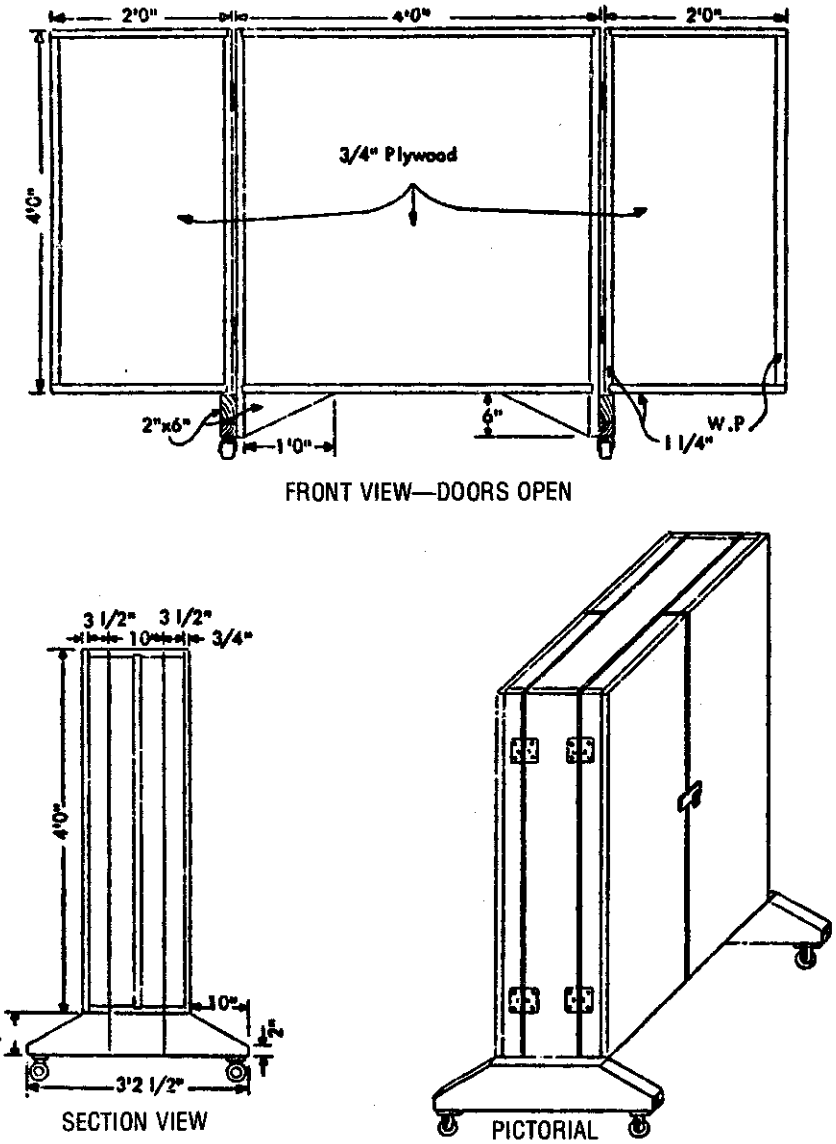
The supplies should be stored as near as possible to the place where they will be used.

Lumber storage may be provided in the shop attic, on a rack, or along a wall. Small pieces of lumber may be stored on a shelf placed below the workbenches.

Iron pieces may be stored in the attic space, on a rack along the wall, or on a shelf below the metalworking bench; or they may be stood on end in a corner of the room.

Small pieces, such as bolts, nails, and screws, may be kept in bins.

Hacksaw blades, welding rod, welding compound, and other supplies for use in metal work should be kept in a cabinet in the vicinity where they will be used.



(Courtesy John Matthews, Vocational Agriculture Service, University of Illinois)

Fig. 3.5. A rolling tool cabinet. (Plans drawn by A. V. Meadors, Illinois.)

Maintaining the Shop and Equipment—The importance of proper maintenance of the shop and equipment cannot be overemphasized. The equipment should be kept properly oiled and adjusted and in good working condition at all times. Frequently check each piece of equipment to see whether or not any rust is present; if so, clean it off immediately. Keep the saws, bits, and chisels sharpened, and do not forget to wipe the dust from all machines occasionally.

Using Safety Precautions—Every precaution should be taken to make a home shop a safe place in which to work. Agricultural workers on and off farms

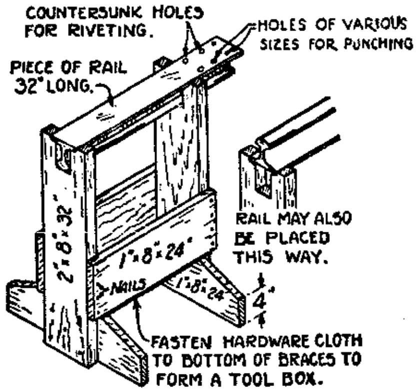
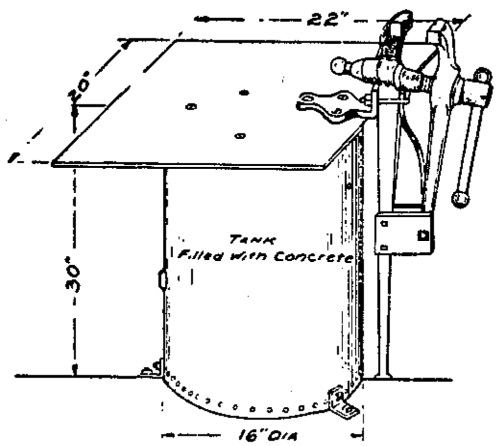


Fig. 3.6. A homemade anvil.



(Courtesy Division of Teacher Training, North Carolina State University)

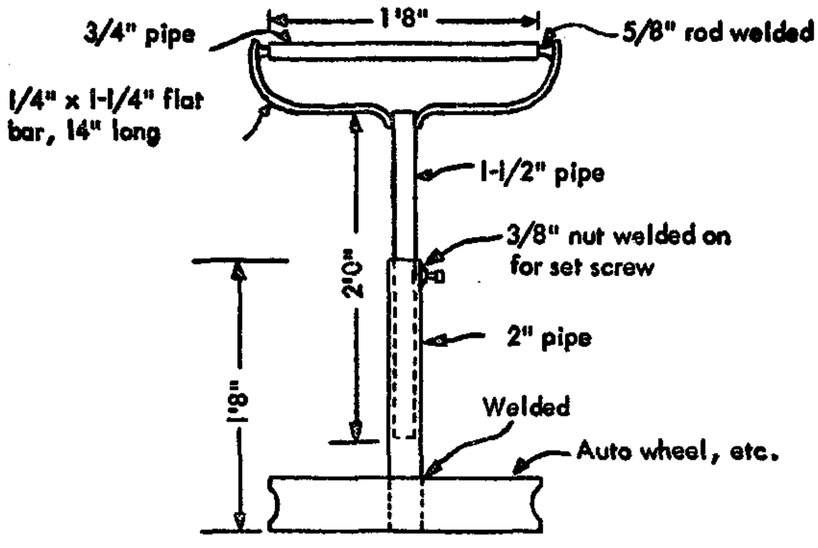
Fig. 3.7. An anchor for a blacksmith's vise.

should recognize the dangers and hazards connected with using shop tools and equipment and take the necessary measures to avoid them. The preceding chapter is devoted to safety in agricultural mechanics.

Fuel Storage and Servicing Center—The home shop should not be used for fuel storage and as a servicing center for tractors and trucks. Oil and fuels stored in a shop create a serious safety hazard. It is best to keep no gasoline in a shop. If a small quantity is kept in the shop, it should be stored in a *safety* can. Tractors and trucks should be refueled outside and not inside buildings.

Fuel storage facilities should be provided at least 50 feet away from any building or any other fire hazard. Most insurance companies will not pay a fire insurance claim if fuel is stored in a building or within 15 feet of a building.

An aboveground tank is the cheapest way of storing fuel. When a tank of this type is provided, gravity may be used to fill the tanks of tractors and trucks. If an



(Courtesy John Matthews, Vocational Agriculture Service, University of Illinois)

Fig. 3.8. A saw roller. (Plans drawn by V. E. Burgener, Illinois.)

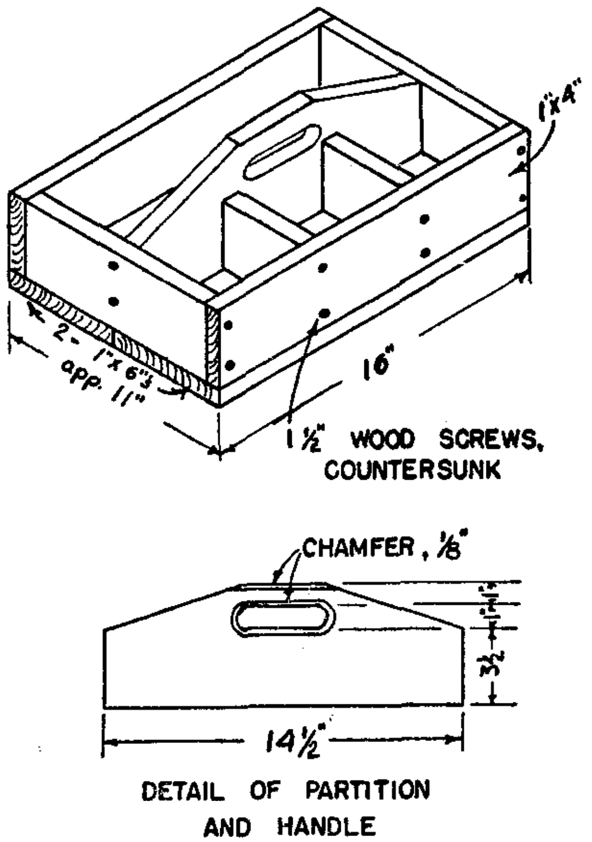
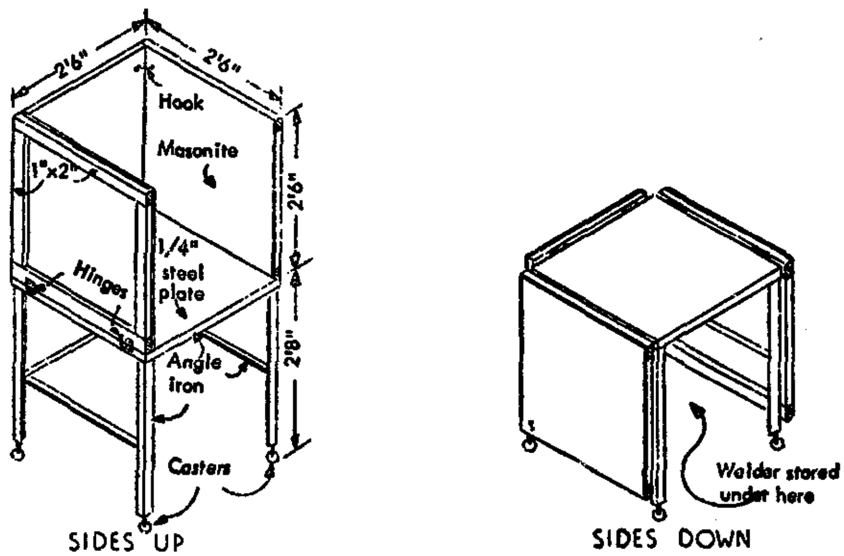


Fig. 3.9. A homemade nail box, which is a desirable piece of equipment in a home shop.

(Courtesy Wire Division, Republic Steel Corporation)

Fig. 3.10. A phone in the shop is very convenient.



(Courtesy John Matthews, Vocational Agriculture Service, University of Illinois)

Fig. 3.11. An arc welding table. (Plans drawn by Kenneth Diehl, Illinois.)

aboveground tank is used, a shade should be provided and the tank should be equipped with an approved pressure ventilating cap to reduce the loss of fuel by evaporation. This pressure ventilating cap must have a vacuum release valve to equalize the pressure when the air temperature drops. If a pressure ventilating cap is installed in a vented storage tank, the vent must be sealed. A storage tank should never be sealed completely, because a rising temperature can increase the pressure inside the tank until it bursts. A pressure ventilating cap allows the pressure to increase only to a certain point.

The loss of fuel from a tank equipped with a pressure ventilating cap will be considerably less than the loss of fuel in a vented tank. Also, more of the lighter parts of the fuel will be saved, and the gum content of the fuel will remain lower.

An underground storage system will save more fuel and is less dangerous than a pressurized tank, which is above the ground, but it is considerably more expensive to install.

A cabinet should be provided by a fuel storage tank for storing oil. As a safety precaution, fuel storage tanks should be marked to identify the type of fuel they contain. All tanks should also be marked as follows: *Flammable—Keep flames and fire away*.

When refueling a truck or tractor, always keep the hose nozzle in metal-to-metal contact with the tank being filled and be sure that the ignition and lights are turned off.

CHAPTER 4

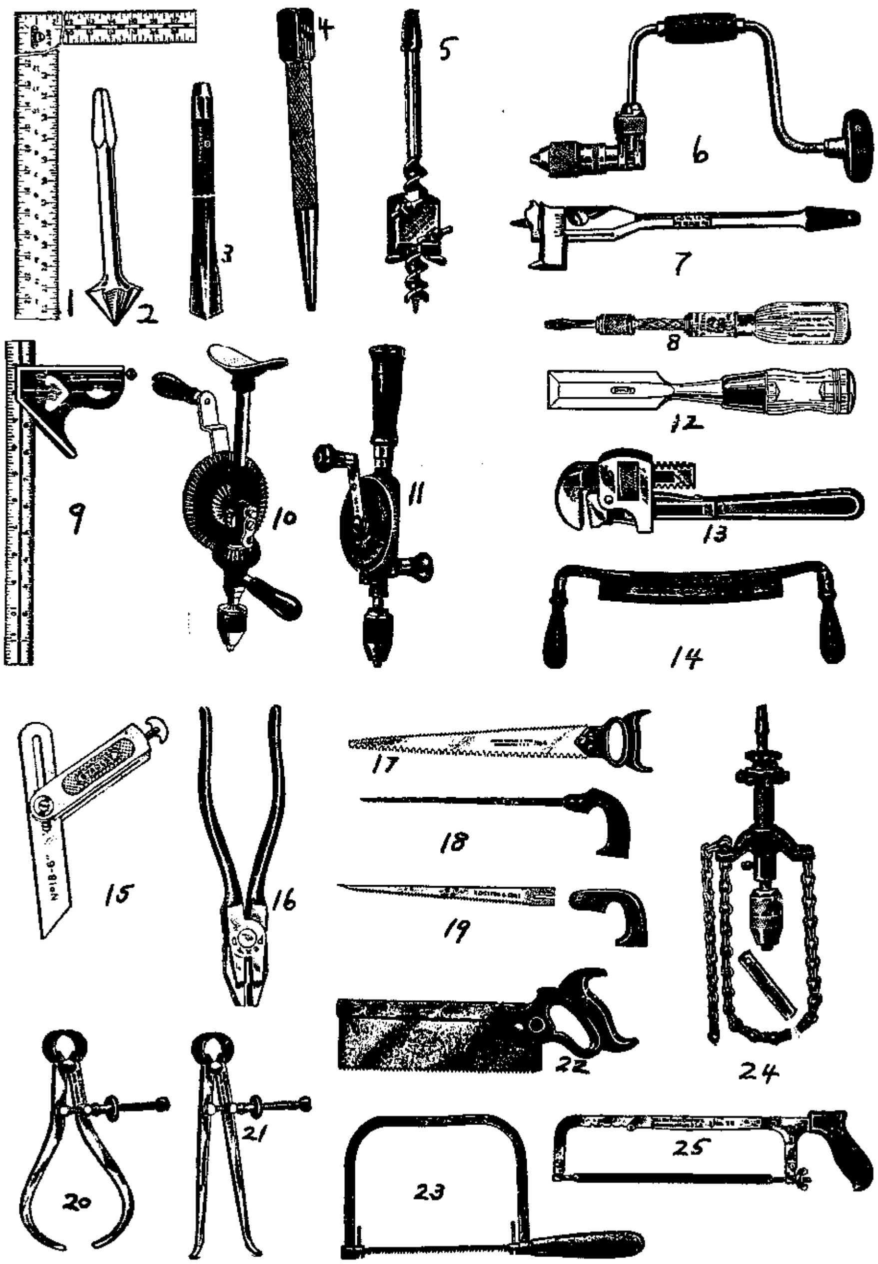
Selecting and Using Hand and Power Tools

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Why is the proper care of tools important?
2. How should tools be cleaned?
3. What are the common kinds of planes and their uses?
4. What are some precautions in planing?
5. How should a plane be assembled and adjusted?
6. What are the common kinds of squares and their uses?
7. What marking tools are necessary?
8. What are the common kinds of saws, and how are they used?
9. How should lumber be held in place when sawing?
10. What are the common kinds of chisels and their uses?
11. What are the common wood boring tools and their uses?
12. What kinds of hammers are best for working with wood?
13. What are the common types of wrenches, and how should they be used?
14. What tools are needed for agricultural machinery repair and adjustment, and how should they be used?
15. How do the principles of using power tools differ from the principles of using hand tools?
16. What dangers are encountered in using power tools? What precautions should be observed?
17. Why and how should power tools be grounded?

Importance of Tool Classification—Students should familiarize themselves with the names of the different kinds of tools and their uses. Much of the success in agricultural mechanics depends upon the proper selection of tools and their proper use. It frequently happens that workers in agricultural businesses and on farms do not know an 8-point saw from a 10-point saw, nor a jack plane from a smoothing plane.

Importance of Proper Care of Tools—Knowing how to care for tools is



(Courtesy Broadhead Garrett Co.)

Fig. 4.1. Some of the hand tools found on farms and in agricultural businesses.

1. Steel framing square
2. Countersink
3. Star drill
4. Nail set
5. Bit with bit gauge
6. Brace
7. Expansion bit
8. Spiral screwdriver
9. Combination square
10. Breast drill
11. Hand drill
12. Wood chisel
13. Pipe wrench
14. Drawing knife
15. Bevel square
16. Lineman's pliers
17. Pruning saw
18. Keyhole saw
19. Compass saw
20. Outside calipers
21. Inside calipers
22. Backsaw
23. Coping saw
24. Chain drill
25. Hacksaw

exceedingly important, since their usefulness depends to a large degree upon their care. Keeping tools well cleaned, oiled, and free from rust is essential, not only for ease in handling, but also for lengthening their life. Tools should always be treated with oil when they are not in frequent use. It is also a good plan to keep tools inclosed in a tool chest or cabinet when not in use. Likewise, tools must be properly sharpened for good results. Tools which are dull and rusty will not work satisfactorily. Some precautions in the care of tools are as follows:

1. Do not drop tools.
2. Keep tools clean and free from rust.
3. Keeps tools sharp.
4. Be careful not to bring cutting edges in contact with metal, or nicking may result.
5. Clean and put tools away in their proper places when through with them.
6. Choose the proper tool. Do not expect a crosscut saw, for example, to rip satisfactorily.

Cleaning Tools—All grease on tools should be carefully removed with a soft material or, if necessary, by washing the tools with a safe cleaning solvent. Rust may be removed and prevented as follows:

1. Apply cleaning solvent and let the tool sit for several hours.
2. Rub and polish with oil and well rotted pumice stone or with an emery cloth.
3. Apply a thin film of light oil to the surface of the tool before it is put away.

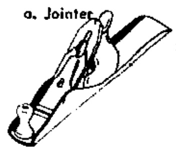
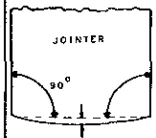
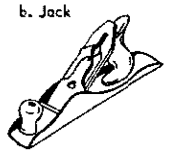
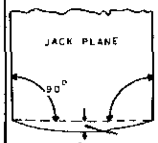
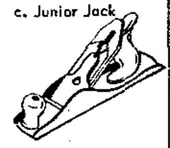
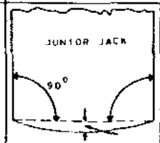
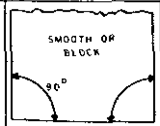
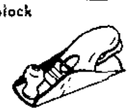
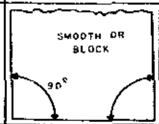
WOODWORKING TOOLS

Common Kinds of Planes and Their Uses—There are several kinds of planes; each is designed for certain uses. The three common types used in agriculture are jack planes, smoothing planes, and block planes.

Jack planes are usually 14 inches long and are used for smoothing long surfaces. See Fig. 4.2. They are the most frequently used type of plane in agricultural work. Planing with a jack plane should always be done with the grain of the wood. This leaves the wood smooth if the plane blade is sharpened and adjusted properly. It is best to begin planing on the highest spot of the area to be planed.

Smoothing planes are 5½ to 10 inches long, with the 8-inch plane being the most common. See Fig. 4.2. As the name indicates, planes of this type are used for finishing work. When using a smoothing plane, the grain of the wood should be followed, since planing against the grain roughens the wood.

Block planes are usually smaller in size, those 6 to 6½ inches long being the most useful. See Fig. 4.2. Block planes are used for cutting across the grain on the ends of pieces of wood, thus smoothing the ends. When using a block plane to smooth the end of a board, care must be exercised to prevent the splitting of the edges of the board. To avoid splitting off corners, clamp a piece of wood on both edges of the board, or plane from the edge toward the center. Marking around the wood with a sharp knife will often prevent splintering, because the wood will break at the cut.

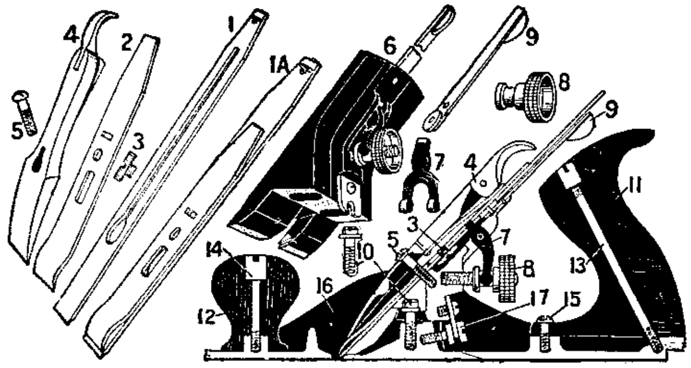
TYPE OF PLANE	LENGTH OF PLANE	WIDTH OF BLADE	SHAPE OF BLADE	POSITION OF BLADE	USE OF PLANE
1. Bench a. Jointer 	18"–24"	2 3/8"–2 5/8"		Bevel of blade turned down	1. Plane long pieces. 2. "True" edges or surfaces.
b. Jack 	11½"–15"	1 3/4"–2 3/8"		Bevel of blade turned down	1. Plane shorter pieces than the jointer plane. 2. May substitute for jointer plane and the smoothing plane if only one is to be purchased. 3. "True" edges or surfaces.
c. Junior Jack 	10"–11½"	1 3/4"		Bevel of blade turned down	1. Will do what the Jack Plane will do. 2. Lighter in weight and easier to handle than the Jack Plane.
d. Smoothing 	5½"–10"	1 1/4"–2 3/8"		Bevel of blade turned down	1. Smooths rough surfaces. 2. Does not true.
2. Block 	4"–8"	1"–1 5/8"		Bevel of blade turned up	1. Smooths across end grain. 2. Handy for small smoothing jobs. 3. Used with one hand.
3. Spoke Shave 	Entire width 9"–11"	1 1/2"–2 1/8"		It depends upon surface to be cut	Smooths convex and concave surfaces.
Cabinet Scraper 	Entire width 11½"	2 1/4" wide 11 1/2" long	Blade made of Malleable iron		1. Smooths burls or irregular grained woods. 2. Removes plane marks in the final dressing of wood.

(Courtesy U.S. Department of the Army)

Fig. 4.2. Types of planes and their uses.

Precautions in Planing—Some precautions to observe are:

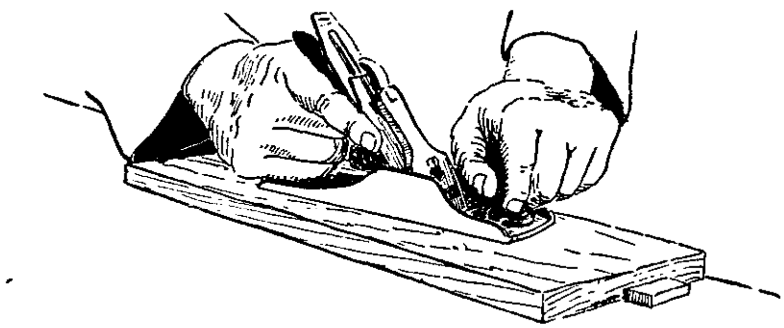
1. Be sure that the plane blade is sharp, with no nicks or high corners.
2. Be sure that the plane blade is properly adjusted.
3. Hold the lumber securely by placing it on a bench hook, in a clamp, or against bench stops.
4. Be sure that there are no nails or other projections in the wood being planed.
5. Use pieces of wood between the jaws of the vise and the lumber to avoid bruising the wood being planed.
6. Place the right hand on the handle and the left hand on the knob of the plane—vice versa for left-handed persons.
7. Begin planing the edge nearest to you and plane toward the opposite end of the piece of wood.



(Courtesy Stanley Tools)

Fig. 4.3. The parts of a plane.

1. Single plane iron
1A. Double plane iron
2. Plane iron cap
3. Cap screw
4. Lever cap
5. Lever cap screw
6. Frog complete
7. "Y" adjusting lever
8. Adjusting nut
9. Lateral adjusting lever
10. Frog screw
11. Plane handle
12. Plane knob
13. Handle bolt and nut
14. Knob bolt and nut
15. Plane handle screw
16. Plane bottom
17. Frog adjusting screw



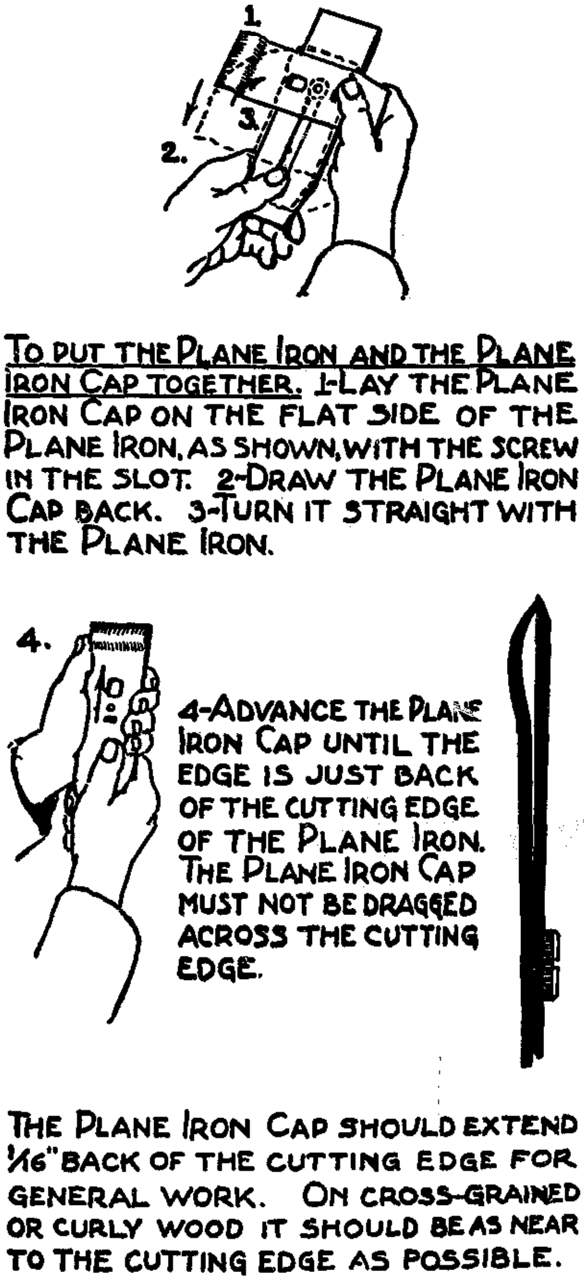
(Courtesy Stanley Tools)

Fig. 4.4. The correct method of holding a plane.

8. Plane with the grain of the wood.
9. Push the plane with long, even strokes.
10. Plane until the wood is even and smooth.
11. Clean the plane of dust and shavings, and lay it on its side to prevent damage to the blade.

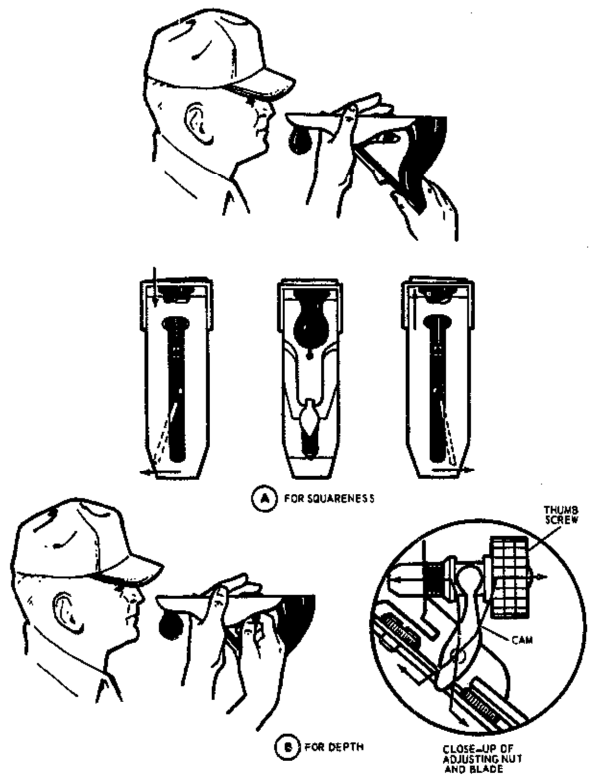
If these precautions are followed, little difficulty should be experienced in planing. It is best not to get in a hurry. Enough time should be taken to sharpen and adjust the plane blade properly. Avoid hitting any metal holding the wood, such as bench stops or vises, which may nick the blade of the plane.

Plane Parts—Assembling and Adjusting—Every farmer and other agricultural worker should know how to assemble and adjust a plane. A correct adjustment is necessary for satisfactory results. See Figs. 4.5 and 4.6.



(Courtesy Stanley Tools)

Fig. 4.5. Assembling a plane blade.



(Courtesy U.S. Department of the Army)

Fig. 4.6. Procedures for adjusting a plane.

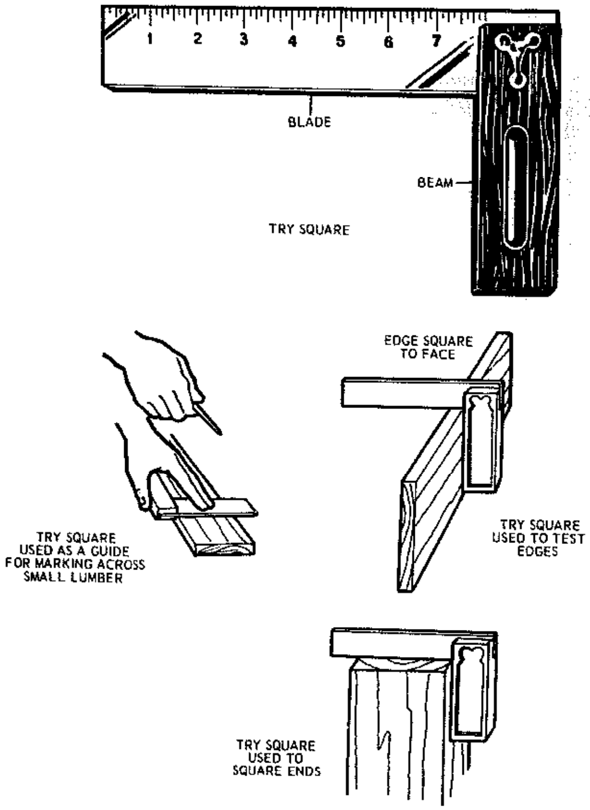
Common Kinds of Squares and Their Uses—Squares are very important because a board should always be marked with a square before it is sawed. The common kinds of squares used in an agricultural shop are:

1. Steel framing square
2. Try square
3. Bevel square
4. Combination square

The *steel framing square* is used for squaring boards and timbers and for laying out rafters. One side or arm of this square is 24 inches long and is called the blade. The other side of the square is usually 16 inches long and is called the tongue.

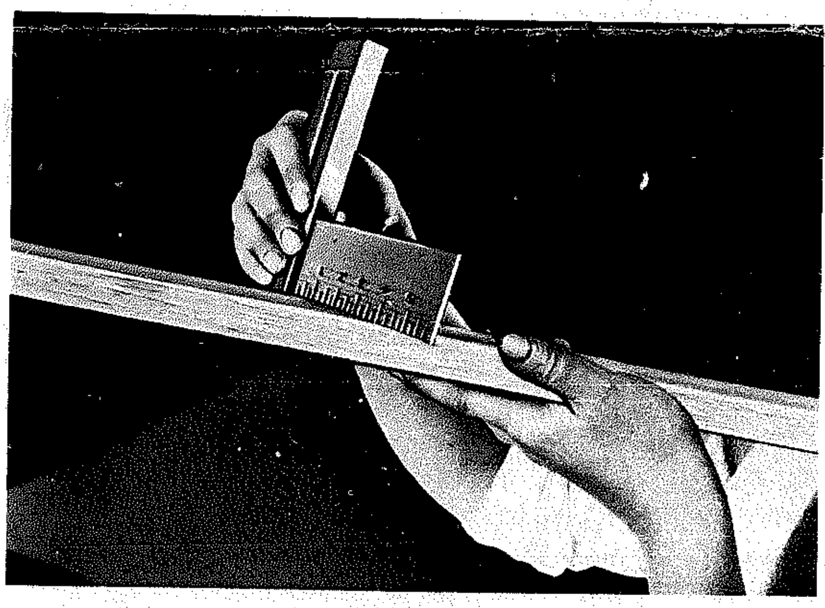
Try squares are smaller than framing squares, the lengths of the blades ranging from 4 to 12 inches. For small or narrow pieces of wood, a try square is more convenient to use than a large framing square. The handles of try squares are made of wood or steel. A try square with an 8-inch blade and a steel handle is a very satisfactory type. Try squares should not be used as hammers, because this will cause them to become bent and not square.

Bevel squares are adjustable so that they can be set for marking various angles from 0 degrees to 180 degrees. A bevel square is often used for marking rafters.



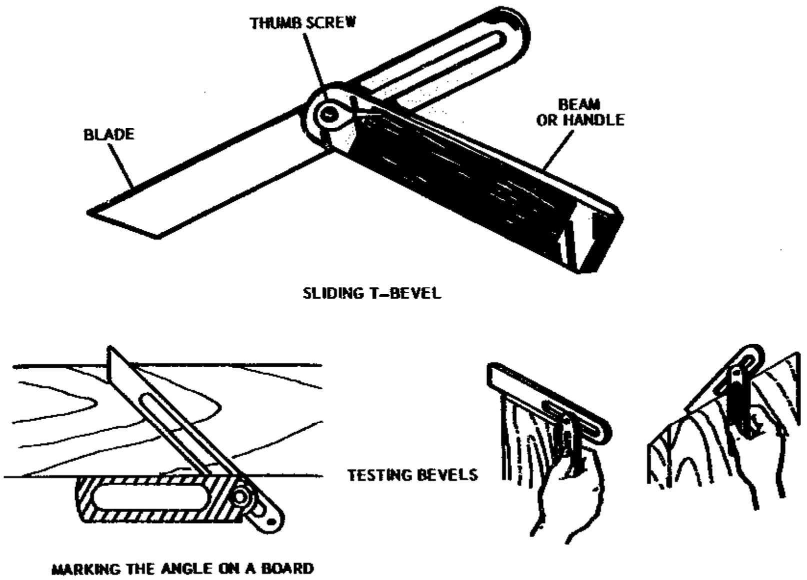
(Courtesy U.S. Department of the Army)

Fig. 4.7. Try square and three of its uses.



(Courtesy Henry Disston and Sons, Inc.)

Fig. 4.8. Using a try square to test the trueness of the surface of a board.



(Courtesy U.S. Department of the Army)

Fig. 4.9. A sliding T-bevel and its uses. A primary use is to transfer angles from one piece of lumber to another.

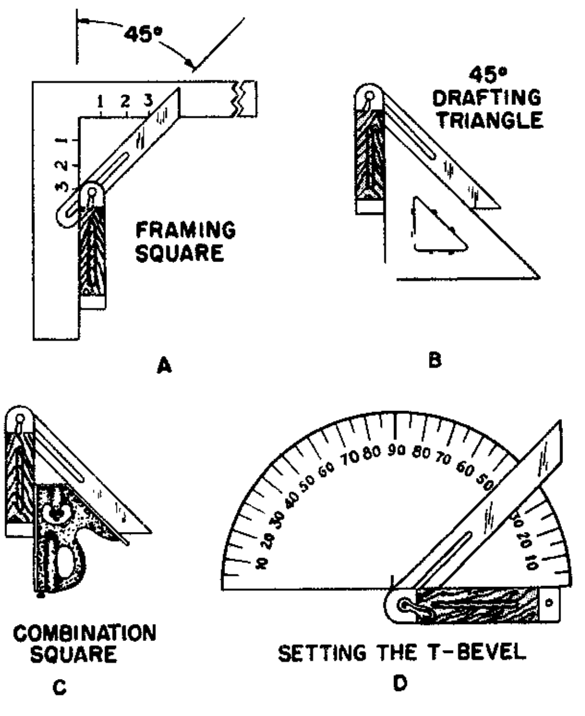


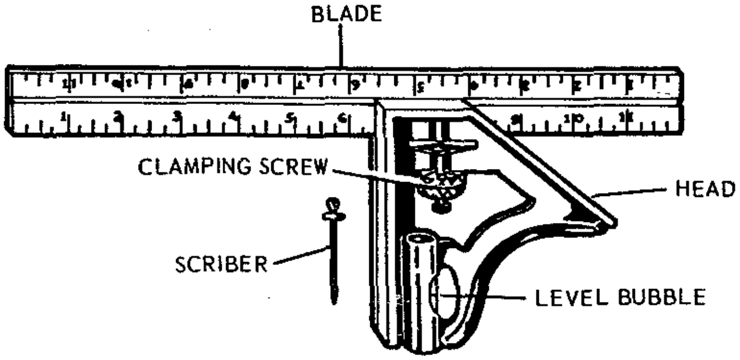
Fig. 4.10. Adjusting a sliding T-bevel to a desired setting.

The angle is first obtained with a framing square, and this angle is then transferred to the bevel square.

A bevel square may also be used to test a bevel or angle to determine whether or not it is correct and whether or not it is true, neither concave nor convex. If a 65-degree bevel or angle is to be tested, for example, a protractor or framing square may be used to adjust the bevel square for this angle.

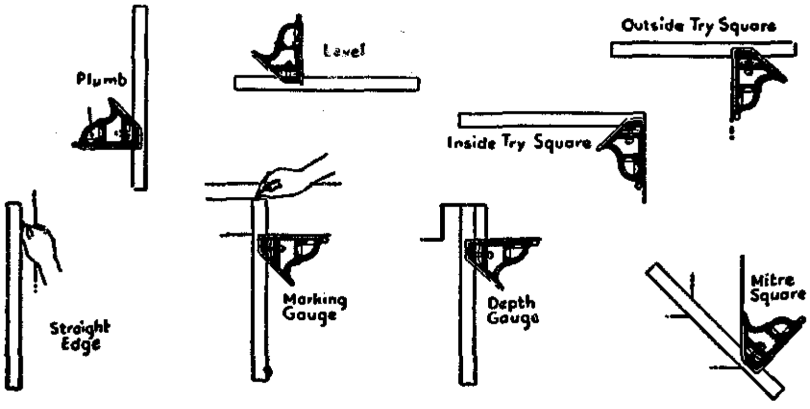
The length of the blade of bevel squares varies from 6 to 12 inches. An 8-inch blade is a very satisfactory size for use in an agricultural shop.

Combination squares may be used for several purposes. The head can be removed from the blade, or it may be moved up and down the blade. The head has a bubble level, a 45-degree-angle side, and a 90-degree-angle side. It is, therefore, possible to use a combination square as a straightedge, as a marking gauge, as a depth gauge, as a miter square, as an outside or inside try square, or as a level. See Fig. 4.12.



(Courtesy U.S. Department of the Army)

Fig. 4.11. A combination square.



(Courtesy Stanley Tools)

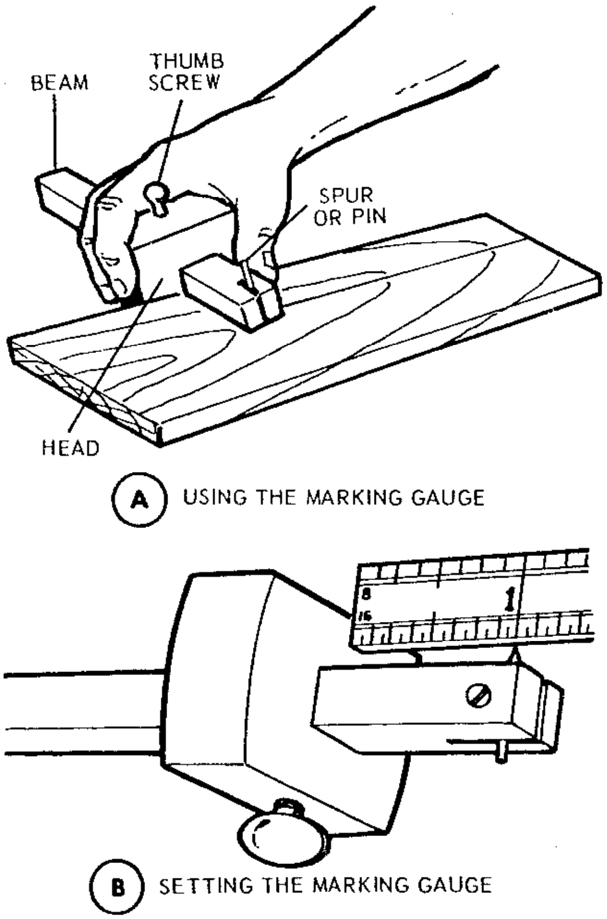
Fig. 4.12. Uses of a combination square.

Marking Tools—In marking wood, the following tools are necessary:

1. Pencil or knife
2. Marking gauge

A board may be marked for squaring and sawing with either a sharp-pointed pencil or a knife. In fine work a very fine line is necessary because a heavy line may cause a variation in the lengths of the pieces, after they are sawed off, of as much as $^1/_{32}$ inch. This difference may be important in fitting small pieces together. A sharp-pointed knife is the best marking tool to use for marking a board that may splinter when it is sawed, chiseled, or smoothed. In laying out a piece of wood, the following should be done:

1. Square piece with a square.
2. Mark around the entire piece.
3. Saw carefully, following the line.



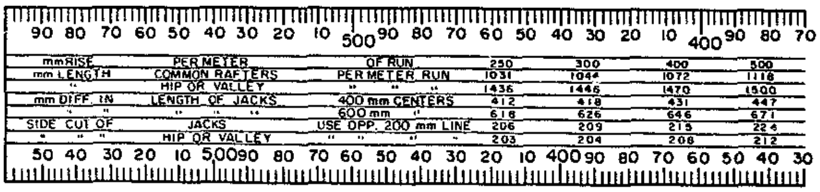
(Courtesy U.S. Department of the Army)

Fig. 4.13. Setting a marking gauge and using the gauge to mark a board to be ripped.

A marking gauge is often used when marking lines parallel to the edges of material. However, this job may also be done with a straightedge and a pencil.

Rules—Rules are graduated or divided into various fractions of an inch. The common graduations used are eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch. See Fig. 4.14 for rules with eighth-inch and sixteenth-inch graduations. Metric rules are also available. Before using them, check the rules to determine graduations.

Fig. 4.14 Examples of two graduations frequently found on rules such as the foot ruler, yardstick, zigzag rule, folding rule, pull-push rule, and tapes. The graduations on the rule to the left are eighth-inch, and the graduations on the rule to the right are sixteenth-inch.

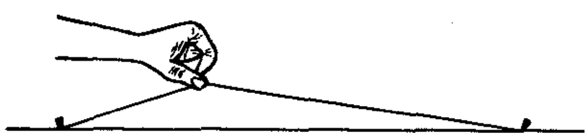


(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 4.15. An example of a metric rule found on a metric square. The numbers in the center are for the rafter table.

Chalk Line—A chalk line is used for marking a straight line on a board, wall, ceiling, or floor. A chalk line is a string that has been coated with chalk dust so that it leaves a line when snapped. A carpenter's chalk may be purchased for this purpose. A self-chalking line is also available. Fig. 4.16 illustrates the snapping of a chalk line.

When a chalk line is used, fasten one end of the line to a nail. Stretch the line taut, but not too taut. If the line is too tight, the chalk dust will fly out of the string before it strikes the surface of the wall, ceiling, floor, or board. Snap the line from the end opposite the fastened end. The number of inches between the end of a



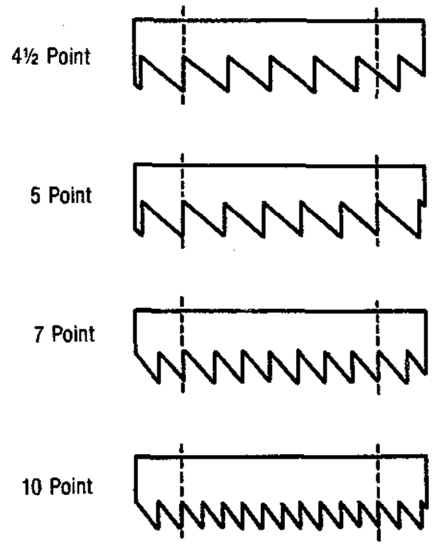
(Drawn by Ronald Ipsen)

Fig. 4.16. Snapping a chalk line to mark a straight line.

chalk line and the point where it is snapped should be equal to the total number of feet of the line. For example, if the line is 20 feet in length, snap the line 20 inches from one end. Pull the line up 1 inch for each 3 feet of the total length of the line. For example, if a line is 20 feet in length, it should be pulled up approximately 7 inches. Always pull the chalk line string straight away from the area which is to be chalked.

Common Kinds of Saws and Their Uses—There are several different types of saws, each being designed for a definite purpose. However, there are only a few which are used frequently by workers in agricultural businesses and by farmers. They are as follows:

1. Crosscut saw
2. Ripsaw
3. Compass saw
4. Coping saw



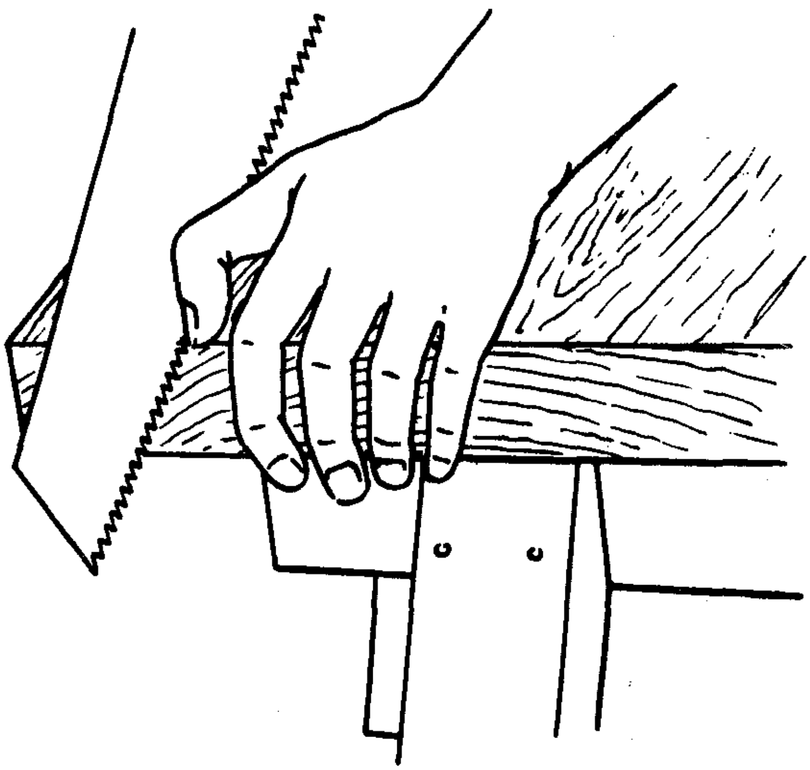
(Drawn by Ronald Ipsen)

Fig. 4.17. Saw points per inch.

Crosscut saws are used frequently on farms and in many agricultural businesses. As the name indicates, they are made for cutting across the grain in wood; consequently, *they cannot be used very successfully in ripping or cutting with the grain.* In sawing a board, after it has been squared and marked, use the following procedure:

1. Grip the handle of the saw with the right hand, placing the index finger and the thumb on the sides of the handle. See Fig. 4.21.
2. Place the left hand on the board to the left side of the mark, so that the side of the thumb is next to the mark.
3. Use the thumb as a guide for the saw blade and take two or three slow upward strokes with the saw, using precaution to keep on the mark and to prevent the saw from jumping.

4. Start sawing on the outer edge of the mark; otherwise, the board will be a trifle short because of the waste in sawing.
5. Hold the saw firmly.
6. Hold the saw at an angle of about 45 degrees when cutting.
7. Keep the saw square with the face of the board. Test with a try square if necessary.
8. Take long, slow strokes, and do not force the saw. Pressure should be applied only on the downward strokes.
9. Hold the end of the board with the left hand after the saw is well started to prevent the binding of the saw and the splitting of the board.



(Courtesy Henry Disston and Sons, Inc.)

Fig. 4.18. In starting a saw, steady the saw blade with the thumb, and pull the blade up several times. In starting a ripsaw, use short forward thrusts of the saw.

Crosscut saws can be secured in lengths of 20, 22, 24, and 26 inches. The 24- and 26-inch lengths are very popular for agricultural shop work.

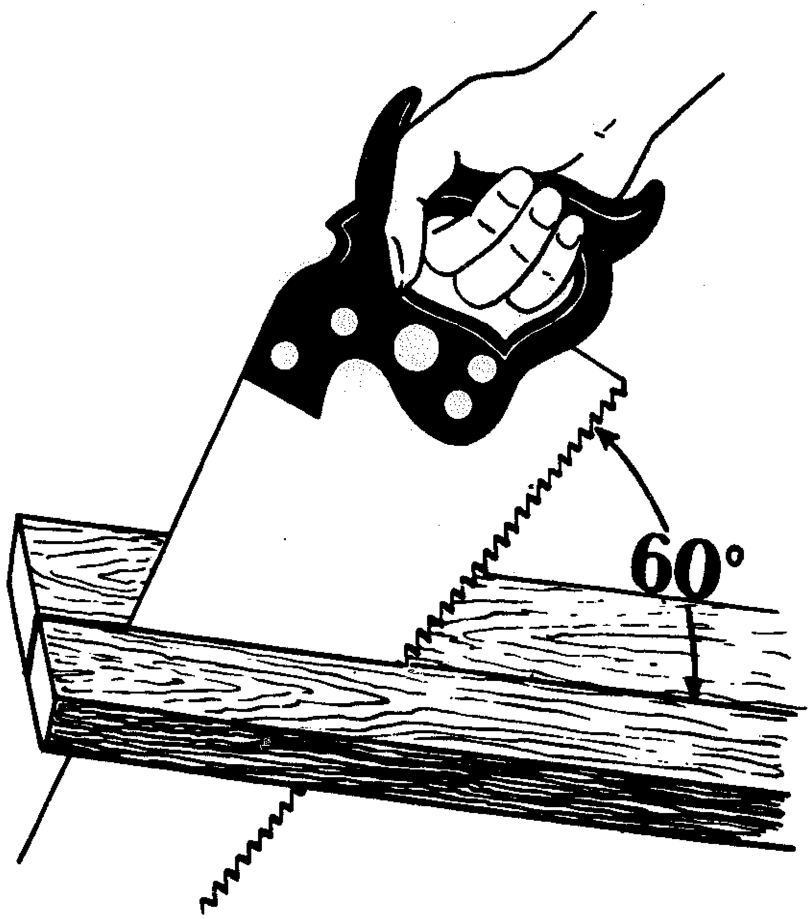
Ripsaws, as the name implies, are used for sawing with the grain. In cutting with ripsaws, use the recommended procedure:

1. Hold and start a ripsaw as outlined in Fig. 4.18.
2. Hold the ripsaw at an angle of about 60 degrees. See Fig. 4.19.
3. Use long, easy strokes in sawing.
4. Use wedges between the cut surfaces if the board binds.

Ripsaws can be secured in 22-, 24-, and 26-inch lengths. The 24- and 26-inch lengths are the lengths often used on farms and in agricultural businesses.

Compass saws are used to cut curves and circles or to start sawing a hole in wood. The most convenient size is one 12 to 14 inches in length with 8 points to the inch.

Coping saws are used for cutting curves. While they are not frequently used by agricultural workers, they are needed occasionally.



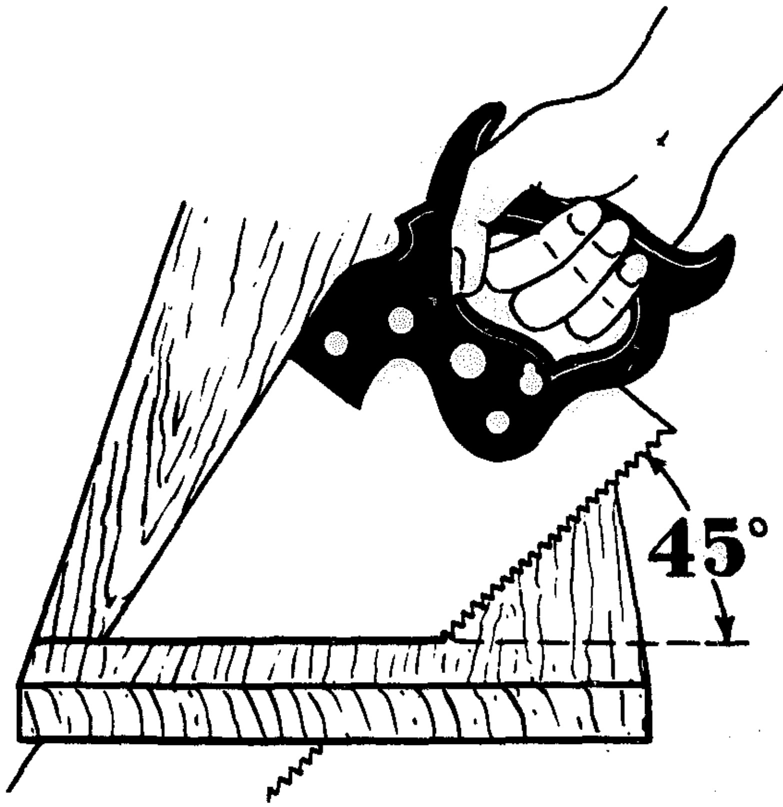
(Courtesy Henry Disston and Sons, Inc.)

Fig. 4.19. A ripsaw should be held at a 60-degree angle to the wood.

Backsaws are not often used in agricultural shops, since their principal use is in cabinet work. The teeth are very fine, which makes this type of saw very desirable for cutting moldings, corner angles, picture frames, and joints. Backsaws may be secured in 8-, 10-, 12-, 14-, and 16-inch lengths with 12 to 16 points to the inch. The most popular backsaw is one 12 inches in length with 14 points to the inch. In using a backsaw, hold the board firmly in place.

Meaning of 8-Point, 10-Point Saws—The coarseness or fineness of the sawing teeth of saws is designated by the number of teeth per inch. An 8-point saw has 8 points to the inch. A 10-point saw has 10 points to the inch. The more points per inch, the finer the saw teeth.

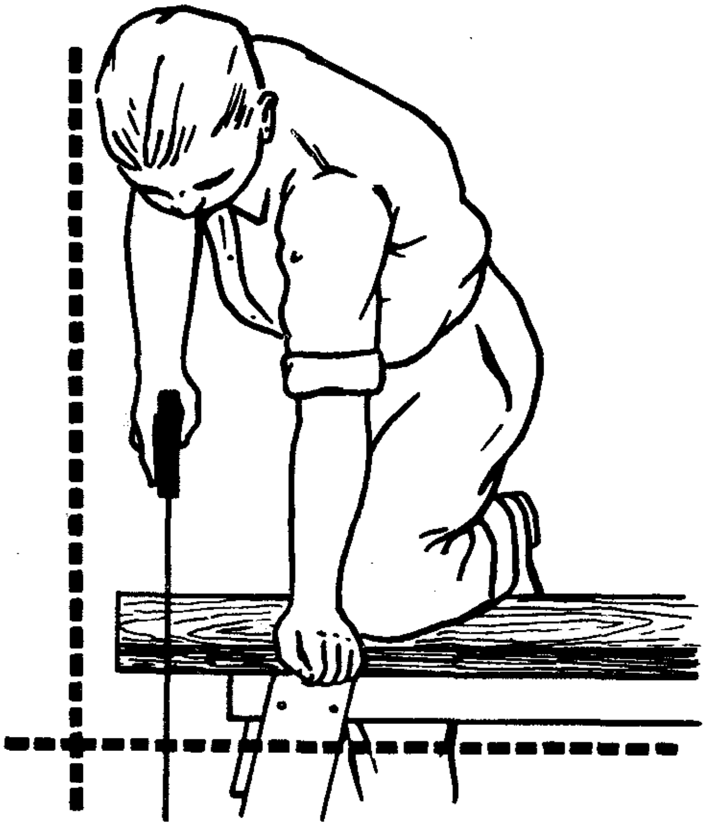
Crosscut saws can be secured with 7 to 10 points per inch. Eight- and 10-point crosscut saws are frequently used in agricultural shop work. Ripsaws can be secured with 4 to 7 points to the inch, the 6-point saw being a good size for agricultural shops.



(Courtesy Henry Disston and Sons, Inc.)

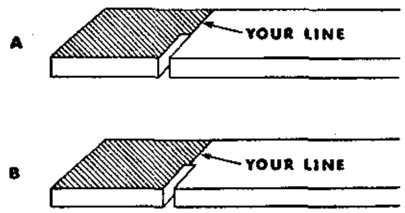
Fig. 4.20. A crosscut saw should be held at a 45-degree angle to the wood.

Holding Lumber in Place for Sawing—All long pieces of lumber should be placed on sawhorses or other supports while being sawed. The person doing the sawing should stand so that one knee may be placed on the piece being sawed. Short pieces of wood should be placed in a vise or on a bench hook. If a piece of lumber is very long, two bench hooks may be used, one at each end of the piece.



(Courtesy Henry Disston and Sons, Inc.)

Fig. 4.21. The proper position for crosscutting.



(Courtesy Henry Disston and Sons, Inc.)

Fig. 4.22. In sawing, follow the mark as illustrated in "A," not as illustrated in "B."

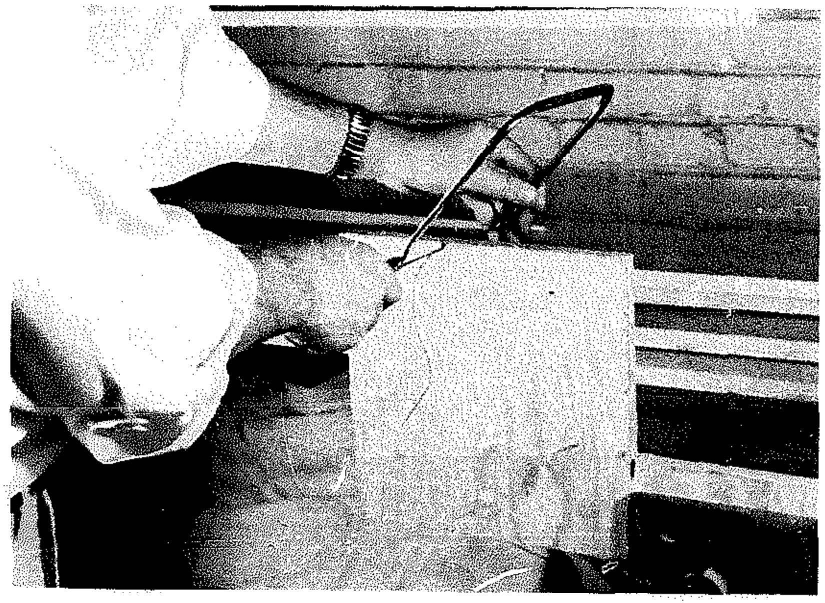


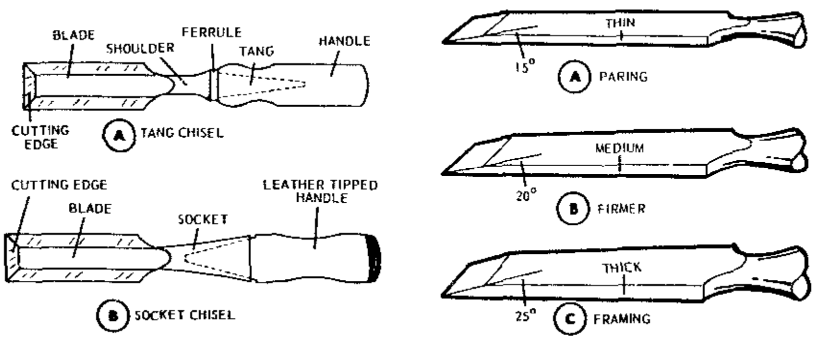
Fig. 4.23. A coping saw is used for sawing curves. Notice how it is held.

Wood Chisels and Their Uses—There are two kinds of wood chisels frequently used in carpentry work:

1. *Socket chisels*, which have a socket for the handle.
2. *Tang chisels*, which have a spike-like projection for the handle.

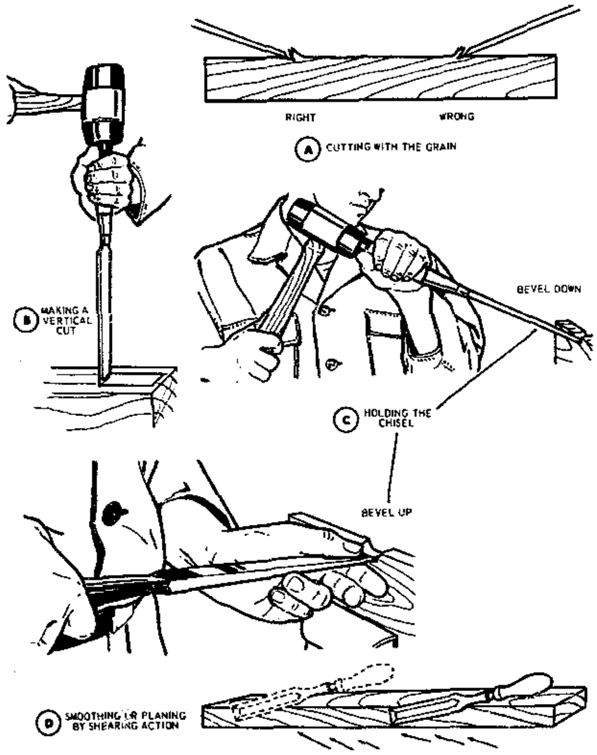
A wooden mallet should be used for pounding on a chisel. Sometimes the top of the handle of a chisel is covered with leather to prevent the wood from splitting.

Chisels are used for cutting both with and across the grain. It is best to use a sharp-pointed knife when marking dimensions for chiseling. The knife cut prevents the wood from splitting away from the mark.



(Courtesy U.S. Department of the Army)

Fig. 4.24. Types of wood chisels.



(Courtesy U.S. Department of the Army)

Fig. 4.25. Note the correct ways of using a wood chisel.

Fig. 4.26. Removing wood with a wood chisel. The bevel of a wood chisel should be up when a small amount of wood is to be removed and down when a large amount is to be removed.

Drawknife—A drawknife is used to remove wood when the amount to be removed is considerable. Grasp the drawknife as shown in Fig. 4.27 and cut with the grain of the wood. Keep the bevel side of the drawknife down when removing small amounts of wood. A drawknife will pull more easily if one hand is kept in front of the other so that a sliding motion is produced.

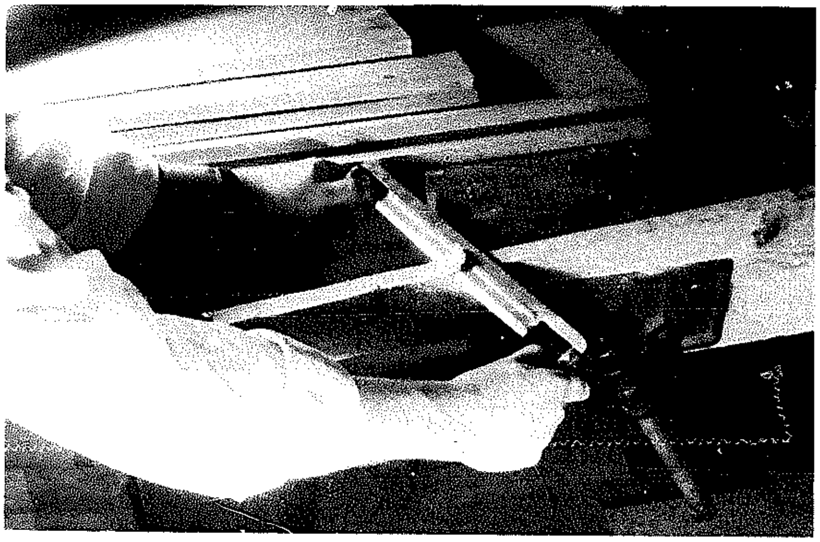


Fig. 4.27. When using a drawknife, keep one hand in front of the other so that a sliding motion is produced.

Wood Rasp—A wood rasp is used for smoothing rough work, and for removing small amounts of wood on curved and irregular-shaped objects. A wood rasp should not be used without a handle, and the material on which the rasp is being used should be firmly secured to prevent accidents. Let the rasp do the cutting. Put only light pressure on the rasp. A rasp may be cleaned with a wire brush or file card.

(Courtesy Nicholson File Company)

Fig. 4.28. Top—a flat wood rasp. Bottom—a half round wood rasp.

Hand Boring Tools and Their Uses—Hand boring tools are very useful in any shop. The most common wood boring tools are:

1. Brace and auger bits
2. Automatic drill

~~*Braces* are of two main types~~—the ordinary and the ratchet. An ordinary brace is satisfactory for all general work where plenty of room is available for making complete revolutions with the handle. A ratchet brace is constructed so that complete revolutions of the handle are not necessary; consequently, it is convenient to use in corners or other places where there is little room to work.

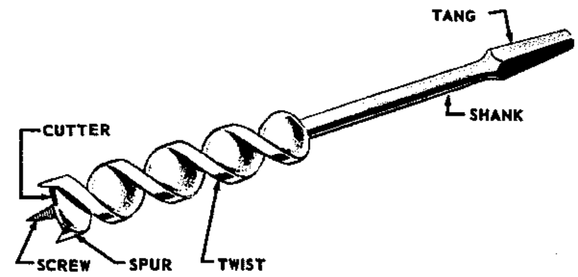


Fig. 4.29. Nomenclature of an auger bit for a hand brace.

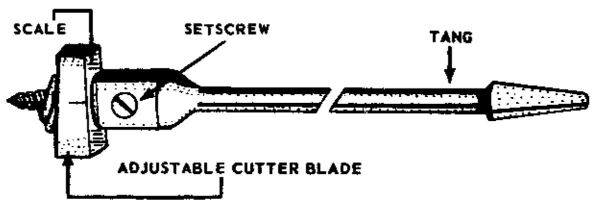


Fig. 4.30. An expansion auger bit for a hand brace.

The *automatic drill* is generally used for making small holes up to ¼ inch in diameter. It is very handy and should be in every shop.

The following procedure is recommended for boring holes in wood:

1. Place the bit in the brace, making sure that the shank of the bit fits firmly in the jaws of the brace.
2. For drilling perpendicular holes, place the point of the bit in the wood where the hole is to be drilled. Hold the brace in place and sight down the bit to make sure it is perpendicular to the piece. A try square may be placed on the wood near the hole as a guide in holding the bit perpendicular.
3. To prevent the wood from splintering on the opposite side, drill until the point of the bit comes through, then remove and drill on the opposite side. A block of wood may also be clamped to the opposite side of the piece.
4. To drill at an angle, set a T-bevel square at the desired angle and place it on the wood. Hold the auger bit parallel to the blade of the square while boring.

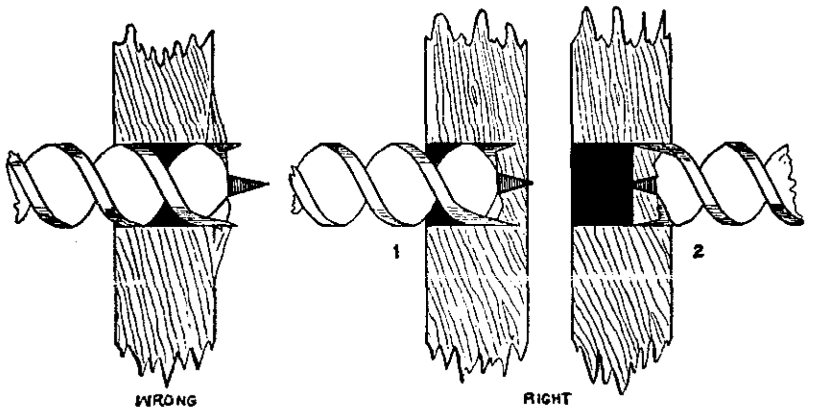
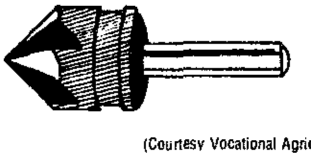


Fig. 4.31. The incorrect and correct way of boring through a piece of wood. To prevent the wood from splintering, drill until the point of the bit comes through, then drill from the opposite direction.

Countersink Bits—Countersinks are used to form a flaring depression around the top of a hole which is to receive the head of a flathead screw or a bolt. Countersink bits may be used in a bit brace, a breast drill, or an electric drill.

(Courtesy Stanley Tools)

Fig. 4.32. A countersink auger bit for a hand brace or a breast drill.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 4.33. A countersink drill bit for a power drill.

Hammers and Their Uses—The most frequently used hammer is the claw hammer. Always select a hammer of good quality, as it will receive a lot of use. A claw hammer weighing 16 ounces is a desirable size. The face of a hammer should be kept clean to prevent it from slipping off the nail. Always strike with the face of the hammer and not with the side. The face is hardened for striking. The handle should be grasped firmly near the end.

Nail Sets and Their Uses—Nail sets are used to drive finishing nails beneath the surface or flush with the surface of the wood without scarring the wood with hammer marks. The tip of a nail set is cupped so that it does not slip off the head

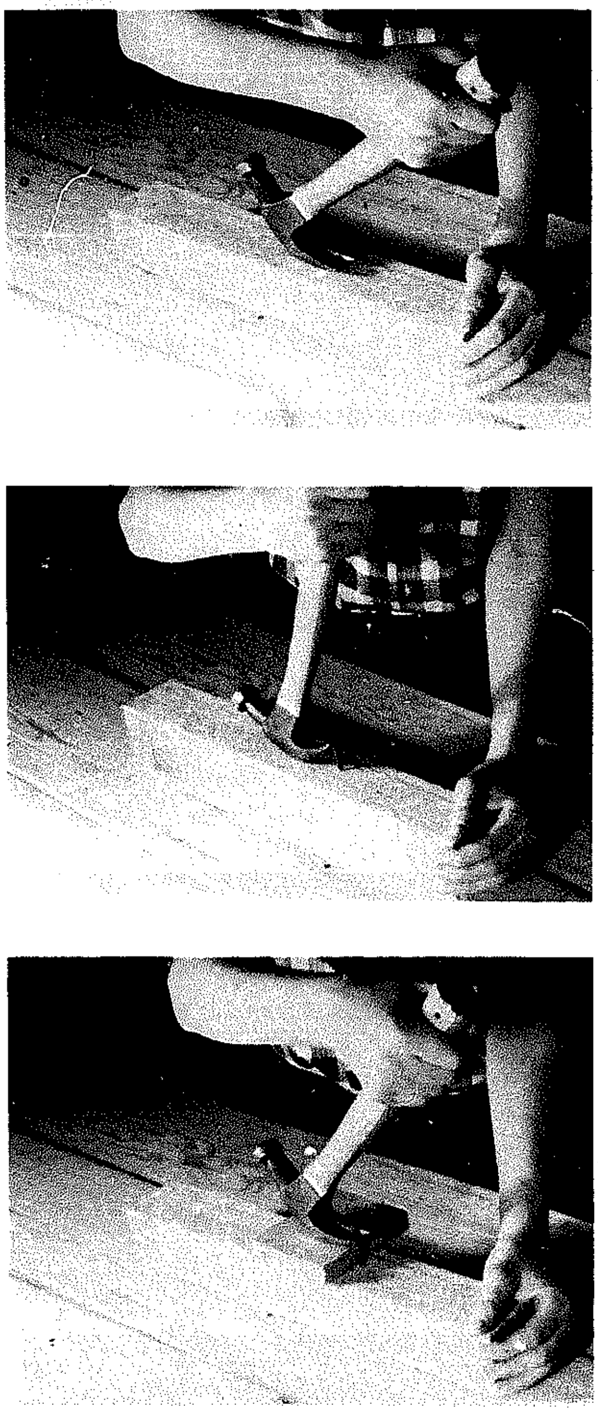
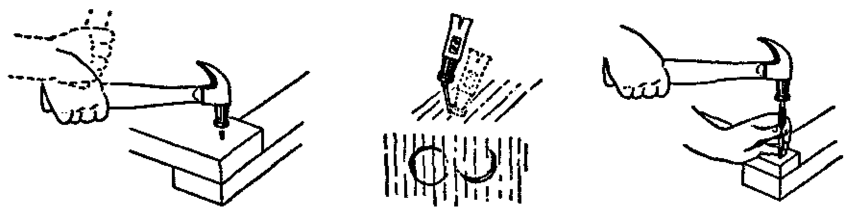


Fig. 4.34. The correct method of pulling a nail with a claw hammer. When the handle of the hammer approaches a vertical position and before the nail starts to bend, insert a block of wood under the head of the hammer and finish pulling the nail.



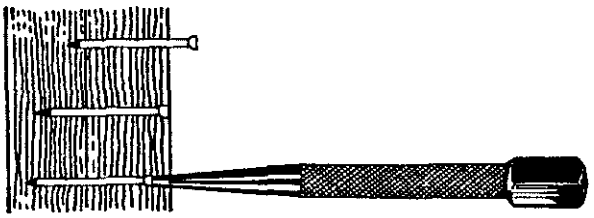
The hammer stroke in driving nail.

Strike the nail squarely to avoid bending the nail and denting the wood.

Set the nail head below the surface of the wood.

(Courtesy Stanley Tools)

Fig. 4.35. How to use a hammer and a nail set.



(Courtesy U.S. Department of the Army)

Fig. 4.36. Use of a nail set.

of the nail. Nail sets are manufactured in various sizes from $^4/_{32}$ inch to $^1/_{32}$ inch. See Figs. 4.35 and 4.36 for illustrations of the use of a nail set.

Selecting and Using Screwdrivers—Screwdrivers are manufactured in many shapes and sizes. A Phillips screwdriver is made to fit cross-slot screws. Offset screwdrivers are used in tight places where a straight screwdriver cannot be used. Spiral ratchet screwdrivers are used to drive or remove screws rapidly. Screwdriver bits may be obtained for use in a brace and in a power drill.

When using a screwdriver, select one that fits the slot in the screw. The tip of a screwdriver should not be wider than the screw. If it is wider, it will scar the wood around the head of the screw. The tip of a screwdriver should not be larger or smaller than the slot in the screw. If it is smaller, it will slip out of the slot easily, and if it is too large, it will not extend to the bottom of the slot in the screw.

Select the longest screwdriver that can be used with convenience, because a long one permits the use of more force than a short one.

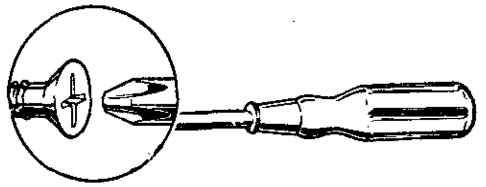
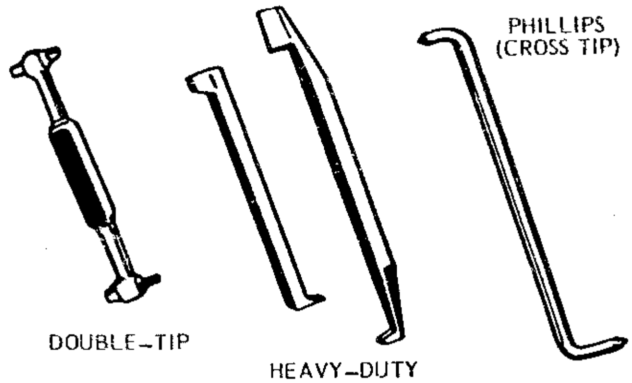


Fig. 4.37. A Phillips-head screwdriver.

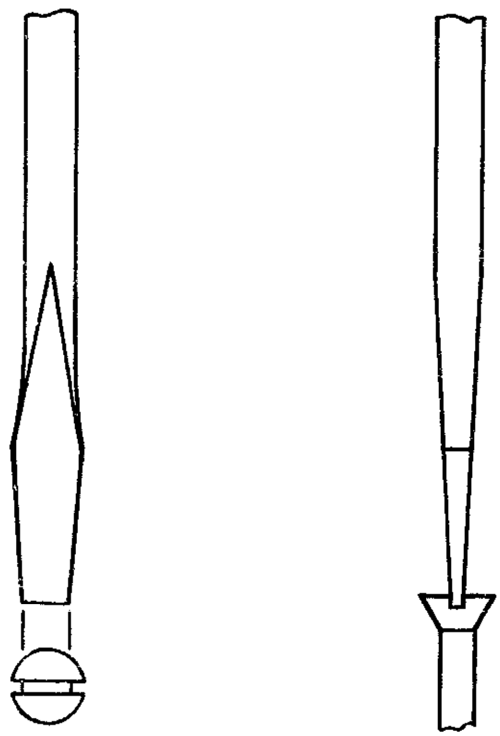
The point or tip of a screwdriver blade should be kept square. Do not use a screwdriver as a chisel or a hammer, or for prying.

If a screw turns hard, bore a pilot hole in the wood for a distance equal to the threaded part of the screw. A pilot hole should be slightly smaller in the diameter than the diameter of the threaded part of the screw.



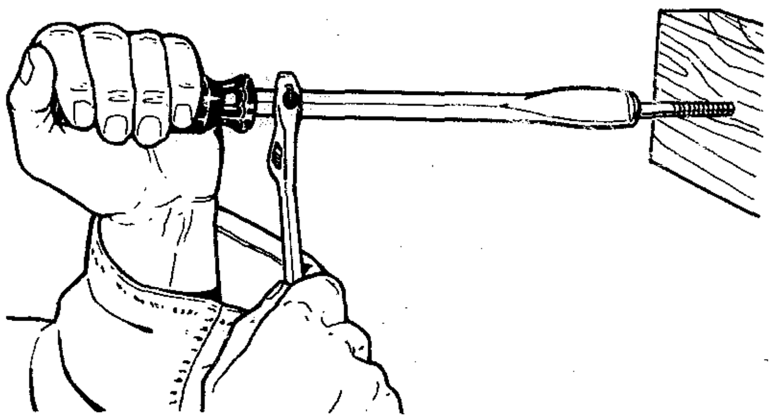
(Courtesy U.S. Department of the Army)

Fig. 4.38. Types of offset screwdrivers for use in tight locations.



(Drawn by Ronald Ipsen)

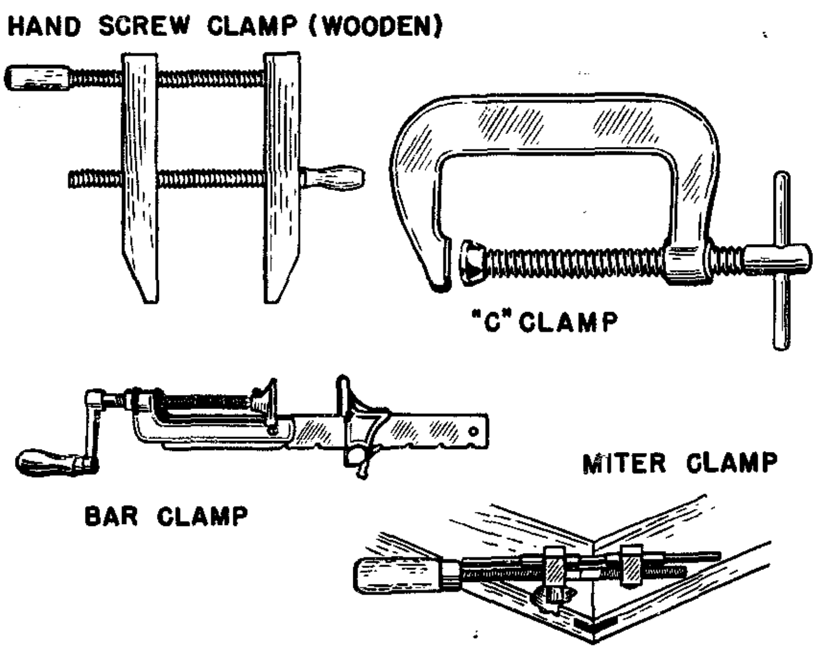
Fig. 4.39. The screwdriver selected should fit the slot in the screw as shown here.



(Courtesy U.S. Department of the Army)

Fig. 4.40. With a square shank screwdriver a wrench may be used, if needed.

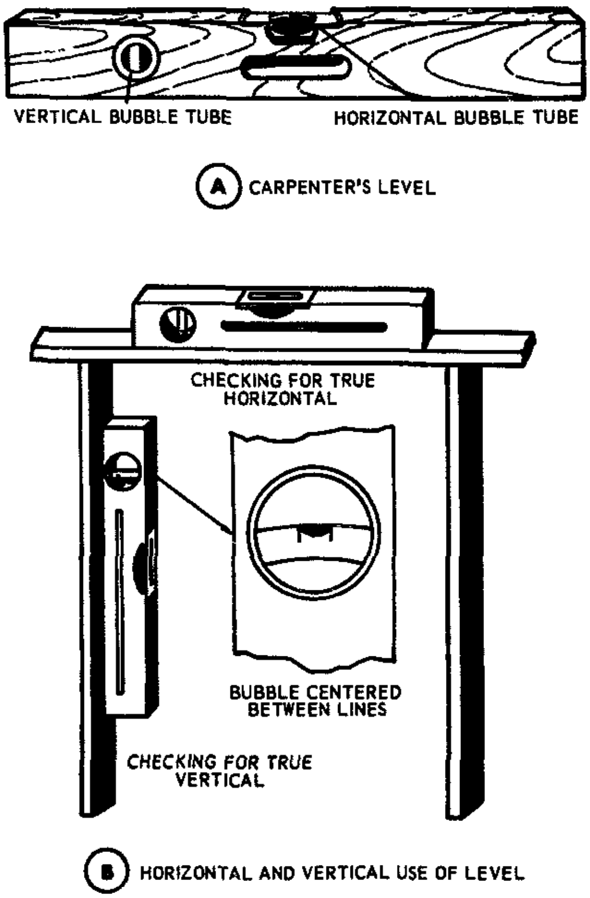
Selecting and Using Clamps—Clamps are used to hold pieces of wood or metal in a certain position until fastened together in that position by nails, screws, bolts, glue, or welding. Clamps also may be used to exert pressure so that materials may be fitted together properly. The types of clamps frequently found in shops are shown in Fig. 4.41.



(Courtesy United States Steel Corporation)

Fig. 4.41. Clamps are used frequently in an agricultural shop.

Levels and Their Uses—Levels are used to determine whether a surface is flat or horizontal. They are also used to determine whether a piece of wood or metal is vertical, or plumb, conforming to a line attached to a plumb. Levels may be purchased in various lengths and sizes. They are made of wood or metal. Metal levels are often preferred because they do not warp. In selecting a level, choose the longest level that is convenient for the work performed.



(Courtesy U.S. Department of the Army)

Fig. 4.42. A level and its uses.

Plumb Bob—A plumb bob is used to determine a plumb, or vertical, line. It may be used to check (1) whether the framing of a building is plumb, or vertical to a level base, and (2) whether a post is vertical. A plumb bob may be used to locate a point directly beneath an overhead point. A breeze may destroy the accuracy when a plumb bob is being used.

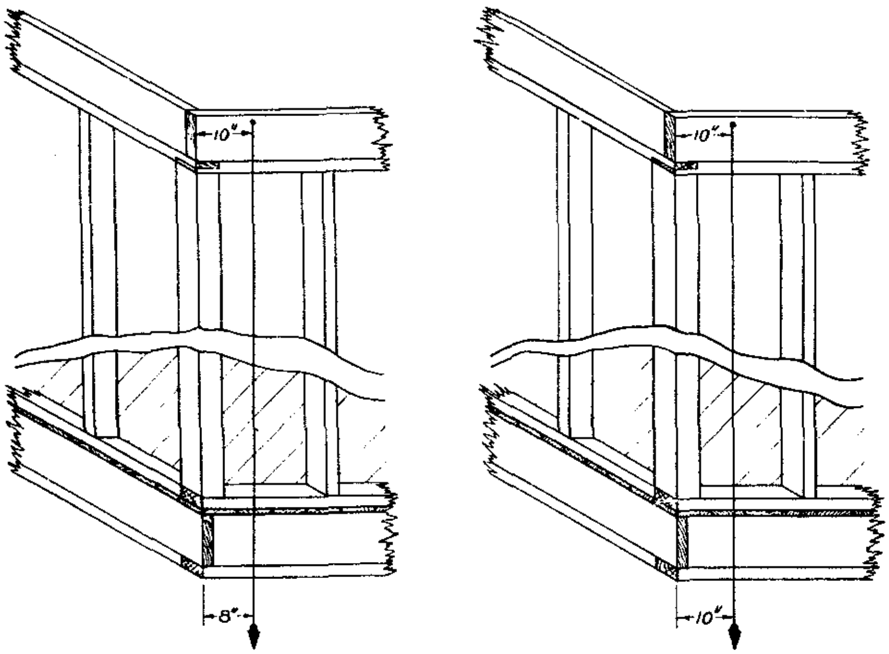


Fig. 4.43. These drawings illustrate how a plumb bob may be used to check whether the corner of a building is plumb, or vertical to a horizontal base. The drawing on the left shows a corner that is not plumb. The drawing on the right shows a corner that is plumb. The distance between the corner and the attachment of the plumb at the top is 10 inches, and the plumb bob at the bottom is also 10 inches from the corner.

PAINTING AND GLAZING TOOLS

Painting and glazing tools and equipment are described and their uses explained in Chapters 11 and 12.

WELDING EQUIPMENT AND TOOLS

The tools and equipment for oxyacetylene welding are described and their uses given in Chapter 14. The tools and equipment for arc welding are presented in Chapter 13.

METALWORKING TOOLS AND EQUIPMENT

Metalworking tools and equipment for sheet metal work are described in Chapters 17 and 18. The tools and equipment for hot and cold metal work are discussed in Chapters 15 and 16.

AGRICULTURAL POWER AND MACHINERY TOOLS

Wrenches—There are several types of wrenches used in the repair and adjustment of farm machinery, and machinery used in agricultural businesses. They are classified into two main groups:

1. Fixed-jaw
2. Adjustable jaw

Two of the common types of fixed-jaw wrenches are open-end and box-end wrenches. *Open-end* wrenches come in various sizes, the smallest having a $^5/_{16}$-inch opening at one end and a $^3/_8$-inch opening at the other end. *Box-end wrenches* have notches which completely box the nut or bolt head. Box-end wrenches are safer

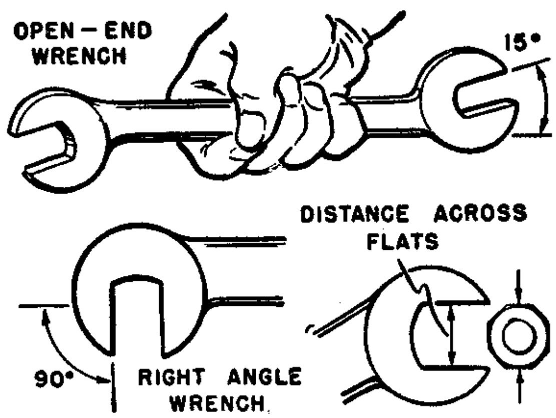
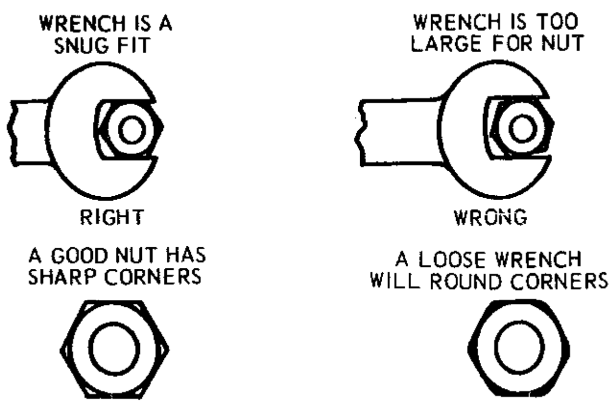
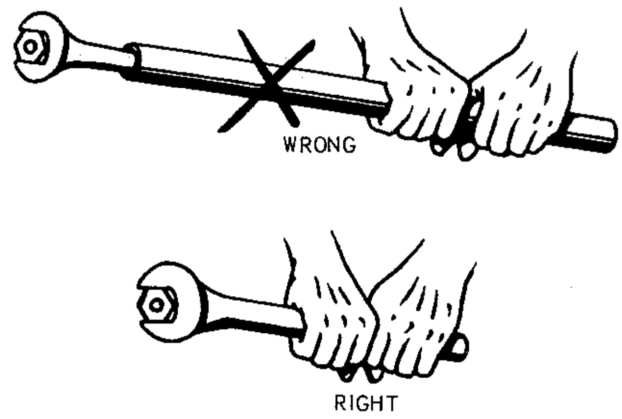


Fig. 4.44. Open-end wrenches. Most open-end wrenches have an angle to facilitate their use in close quarters.



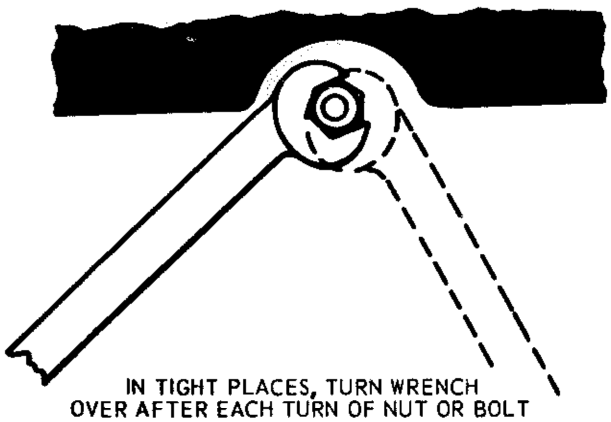
(Courtesy U.S. Department of the Army)

Fig. 4.45. Always use a wrench that fits the nut.



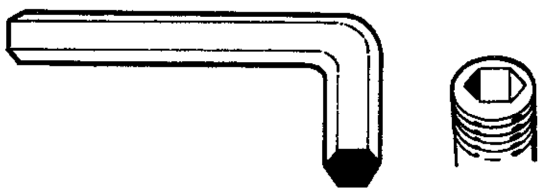
(Courtesy U.S. Department of the Army)

Fig. 4.46. Increasing the leverage on a wrench is not advisable.



(Courtesy U.S. Department of the Army)

Fig. 4.47. The angle on an open-end wrench makes it more usable in tight places.



(Courtesy U.S. Department of the Army)

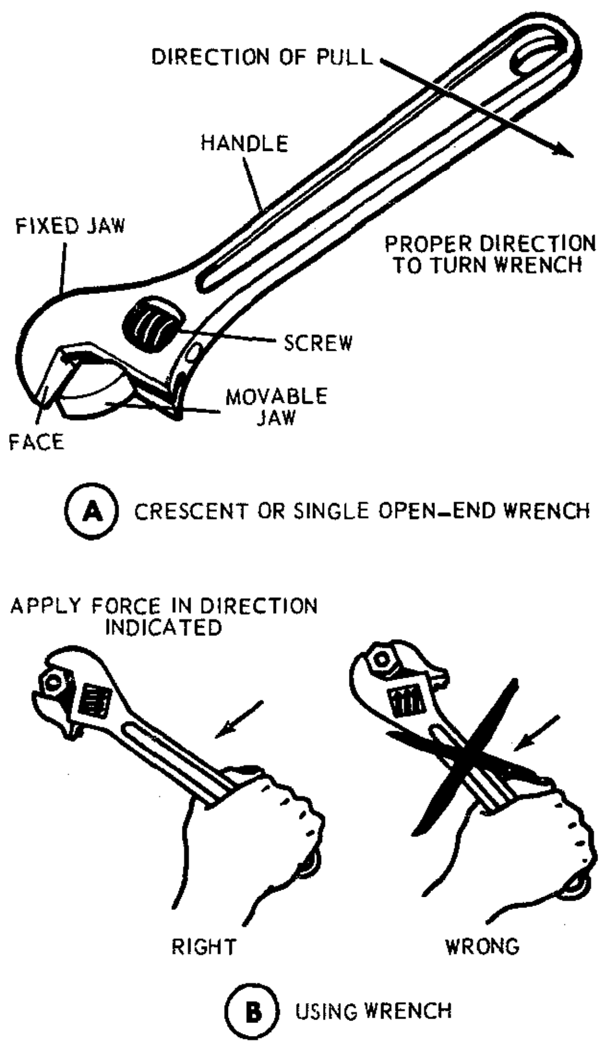
Fig. 4.48. Left—an Allen wrench. Right—a setscrew.

than open-end wrenches if the correct size is used. *Socket* wrenches also completely box the nut or bolt head.

In shops on farms and in agricultural businesses, the following fixed-jaw wrenches are often used:

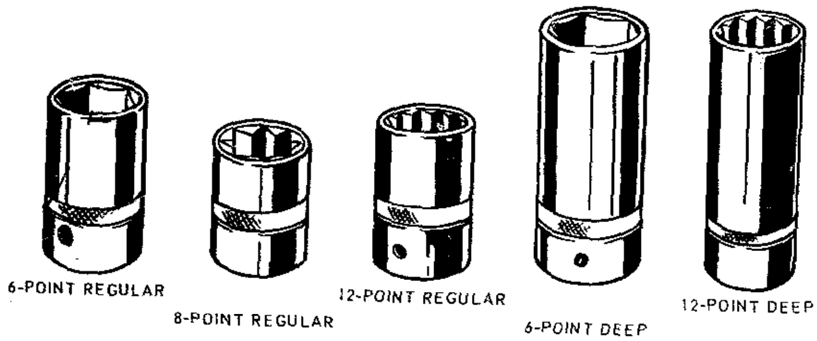
1. Socket wrench set—6, 8, and 12 point, 1/4" to 1 1/4", with attachments.
2. Straight wrench set—12 sizes, 5/16" to 1".
3. Box-end wrench set—6 offset, 3/8" to 1".

Socket wrenches are best adapted for heavy-duty jobs. The vise-grip wrench is popular, because a firm or vise-like grip on a nut is possible.



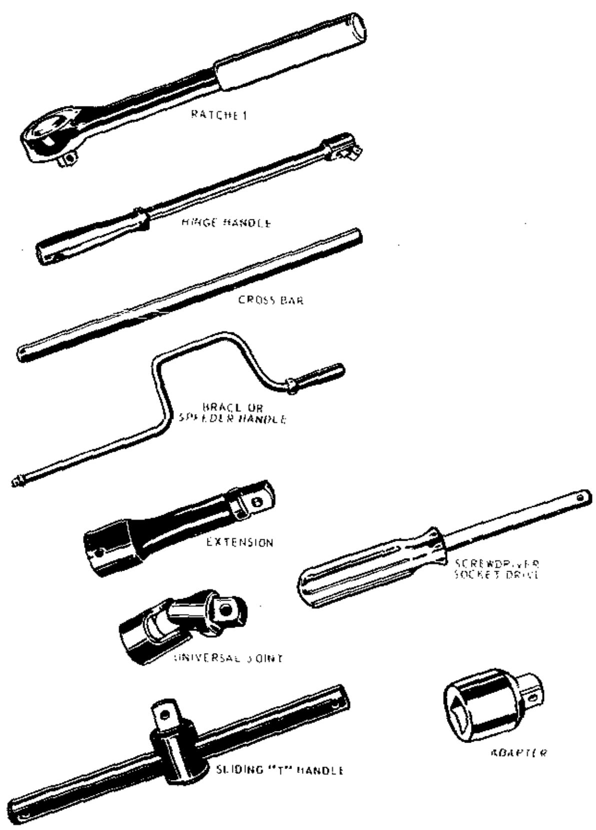
(Courtesy U.S. Department of the Army)

Fig. 4.49. Learn how to use the crescent wrench correctly.



(Courtesy U.S. Department of the Army)

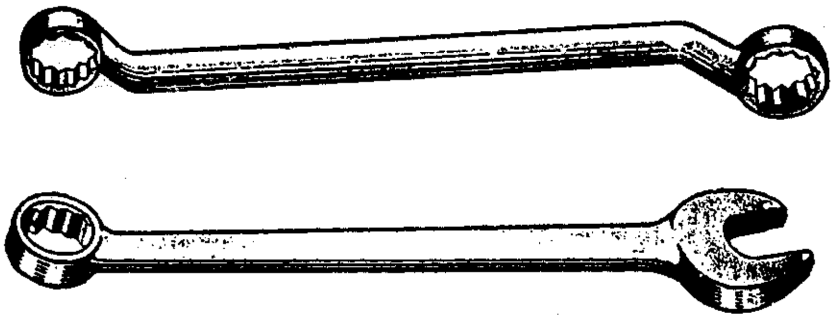
Fig. 4.50. Sockets for socket wrenches.



(Courtesy U.S. Department of the Army)

Fig. 4.51. Various driving attachments for a socket wrench.

In selecting and using wrenches, consider the type of job to be done. The number and location of the nuts and bolts may indicate the type of wrench to use. Learn to judge the size of nuts and bolt heads so that the correct size of wrench may be selected. Always choose the safest wrench. Choose a socket wrench if the nut or bolt is in a relatively inaccessible place. A ratchet handle may be used with a socket wrench. Box-end wrenches are for general purpose work. They are suited for use in close quarters, because as little as $^{1}/_{12}$ of a turn can be taken each time the wrench is shifted. Open-end wrenches are light, strong, and convenient. The jaws are set at an angle, which makes it easy to increase the swing of the handle by turning the wrench over.



(Courtesy Bureau of Labor Standards)

Fig. 4.52. A box wrench and a box and open-end combination wrench.

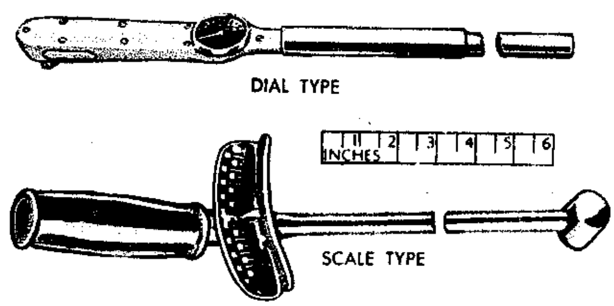


Fig. 4.53. Torque wrenches for use with sockets.

In tightening a nut, turn it until the wrench feels solid. Then give the wrench a sharp jerk. The sharp jerk will set the nut in a final postion without twisting if off or stripping the threads. Knowing when a wrench feels solid comes with experience.

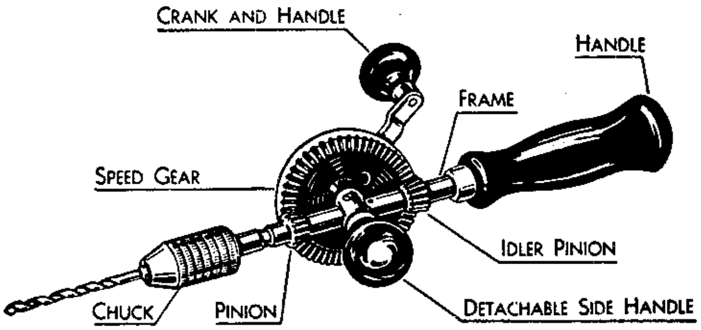
There are several types of adjustable wrenches. The common types used in agricultural business and on farms are:

1. Crescent type wrench
2. Vise-grip wrench

Pliers—Pliers are designed to hold and to cut materials. They are not wrenches. Wrenches are tools for tightening or loosening nuts or bolt heads. The most common type of pliers used on farms and in agricultural businesses is the adjustable combination pliers. They are a general purpose tool for holding flat or round stock and for cutting wire. If used as wrenches to tighten or loosen nuts, they may damage the sides of the nuts.

Hand Drills and Drill Bits—Hand-drilling tools are the hand drill, breast drill, and brace. Holes ¼ inch and smaller may be drilled in metal by hand-operated drills. The bits used in metal drilling tools are called twist bits.

In using twist drills, lubricate tool steel, soft steel, wrought iron, and copper with oil. Drill cast iron, brass, and babbitt dry. Lubricate glass with turpentine.



(Courtesy Stanley Tools)

Fig. 4.54. A hand drill with the principal parts named.

In drilling with hand-operated drills, use the following procedure, which will give good results:

1. Locate the exact center of the hole.
2. Mark the center of the hole with a prick punch. Sink mark deep enough with a center punch to receive the point of the twist drill.
3. Select a twist drill bit of the desired size.
4. Fasten the work securely.
5. Drill horizontally whenever possible.
6. Place a drop of oil in center punch mark.
7. Set the ratchet so that the drill will turn clockwise.
8. Keep the drill at right angles to the work while drilling.
9. Provide a steady, firm pressure on the head of the brace.
10. Check to determine whether or not cut is located properly. If not, make a nick with a chisel on the side of the cut toward which the drill should be drawn.
11. Put another drop of oil on the cut.
12. Ease the pressure and drill slowly when the point of the drill breaks through the metal.
13. Put the ratchet in the neutral position and work the drill back and forth if the drill bit catches while finishing the hole.
14. Drill a pilot hole first about one-half the diameter of the hole desired if the drill is difficult to force through the metal.

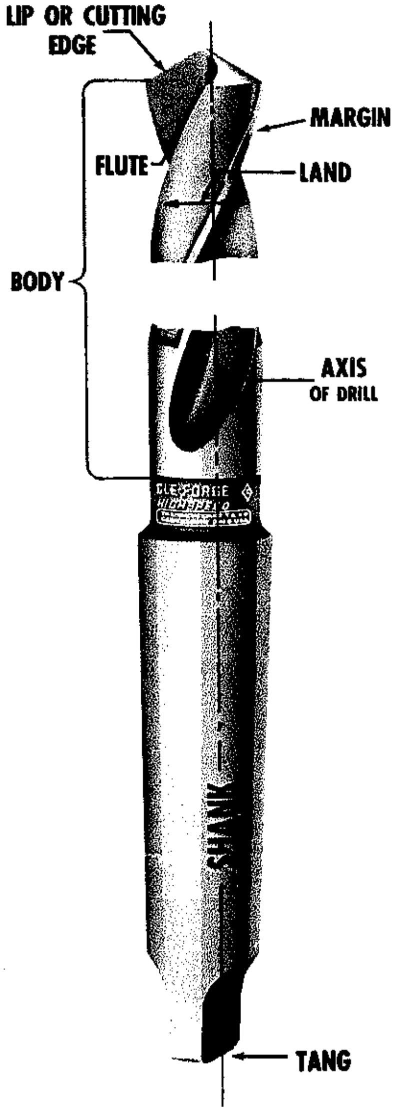
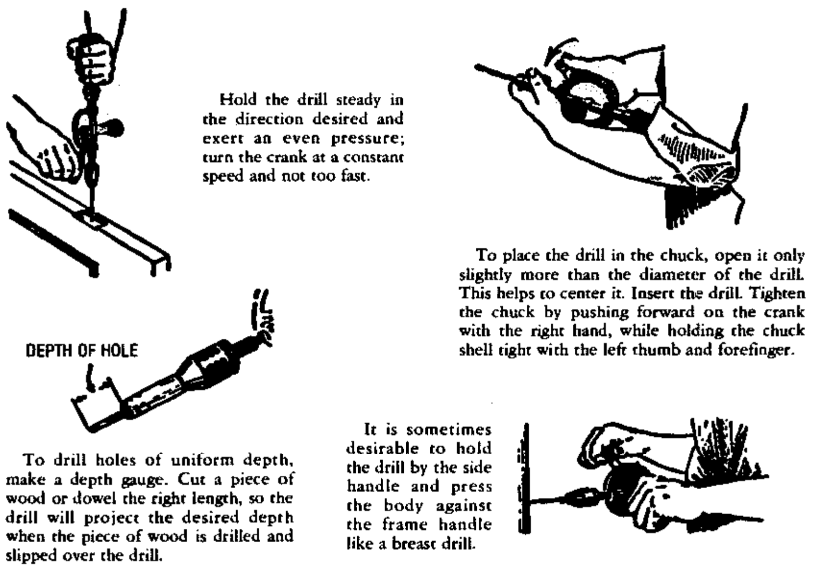


Fig. 4.55. Twist drill nomenclature.

Vises—Vises are used for holding work. There are three types of vises used in agricultural work. They are the machinist's vise, the blacksmith's vise, and the general utility vise. The blacksmith's vise is made for heavy work. The general utility vise has a small anvil on the back and has removable jaws. Pipe jaws may also be used in a general utility vise.

When light or soft materials are clamped in a vise, light tension on the jaws is essential. For light, soft, and finished materials, loose jaws made of copper, brass, or lead which fit over the regular vise jaws may prevent damage to the work.

When heavy or hard materials are secured in a vise, pull the vise up tight and then give the end of the handle a sharp, quick push. The screw of vises should be



(Courtesy Stanley Tools)

Fig. 4.56. The techniques of using a hand drill.

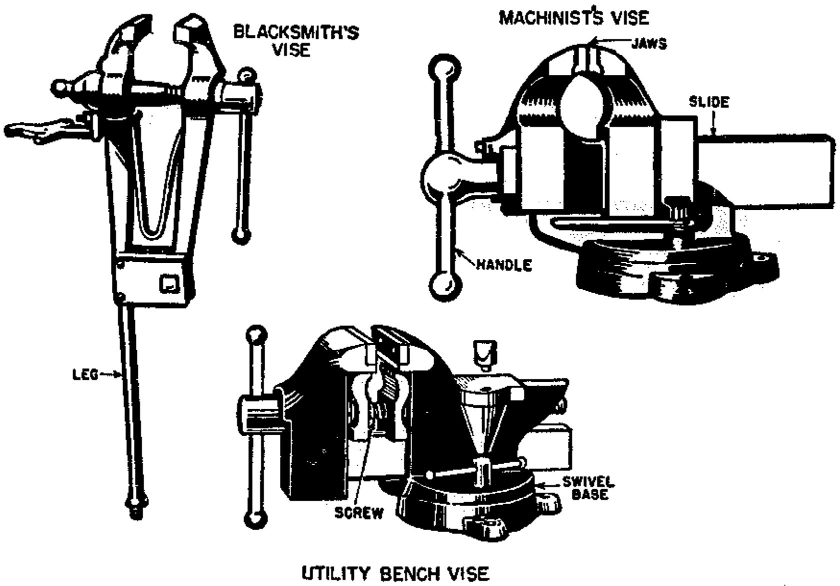


Fig. 4.57. The types of vises needed in an agricultural shop.

lubricated frequently with heavy 30- or 40-weight oil. Do not oil the swivel joint of a vise because oil impairs its holding power. When a vise is not in use, close jaws lightly and leave the handle in a vertical position.

Files—Files are made from hardened steel. They come in various shapes and sizes, and in various sizes of cuts (chisel teeth).

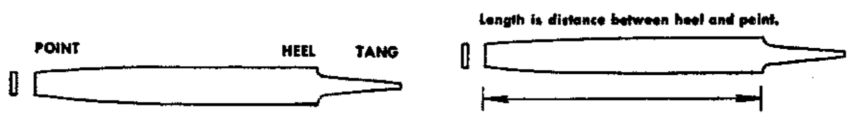
The more common files are:

1. Flat files which are used for smoothing both wood and metal.
2. Rasp cut files which are used for smoothing coarse wood work.
3. Half round files which are used for both metal and wood.
4. Round bastard files which are used for enlarging and smoothing holes.
5. Taper triangular files which are used for filing saws or cleaning threads.

Some precautions in using files are as follows:

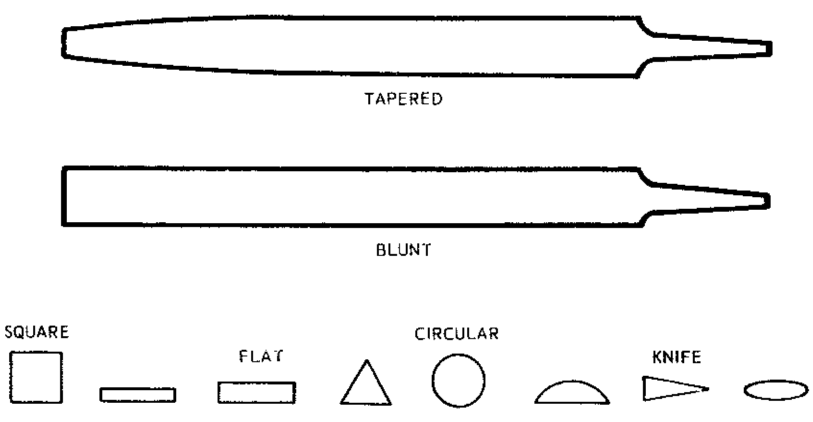
1. Fasten material to be filed securely.
2. Do not put too much pressure on the file.
3. Keep the file clean. This may be done with a wire brush.
4. Do not throw files on a bench, as it may dull their teeth.

In using a file, hold the handle of the file against the palm of the hand, with the thumb on the top of the handle. Hold the end of the file with the other hand. Use pressure on the forward stroke only, and use only enough pressure to make the file cut evenly. Do not bear down hard on a new file, or the teeth will be ruined. A new file should be broken in by using it first on brass or bronze. Lift the file on the return stroke. Do not take more than 30 or 40 strokes a minute. Excessive speeds will ruin both the file and the work. When work chatters because the metal is not held tightly, the teeth of the file may be damaged.



(Courtesy Henry Disston and Sons, Inc.)

Fig. 4.58. The names of parts of a file.

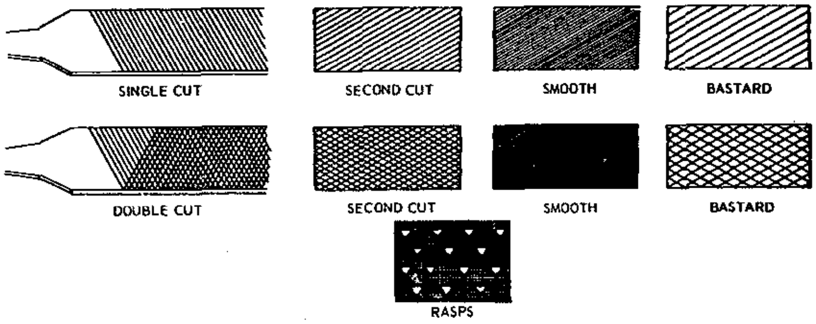


(Courtesy U.S. Department of the Army)

Fig. 4.59. Various shapes of files.

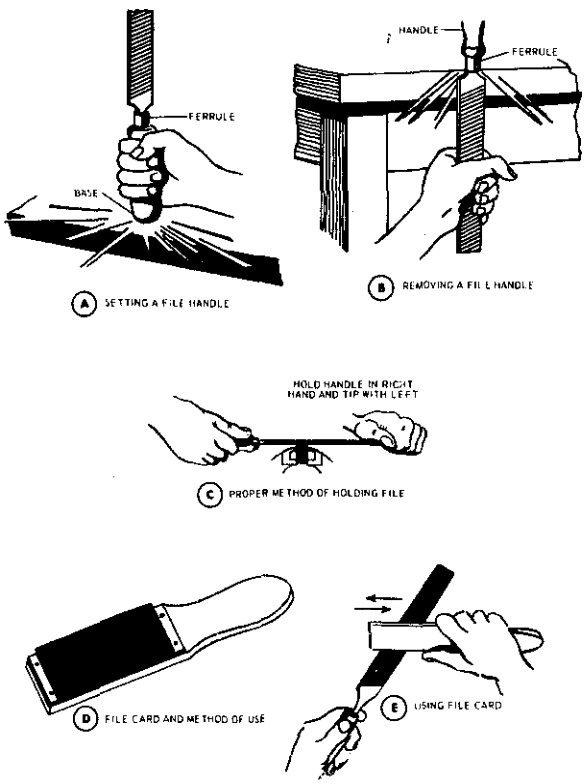
Rubbing chalk on a file before it is used will help to prevent it from becoming clogged. If a file becomes clogged, it may be cleaned with a file card, pick, and brush.

Do not use a file on material harder than the file. To prevent scratching or cutting too deeply, use a little oil on the file.



(Courtesy U.S. Department of the Army)

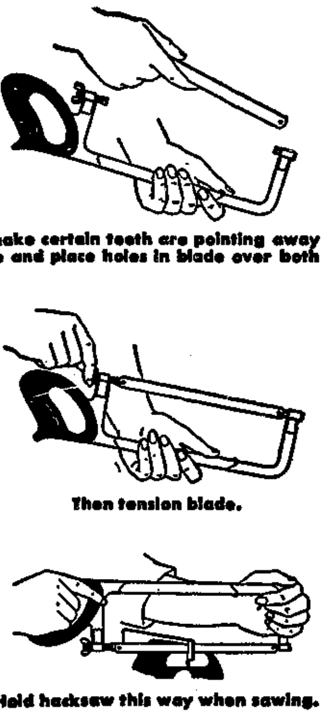
Fig. 4.60. Various cuts of files.



(Courtesy U.S. Department of the Army)

Fig. 4.61. Care and use of a file.

Hacksaws—Hacksaws are made to cut metal. Hacksaw blades are of two types: all-hard blades and flexible blades. The all-hard blades are hardened throughout. Only the teeth of the flexible blades are hardened. Use an all-hard blade for sawing heavy work, tool steel, cast iron, and brass. Use a flexible blade for sawing light and hollow materials. Blades have from 14 to 32 teeth per inch. Blades with 24 teeth per inch are recommended for general use. For heavy material select a blade with fewer teeth per inch. For light material select a blade with more teeth per inch.



(Courtesy Henry Disston and Sons, Inc.)

Fig. 4.62. Installing a hacksaw blade and holding a hacksaw when sawing.

The following procedure should be followed in using a hacksaw:

1. Mark the material to be sawed. A file may be used to nick the material to be sawed, and the saw can be started in this nick.
2. Make sure that the material is secure before sawing.
3. Do not start the saw on a corner of the material to be sawed. The maximum number of teeth should be engaged at all times. Start saw on the widest part of the material.
4. Push the hacksaw forward with a light stroke.
5. Remove the pressure and pull straight back on the return stroke.
6. Do not use more than 50 to 60 strokes a minute.
7. Prevent chattering on thin materials by placing pieces of wood or soft metal on each side of the material being sawed.

Punches—Punches are used to start holes for drilling and to punch holes in sheet metal, 24-gauge or thinner. Center punches are used to start holes for drilling. Prick punches are used for marking. Pin punches are used for driving out pins. Holes $^1/_{16}$ to $^1/_4$ inch in diameter may be made in sheet metal with a solid punch. In punching holes with a solid punch, mark the metal with a center punch, place the metal on a block of wood, and strike the solid punch with a heavy hammer.

The procedure to follow in using a hollow punch is to:

1. Mark the center of the hole with a prick punch.
2. Use a pair of dividers to mark the circle for the hole. Set distance of dividers at one-half the diameter of the hole desired.
3. Place the work on a piece of wood and select a punch of the correct size.

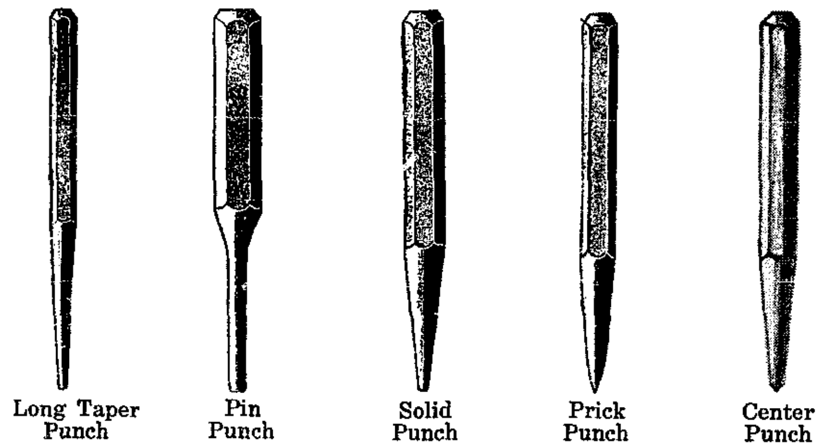
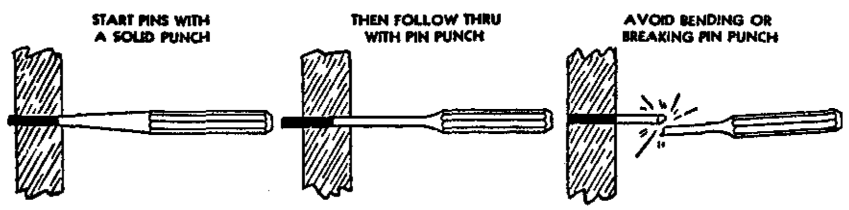


Fig. 4.63. The types of punches.

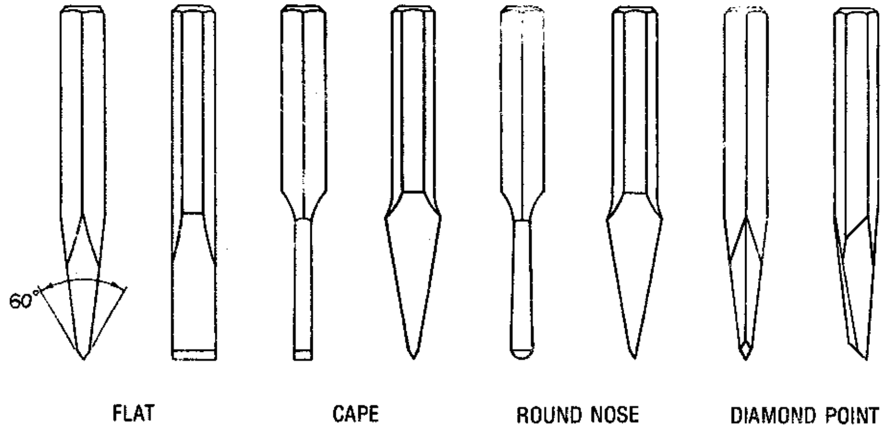


(Courtesy Cincinnati Tool Co., Mfrs. of Hargrave Tested Tools)

Fig. 4.64. The correct use of solid and pin punches.

Chisels—Chisels are made to cut cold metal. They will usually cut any metal which can be filed.

The four types of cold chisels, classified according to shape, and frequently found in a shop in an agricultural business or on a farm, are flat, cape, round nose, and diamond point. Flat chisels are used for chipping, removing metal from a flat surface, and cutting sheet metal. Cape chisels are used for cutting grooves and slots. Round nose chisels are used to cut concave grooves, and diamond point chisels are used to cut V-shaped grooves.



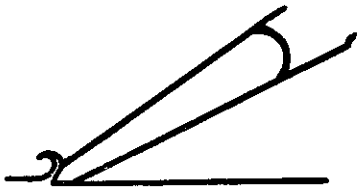
(Drawn by Ronald Ipsen)

Fig. 4.65. The types of cold chisels frequently used on farms and in agricultural businesses.

In using a chisel, watch the edge of it. Sharp, quick blows are best. Reset the chisel after each blow.

In cutting heavy, round stock, cut halfway through and then turn the stock and make the rest of the cut from the opposite side. Cutting sheet metal with a chisel will stretch the metal, so this method of cutting should be avoided whenever possible. In cutting sheet metal, mark the metal and use the vise jaws as a base to secure a shearing action. Keep the cutting edge of the chisel flat against the vise jaws.

The angle of the cutting edge of a chisel should be approximately 60 degrees with the cutting edge slightly rounded. Sharpen chisels on an ordinary coarse grinding wheel. Don't grind so fast that the chisel becomes heated, because heating takes the temper out of a chisel.



(Courtesy Stanley Tools)

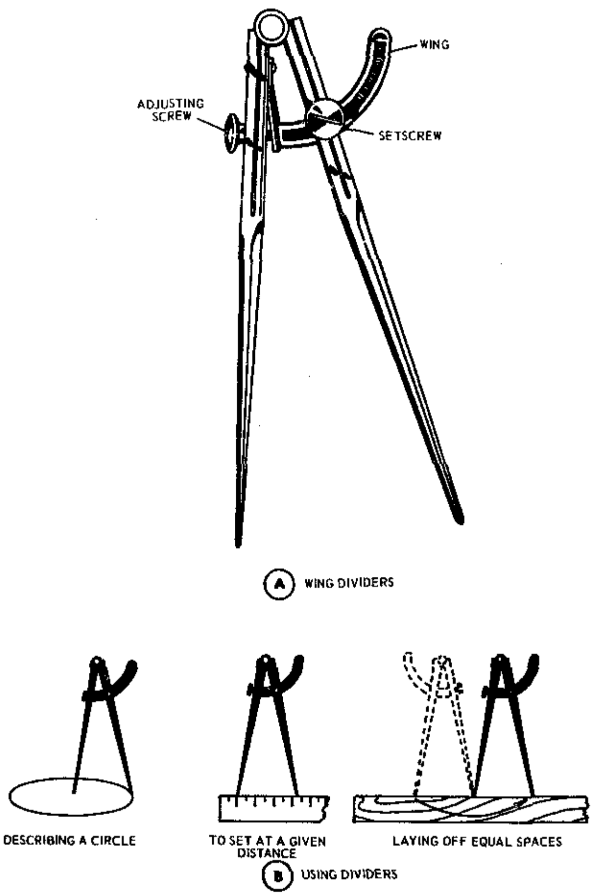
Fig. 4.66. In removing metal, hold the chisel at an angle that will keep the surface of the work and the lower bevel of the chisel parallel.

MEASURING TOOLS

Scriber—A scriber is used for marking lines on metal the same as a marking pencil is used to mark lines on wood. Put only enough pressure on a scriber to make the mark clear.

Fig. 4.67. A scriber.

Calipers—Three types of calipers used frequently are dividers, inside calipers, and outside calipers. *Dividers* are used for scribing circles, for measuring distances, and for transferring distances. *Inside calipers* are used for measuring inside diameters of holes and slots. *Outside calipers* are used to measure outside dimensions, such as the diameters of rods.



(Courtesy U.S. Department of the Army)

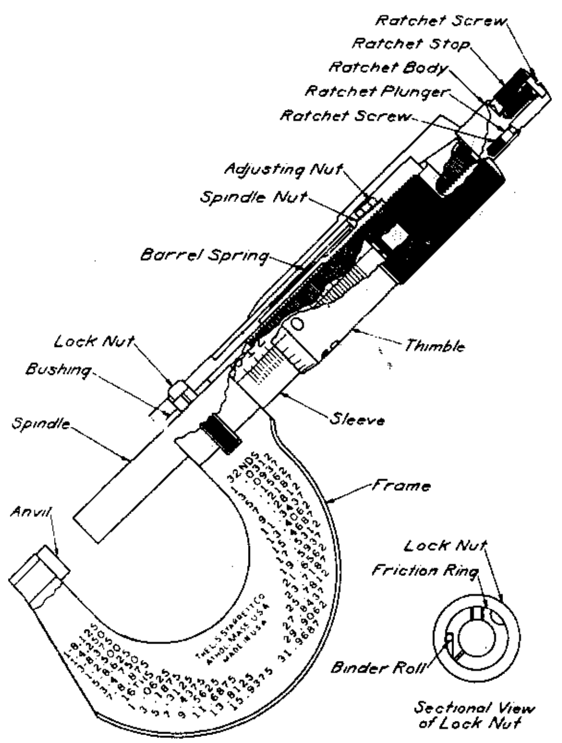
Fig. 4.68. Dividers and their uses.

Micrometer—A micrometer is used for very accurate measuring. It measures to thousandths of an inch. A mechanic may use a micrometer to measure the amount of wear on parts such as valve stems.

A micrometer is a very delicate tool and must be used with care. It will take measurements of less than the thickness of a page in this book. In measuring with a micrometer, place the piece to be measured between the anvil and the spindle. See Fig. 4.69. Screw the spindle until it touches the piece, but do not screw the spindle until it clamps on the piece being measured. Excessive pressure on a piece will ruin a micrometer.

In reading a micrometer, notice that there are 24 numbers on 25 equal divisions around the spindle. Each mark or division line represents one thousandth of an inch. There are also gradation markings on the hub. Each gradation mark on the hub represents 25 thousandths of an inch. Each number on the hub includes four gradation marks and represents 100 thousandths of an inch. When the micrometer is closed completely, the "0" on the spindle is aligned with the "0" on the hub. If the spindle is unscrewed until the "10" mark on the spindle is aligned with the lengthwise or reference line on the hub, the opening is 10 thousandths of an inch. If the spindle is unscrewed one complete turn so that the "0" line on the thimble is aligned with the reference line, the first gradation mark will be uncovered. The opening will be 25 thousandths of an inch. When the "0" line on the thimble is aligned with the reference line and the "1" mark on the hub is uncovered, the opening is 100 thousandths of an inch.

One complete turn of the spindle will change the opening of the micrometer 25 thousandths of an inch. As an example of an actual measurement, assume that the "1" on the hub and two additional marks on the hub have been uncovered and



(Courtesy L. S. Starrett Co.)

Fig. 4.69. A sectional view of a Starrett Micrometer Caliper.

that the number "16" on the spindle aligns with the reference line on the hub. The "1" represents 100 thousandths of an inch. The two additional marks on the hub each represent 25 thousandths of an inch. The total on the hub is 150 thousandths of an inch. The reading on the spindle represents 16 thousandths of an inch. The 16 thousandths is added to the 150 thousandths, making a total of 166 thousandths of an inch.

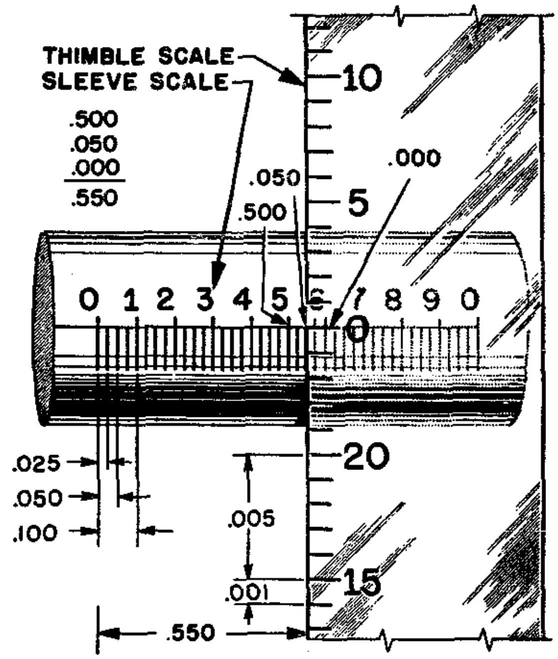


Fig. 4.70. Sleeve and thimble scales of a micrometer (enlarged).

CONCRETE TOOLS

The tools and equipment used in concrete work are discussed in Chapter 31.

PLUMBING TOOLS

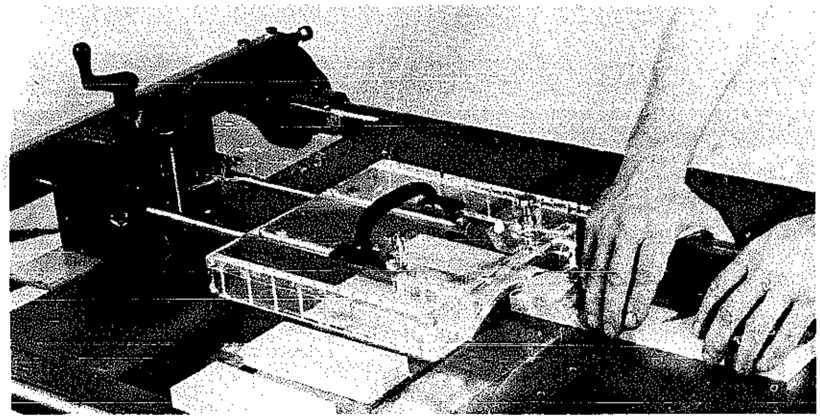
Plumbing tools and equipment are shown and their uses are described in Chapter 34.

ELECTRIFICATION TOOLS

The special equipment and tools needed for wiring for agricultural purposes in businesses and on farms are presented in Chapter 38.

POWER TOOLS

Principles of Using—Many of the principles of using power tools are identical with the principles of using the hand tools designed for the same purposes. The difference is often the fact that the power for operating is furnished by an electric motor instead of by the operator. Therefore, be sure you understand the principles of using hand drills, saws, files, and sanders before you attempt to use power drills, saws, and grinders.



(Courtesy Brett-Guard Co., Englewood, New Jersey)

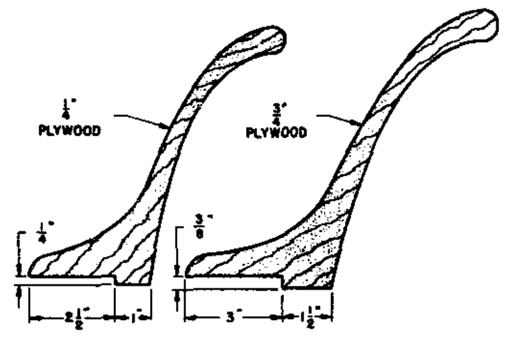
Fig. 4.71. Crosscutting with a table saw. Notice the use of the guard. A saw should not be used without a guard. If the guard does not work properly, adjust it or obtain a new one.

Safety Precautions—A big difference between hand tools and power tools is that power tools are more dangerous. Accidents with power tools are often more serious. Many examples could be given relating to the loss of fingers, hands, feet, eyes, and even lives, in the use of power tools.

Before you use a power tool, be sure you have been "checked out" on the safe use of the tool. Study the operator's manual regarding the safe use of the tool, and never operate a power tool unless all the safety guards provided by the manufacturer of the tool are functioning properly.

All power tools should be grounded properly before they are used. When power tools come from the factory, they are insulated so that the operator receives no shock when using them. However, unless a safe ground is provided, an operator will be shocked if a short develops. Headlines in papers frequently tell about electrocutions resulting from the use of power tools that have not been grounded safely.

How can a safe ground be provided for power tools? Most new power tools are provided with three-prong plugs. The third prong of the plug connects with the ground wire in the receptacle. Thus, if the tool's insulation is damaged and a live wire touches the frame of the tool, the current will pass through the ground instead of through the operator's body.



(Drawn by Ronald Ipsen)

Fig. 4.72. Push sticks for ripping.

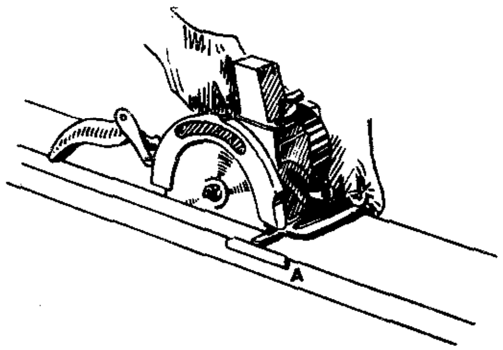


Fig. 4.73. Ripping with a portable circular saw, using a ripping guide (A).

What should be done if the receptacle outlets for power tools are for two-prong plugs instead of three-prong plugs? The correct procedure depends on the type of wiring in the building. Since the fuse boxes in approved wiring systems are grounded, a third or ground wire may be installed back to the fuse box. Receptacles for three-prong plugs may then be installed. If the wiring is in conduit, the conduit may be used as the ground if it runs to the fuse box. If the outlet boxes are metal and the wiring is in conduit, an adapter plug may be installed so that the three-prong plug on the tool may be used. The adapter plug has a ground wire that is fastened under the center screw on the receptacle. If the receptacle is plastic, the ground wire on the adapter plug should be fastened to the conduit or to a water pipe, if the water system contains underground metal pipe.

If a portable power tool does not have a three-prong plug, it should be provided with a three-wire cable and a three-prong plug. However, until this is done it may be grounded by attaching an insulated wire to the frame of the tool and fastening the other end of the wire to a grounded water pipe or grounded conduit. A stationary power tool may be grounded permanentaly by attaching a copper metal strap or wire to the frame of the tool and to a grounded water pipe or conduit. A two-prong plug may be used if the power tool is insulated with plastic housings. To prevent ground faults when you are operating power tools, use a power cord with a portable ground fault circuit interrupter (G.F.I.C.).

Power Drills

Electric drills may be mounted or portable. The size of a drill indicates the maximum size of hole which the drill is capable of drilling. If a larger hole is drilled, the motor will be overloaded and the drill will stall.

The procedure for drilling with an electric drill is similar to the procedure used in hand drilling. Have the motor running when the point of the drill bit is inserted in the punch mark. Remember that twist drills do not pull themselves through the metal and that pressure must be exerted by the operator. Relieve the pressure when the point of the drill begins to break through. Pull straight back when removing the drill.

Portable Power Drills—One-fourth-inch, ⅜-inch, and ½-inch portable power drills are popular in agricultural businesses and on farms. The size of a drill refers to the maximum size shank the drill will hold.

Portable power drills may be used for drilling in wood, metal, plastic, masonry, and so forth. Attachments of various sorts are available for such activities as grinding, brushing, sanding, buffing, and polishing.

The chuck of a drill is the three-jaw part which holds the bit. A portable power drill may be equipped with chucks that are tightened in four different ways. These four different types of chucks are (1) keyless, self-tightening, (2) geared key

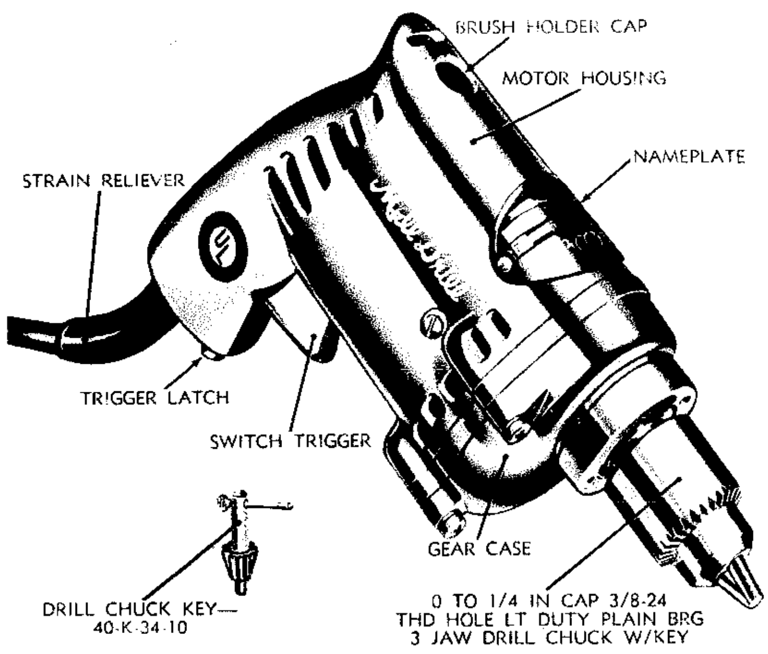


Fig. 4.74. A portable electric drill.

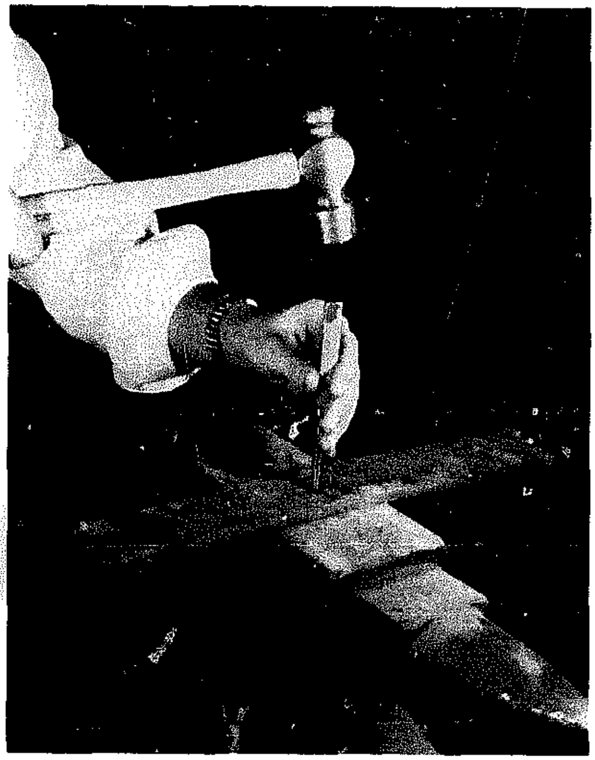


Fig. 4.75. The location of a hole to be drilled should be marked with a center punch.

(Jacobs-type), (3) hex-key, and (4) hand-tightened. The keyless, self-tightening chuck is the most convenient type.

With the geared key chuck, a key is used to tighten the three jaws of the chuck quickly and uniformly, and the bit is centered and gripped firmly in the process. With the hex-key chuck, a small hex-key wrench is used to tighten the chuck.

Most portable power drills are equipped with universal motors which may be operated on alternating or direct current.

In using a portable power drill for drilling holes in steel, iron, and aluminum, remember to use a lubricant. A lightweight oil for engines is suitable. It is not necessary to use a lubricant in drilling brass. To prevent the "walking" of a drill and the scarring of the work, it is advisable to punch a depression in the material being drilled with a center punch.

The operator of a portable power drill should be careful to hold the drill at the correct angle for the hole desired. Light pressure should be exerted on the drill if drilling metal because the drill bit does not pull itself into the metal. The pressure on the drill should be reduced when the point of the bit begins to break through the work. Remove the bit by pulling *straight back* on the drill so that the bit is not broken. The motor of the drill should then be shut off.

Pilot holes, small lead holes, are advisable when drilling large holes. Pilot holes reduce the amount of pressure needed for drilling.

In using a portable drill, select a larger drill if it is necessary to "bear down" on the drill until it overheats or stalls. The excessive overloading of a drill may damage or burn out the motor.

Most drills are permanently lubricated at the factory. If not, they should be lubricated according to the instructions provided with the drill. The brushes in the motor of an electric drill will wear down eventually. It is advisable, therefore, to check the brushes every six months. When the brushes become shorter than 1/4 inch, they should be replaced. For further information regarding the care of the motors of portable power drills, see Chapter 39, "Selecting and Maintaining Motors."

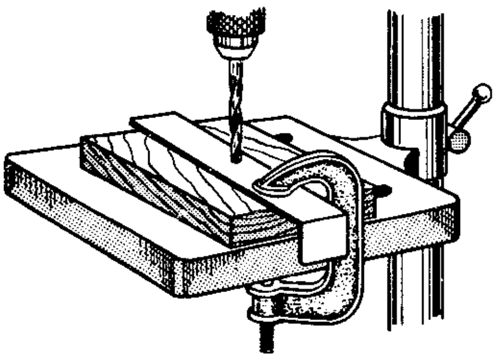


Fig. 4.76. Holding thin gauge metal for drilling.

Safety precautions are important in the use of all drills, but they are especially important in using a portable power drill.

When a power drill comes from the factory, it is insulated so that the operator receives no shock when using it. However, if this insulation breaks down, the current will pass through the operator if the drill is not grounded. See the preceding section of this chapter for information regarding the safe grounding of power tools. Care should be taken,, in using a portable drill, not to drop the drill on the feet or allow the drill bit to touch any part of the body. A turning drill bit will break the skin easily or become entangled in clothing quickly.

A brush should be used to remove the sharp metal drill chips. These sharp drill chips penetrate the skin easily. Check before starting to drill to be sure that you have removed the chuck key. Use a vise, clamps, or vise-grip pliers to hold small parts being drilled so that they do not spin around and injure you. Avoid forcing a drill. Wear safety glasses to prevent flying chips from becoming lodged in the eyes.

Drill Press—A drill press is a stationary drill designed for accurate and heavy drilling jobs. A drill press provides an operator with an easy control mechanism for feeding the drill bit into the work.

The metal to be drilled should be clamped securely to prevent accidents. The general principles of drilling presented for hand drilling and for the portable power

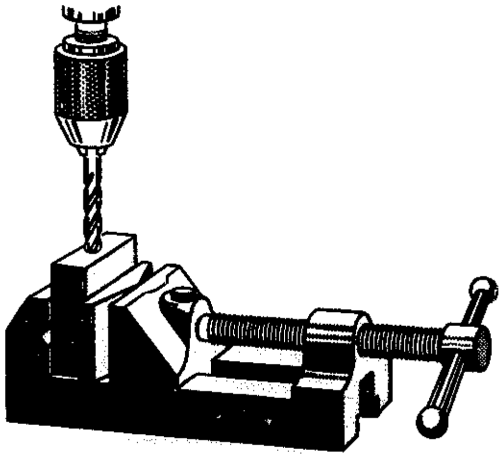
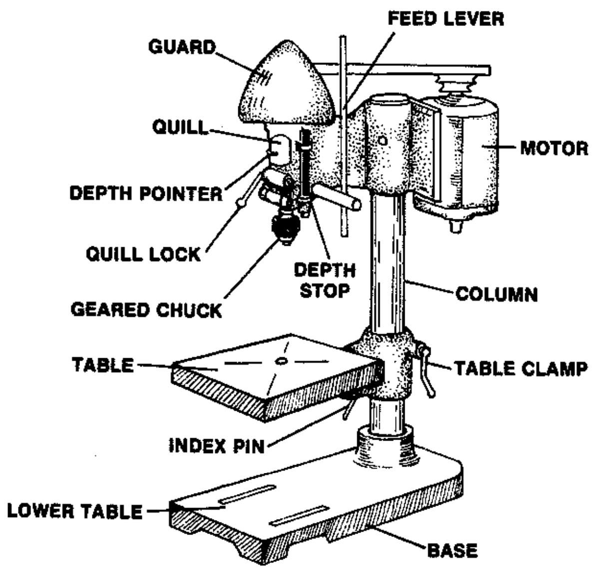


Fig. 4.77. Holding work with a drill press vise.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 4.78. A bench model drill press.

drill apply in the use of a drill press. In using a drill press, lower the drill bit to the material being drilled. Thus, the location of the desired hole must be placed directly under the bit for the hole to be in the correct location. The drill bit should be fed into the work with only sufficient pressure for cutting. If too much pressure is used, the drill will overheat or the motor will stall.

A portable power drill may be made into a drill press by the use of a drill stand.

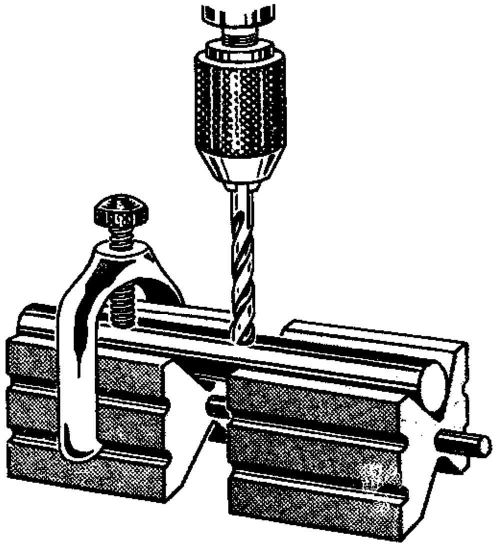


Fig. 4.79. Holding work in V-blocks.

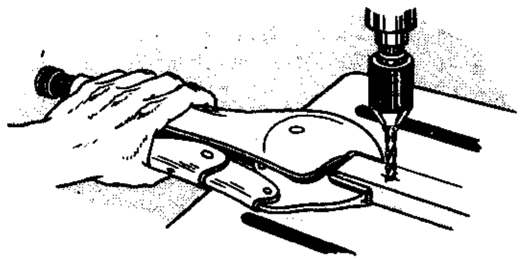


Fig. 4.80. Holding work with a pair of locking pliers.

Power Saws

Power saws are labor savers and time savers. In agricultural mechanics, power saws are used primarily for crosscutting, ripping, and cutting angles and bevels. A power saw may be either stationary or portable. Many shops on farms and in agricultural businesses have both types. Stationary power saws are usually of the (1) table or (2) radial arm types.

Saw blades for circular saws are designed for particular purposes. Most workers in agricultural businesses and on farms use a combination saw blade, but blades for ripping, crosscutting, and sawing concrete block, tile, and masonite materials are available. A combination blade may be used for ripping or crosscutting, but a ripping blade should be used for ripping only and a crosscutting blade for crosscutting only. The special blades for sawing concrete blocks, tile, and masonite material usually have teeth with carbide tips.

Portable Power Saw—A portable power saw is a lightweight saw for use on the job. With attachments it can be converted into a table or radial arm saw, but its primary use is for construction work where a table or radial arm saw is not available or cannot be used. It often can be used for the sawing ordinarily done with a handsaw. A portable power saw saves much labor and time in construction work. It is used for both crosscutting and ripping.

A portable power saw is *dangerous if used improperly*. The operator of a portable saw should not attempt to saw in an awkward position. A slip or fall while sawing may bring the saw in contact with a leg, foot, arm, or hand, and the resulting injury is often serious. Reaching around or in front of the saw may also result in an accident. Always keep the saw away from all parts of the body. Never use a portable power saw unless it is safely grounded. See section earlier in this chapter on the safe grounding of power tools.

A portable power saw is equipped with a guard for the saw blade. A portable power saw should never be used without its guard. The operator should also not use a saw if the guard does not work freely. A dull saw blade is dangerous, and pushing a saw too rapidly is dangerous. A portable power saw will save you much labor if used carefully and safely. If not used carefully and safely, it may kill you or incapacitate you for further work.

The *size* of saw usually found on farms and in agricultural businesses is a 6-inch or an 8-inch saw. A 6-inch saw will saw a piece of lumber 2 inches thick. An 8-inch saw will saw to a depth of 2⅞ inches. Saw motors are often permanently lubricated at the factory. If not, the operator's manual for the saw should be consulted for lubricating instructions. The motor of the saw should be kept clean, and the brushes and commutator should be checked at regular intervals. For information on the care and maintenance of motors see Chapter 39, "Selecting and Maintaining Motors."

Before *operating* a portable power saw, read the operator's manual for the saw and check to determine whether or not the guard is working freely, the saw is grounded, and the blade is sharp. If you have never used a portable power saw, practice on waste boards until you get the "feel" of it. Use a constant, but not excessive, pressure on the saw. If the saw binds or slows down, let it run and back it out slowly.

Check to see whether or not the saw kerf is on the waste part of the board. If the saw blade heats, it is probably dull and should be replaced with a sharp blade. Most portable saws are equipped with a gauge that may be used in ripping or in making cuts a certain distance from the end of a board.

Table Saws—Table saws are of two types, tilting table and tilting arbor. With a tilting table saw, the table is tilted for bevel sawing. With a tilting arbor saw, the blade is tilted so that sawing at an angle or bevel is possible. The tilting arbor saw is the more popular type because it is easier to use and it is safer.

The *safe use* of a table saw is important because many accidents result from the incorrect use of table saws. When using a table saw, do not stand directly in front of the saw blade. The saw may "kick" the board back toward the operator and

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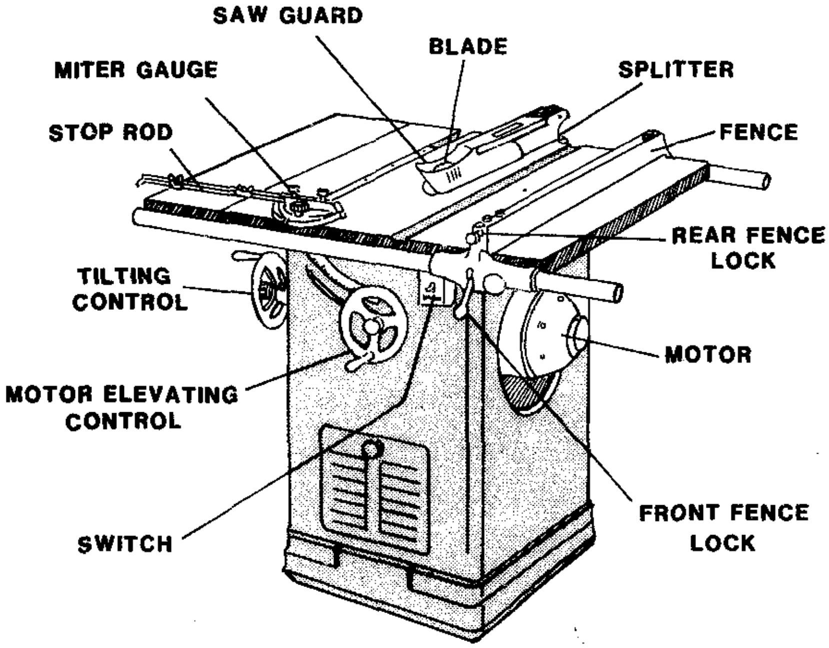


(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 4.81. A table circular saw.

cause a serious injury. While using a saw, wear safety glasses or an eye shield to keep chips and sawdust out of the eyes. Always use the guard for the blade of the saw even though it may seem inconvenient at first. Failure to use a guard may mean the loss of a finger, a hand, or your life. It is better to endure some inconvenience than it is to be the victim of an accident.

When ripping narrow pieces use a *push stick* instead of the hands. Always keep the hands away from the saw blade. Refuse to use a saw with a dull blade, because it is dangerous. A dull blade may cause a board to bind and "kick back" while being ripped.

Set the saw blade so that it extends through the board, but do not allow the blade to project too far. If the blade projects too far, binding and "kickbacks" are more frequent, and chips and sawdust are thrown a greater distance.

Twisted and warped boards cannot be safely ripped. If they are sawed, they may bind and kick back. To avoid binding when ripping a long board, use a helper or a support for the board. In ripping, do not allow the piece of wood being cut off to remain between the fence and the blade, because the saw blade may kick it back. "Kickbacks" are dangerous because they may throw the hands of the operator into the saw blade or injure the operator or other persons who are in line with the saw.

Before starting a table saw, check the location of others near the saw. Avoid sawing if other persons are near the saw or are in back of you and in line with the saw blade. Never rip without using a ripping fence.

When *ripping* adjust the ripping fence so that it is parallel to the blade of the saw and to the miter gauge slots. The distances from the front and the back of the blade to the fence should be equal. Set the distance of the ripping fence by measuring the distance between the fence and the point of a tooth of the blade.

In *crosscutting*, check the squareness of the miter gauge to the saw blade. The gauge may be placed in the groove on either the right or left side of the blade. The use of the miter gauge increases the accuracy of crosscutting and decreases the danger involved.

The height of the saw blade should be set 1/8 to 1/4 inch higher than the thickness of the wood being sawed.

Feed the wood into the saw at a uniform rate. Do not feed the wood into the saw so fast that the cut is rough and a chattering noise is produced. Also, do not feed the wood into the saw too slowly. Sawing too slowly causes the saw blade to heat and become dull.

In using a table saw, adjust the wood to be sawed so that the kerf, the wood removed by the saw blade, is on the waste end of the board. A mark may be made on the table of the saw to show the width of the kerf of the saw blade, or a wood facing may be placed on the front of the miter gauge. A notch or kerf is then sawed in this wood facing. After a board is marked for sawing, the mark on the board is aligned with the kerf in the wood facing of the miter gauge so that the mark on the board will not be sawed out by the blade of the saw.

When several boards are to be sawed the same length, clamp a stop block to the ripping fence or the miter gauge. When sawing a piece of plywood, a guide strip may be clamped to the plywood. This strip will guide the plywood along the edge of the saw's table as shown in Fig. 4.82. A board or piece of plywood that is too wide to fit between the miter gauge and the saw blade may be sawed by placing

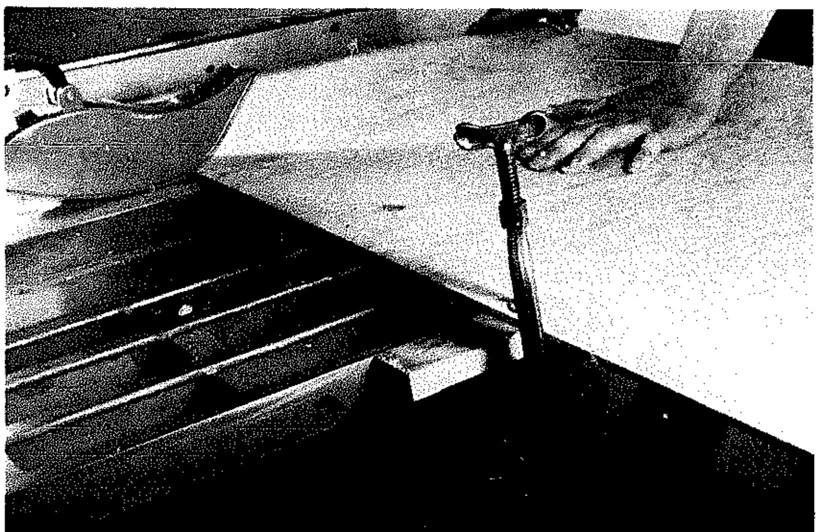


Fig. 4.82. A guide strip is clamped to the plywood being sawed.

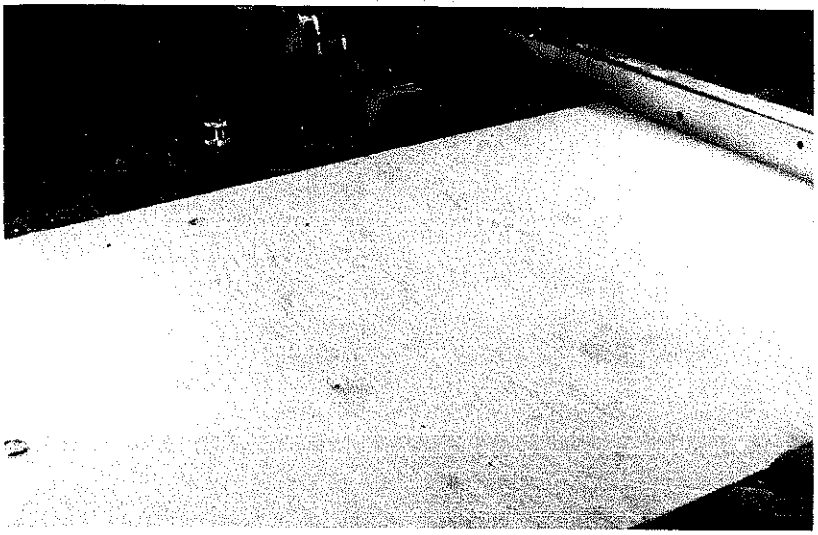


Fig. 4.83. When an extra-wide piece of plywood is sawed, place the miter gauge in front of the plywood and push the plywood against it.

the miter gauge in front of the board in a reversed position. The board is then pushed against the miter gauge as shown in Fig. 4.83.

In sawing *miters*, angles other than 90 degrees, the miter gauge is set for the angle desired. Before angles or miters are sawed, the accuracy of the miter gauge should be checked. A simple way to check the adjustment of a miter gauge is to set it for a 45-degree miter and saw a waste board. Check the angle of the cut with a square. If the miter gauge is not accurate, loosen the stop screw on the gauge and adjust the gauge until it is accurate.

A problem in sawing miters is the creeping of the board being sawed. Hold the board being sawed firmly against the miter gauge to prevent creeping. If the creeping problem is severe, put a hollow ground combination blade on the saw.

A 10-inch saw powered with a 1-HP motor is recommended for most shops on farms and in agricultural businesses. In installing a saw, place it so that the light for the saw comes from the left.

Radial Arm Saw—The motor and blade of a radial arm saw are suspended over the table of the saw. Radial arm saws are used for precision and heavy work. They are often more expensive to purchase than table saws.

A radial arm saw may be used for crosscutting, ripping, mitering, and beveling. Since adjustments for crosscutting, mitering, and beveling vary with the saw, the operator's manual should be consulted before a saw is used.

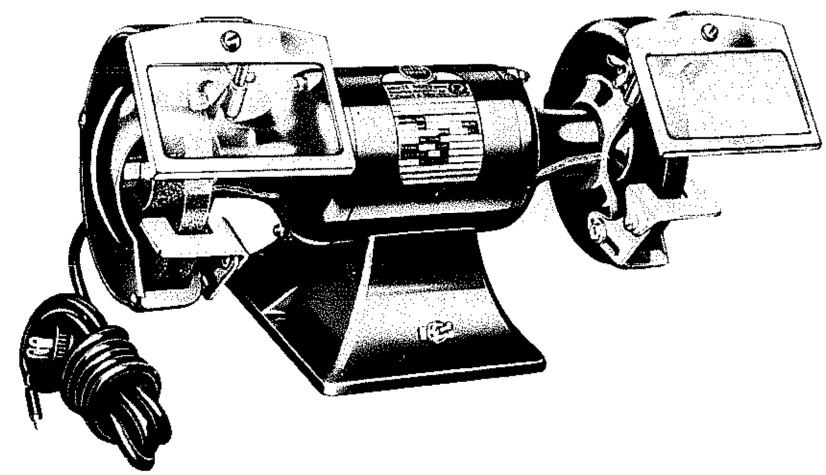
The body of the operator should be kept away from the front of the saw blade.

Power Grinder

Most bench grinders have both a medium grain and a fine grain abrasive wheel. The wheels are usually removable so that wire brushes, polishing wheels, and buffing wheels may be used.

The fine grain abrasive wheel is for sharpening tools and for work requiring a smooth finish or exact size. The medium abrasive wheel is for rough grinding when a quantity of metal is being removed

In grinding, do not use the side of the wheel because the pressure may crack it. Support work on the rests provided. The use of the rests is a safety precaution and makes grinding easier. A tool rest on a grinder should not be below the center of the wheel. It should be adjusted to within ⅛ inch of the wheel.



(Courtesy Walker-Turner Division, Rockwell Manufacturing Co.)

Fig. 4.84. A bench grinder.

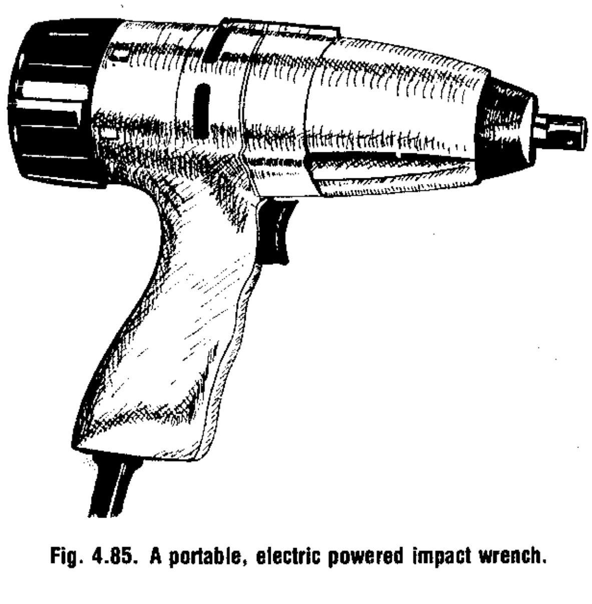


Fig. 4.85. A portable, electric powered impact wrench.

CHAPTER 5

Repairing and Sharpening Tools

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Why is it important that woodworking tools be kept sharp?
2. What sharpening equipment is needed?
3. Which tools are ground and honed? Which are filed?
4. How are wood chisels sharpened? Plane blades? Knives?
5. How are axes and hatchets sharpened?
6. What are the chief differences in the teeth of crosscut saws and ripsaws?
7. How are chain saws sharpened?
8. What precautions are necessary in sharpening auger bits?
9. How is a twist drill sharpened?
10. How is an edge put on a cold chisel?
11. How should pliers, screwdrivers, and punches be reconditioned?
12. How should shears be sharpened?
13. What general instructions should be followed in fitting tool handles?

Sharp Tools Necessary for Good Work—Keen-edged tools are essential for good work quality. Skilled workers cannot do their best work with dull, nicked, or improperly sharpened tools; beginners are under an even greater handicap. Tools are designed and sharpened by their manufacturers to give the maximum amount of service. A person who buys and uses them expects them to do efficient work. If users do not keep tools in proper working condition, they will not obtain satisfaction from their use.

Time used in keeping tools in good condition is time saved. A good worker takes pride in keeping tools sharp and derives pleasure and satisfaction in using them when they are in good condition. Sharp tools are also safer to use than dull ones.

Sharpening Equipment and Its Use—Very little equipment is needed for sharpening tools, and it is easily and cheaply obtained. Many tools are sharpened by grinding. In addition to grinding, most woodworking tools require whetting or honing on a carborundum stone or an oilstone to produce a fine edge.

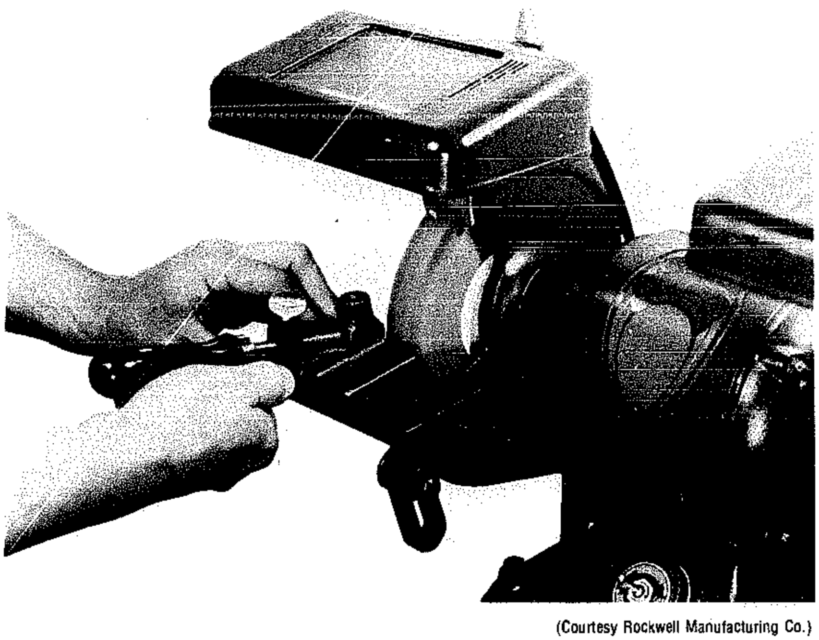
A shop should be equipped with a good bench grinder to do rough sharpening and to give cutting edges the proper bevel. Care should be taken to turn the surface of a stone *toward* the cutting edge of a tool rather than away from it.

There is less tendency to form a wire edge on a tool, and a more uniform job of grinding is possible, when the grinding wheel turns toward the cutting edge of the tool being sharpened. If a power grinder is used, care must be taken not to overheat the tool, which may cause it to soften and "lose its temper." The grinding wheel should be provided with a tool rest.

Honing or whetting is necessary to put a fine, keen edge on a tool. A double carborundum stone with a coarse side and a fine side is useful. Oilstones are used for finishing the sharpening process. An oilstone should be wiped after it is used and kept free from dust and grime.

A saw jointer, a saw set, a three-cornered file, and an ordinary flat mill file are needed for setting and sharpening hand saws. A clamp or vise is necessary for holding saws rigid while they are being set and sharpened. See Fig. 5.7.

Dressing and Truing Grinding Wheels—Properly maintained grinding wheels are essential for the successful sharpening of tools. After much use, the face of a grinding wheel may become glazed and not true. A wheel that is not true may have humps or high points, or it may be ridged and grooved. A dressing tool (see Fig. 5.1) is used to remove the glaze from the face of a grinding wheel and to true the wheel. When a dressing tool is used, adjust the tool rest to a horizontal or flat position and close to the wheel. Lay the dresser on the tool rest and push it firmly against the wheel. Use enough pressure on the dressing tool to prevent sparks. If sparks are produced, the wheel is grinding the dressing tool. A dressing tool should true the wheel and not be ground away.



(Courtesy Rockwell Manufacturing Co.)

Fig. 5.1. Dressing and truing a grinding wheel using a special attachment for the job.

Removing Rust and Dirt—Tools that are dirty and greasy are dangerous because they slip out of the hands more easily. Dirty tools also are more susceptible to rust. Rust pits tools, decreases their strength, lessens their efficiency, and reduces their value.

A safe solvent available from most oil companies may be used to clean dirt and excessive grease from a tool. Do not use gasoline. If the tool is not rusty, rust may be prevented by saturating a rag with a high-grade lubricating oil and rubbing the rag over the tool. Be careful to cover all metal parts on the tool with a light coating of the oil.

If a tool is rusty, the rust should be removed before the oil coating is applied. A wire brush may be used to remove rust if scratches on the tool are not objectionable. Scrapers may be used to remove large rust scales. A kerosene-soaked rag may be used to remove rust, but this method of removal is slow. It leaves no scratches, however. A fine emery cloth may also be used. Rust-removing solvents should not be used, because they may remove some of the metal along with the rust. Paint should not be applied to any part of a tool requiring a polished finish or to the cutting edge of a tool. If a tool is painted, a rust-inhibiting paint should be used as a first coat. See Chapter 11 for information on painting metals.

Cleaning Files—If a file is not cutting properly, it probably needs cleaning. A file is cleaned with a file card, pick, and brush. Figure 5.2 shows a file cleaner. A pick is a small, pointed wire tool used for picking out the pieces of metal lodged in the cuts of a file which cannot be removed with a file card.

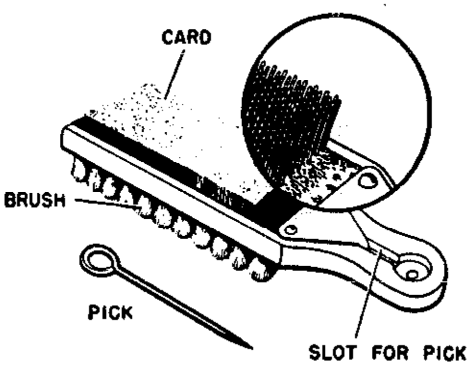


Fig. 5.2. A file cleaner. When cleaning a file with a file cleaner, lay it flat on a bench and draw the cleaner across it parallel with the cuts of the file.

When cleaning a file, lay it flat on a bench and draw the file cleaner across the file parallel with the cuts. Finish the cleaning process by brushing the file lengthwise.

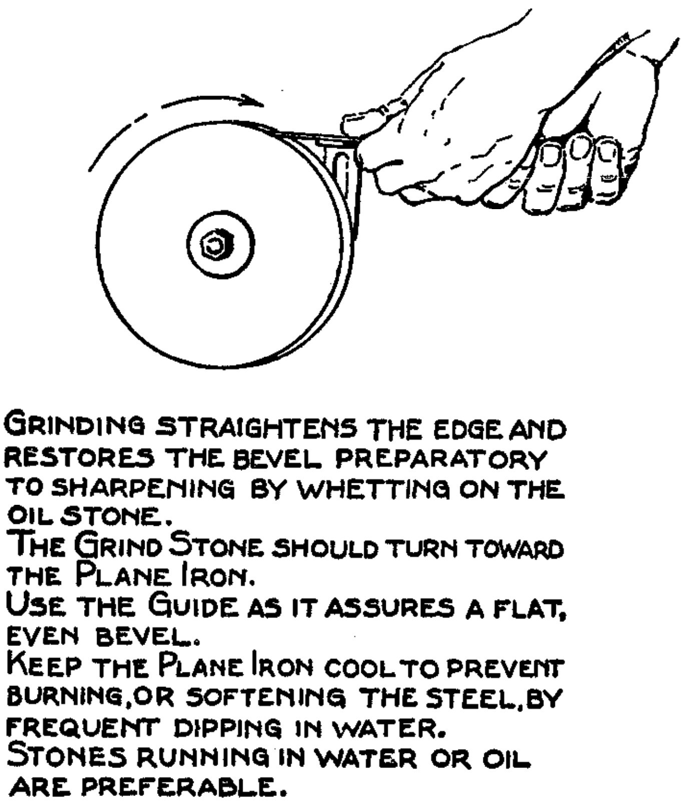
Sharpening Wood Chisels—If a chisel is nicked badly, the nicks should be ground out by holding the cutting edge of the chisel at a right angle to the stone until the nicks are removed. The chisel is then ready to be sharpened.

Grind the chisel on the beveled edge only. The length of the bevel will depend upon the type of cutting to be done with the chisel. For fine work a long bevel with a thin edge is best. For heavy cutting and mortising a shorter bevel is more satisfactory. For general work a bevel about ¼ inch long is most suitable, which means holding the chisel at a 25- to 30-degree angle to the wheel of the grinder. By using the tool rest on a grinder it is easier to obtain a uniform bevel. Move the chisel from side to side to wear the stone evenly. Continue the grinding until a uniform bevel is obtained and a "wire edge" has been formed. The corners of a chisel should be kept square.

Hone the chisel on the oilstone. Hold the chisel at a slightly greater angle than when grinding so that a second very small bevel will develop. After four or five forward strokes on the oilstone, turn the flat side of the chisel toward the oilstone. A few forward strokes will remove any wire edge and produce a very keen edge. Avoid producing a bevel on the flat side of the chisel.

A chisel may be kept sharp by an occasional honing, but after several honings, regrinding will be necessary to restore the proper bevel.

Sharpening Plane Blades—The method of sharpening plane blades is the same as the method of sharpening wood chisels, with two exceptions. The bevel should be made shorter, and the corners of the blade are rounded slightly. Unless

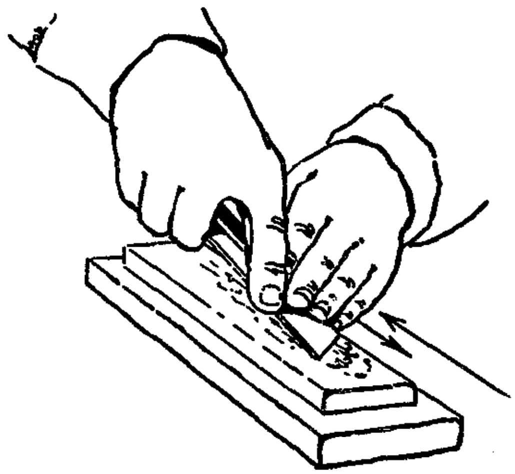


(Courtesy Stanley Tools)

Fig. 5.3. The technique of sharpening a plane blade.

the corners are rounded slightly, it is difficult to plane a surface perfectly smooth due to the plane marks which will be made by the square corners of the blade. A plane blade should be held to the grindstone at an angle of about 25 to 30 degrees, cutting a bevel about $^{3}/_{16}$ inch long or slightly longer than twice the thickness of the plane blade. It is very important that the bevel be kept straight and of uniform width.

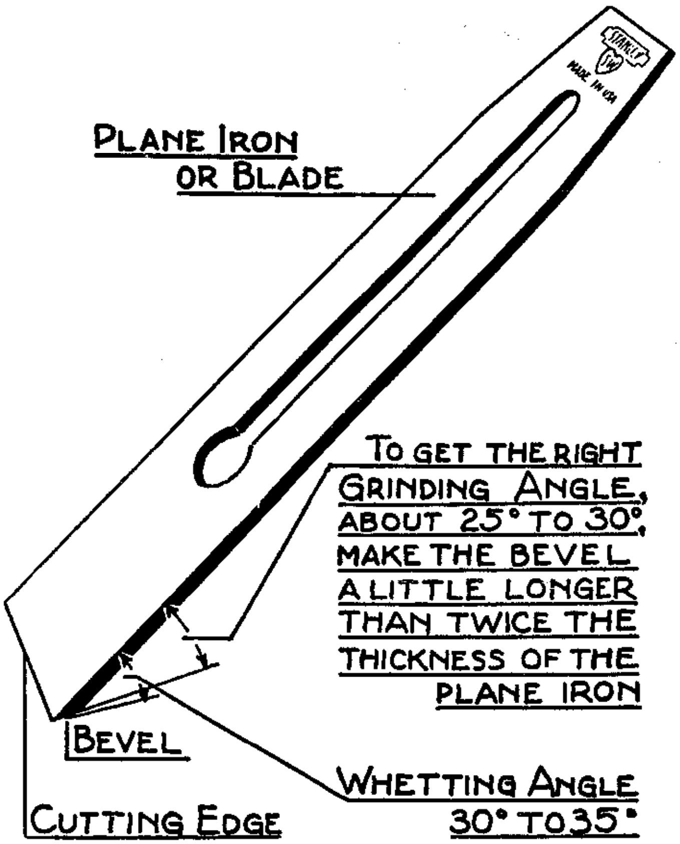
Hone a plane blade on an oilstone at a larger angle than when grinding so that a second very small bevel will develop near the edge of the blade. Remove any wire edge by a few strokes with the flat side of the blade held against the stone. Avoid a bevel on the flat side of the blade, because this prevents the cap iron from fitting tight. When the cap iron does not fit tight, shavings will clog the plane.



(Courtesy Stanley Tools)

Fig. 5.4. The technique of whetting a plane blade. Whet the plane iron on an oilstone to produce a very sharp cutting edge. Hold the plane iron in the right hand with the left hand helping. Place the bevel on the stone with the back edge slightly raised. Move the plane iron back and forth. Be sure the hands move parallel to the stone so that the angle between the plane iron and the stone will stay the same throughout the stroke. Use enough oil to keep the surface of the stone moist. Oil keeps the stone sharp by preventing particles of steel from filling the pores of the stone. Try to wear the stone evenly.

Sharpening Knives—A grinding wheel, a whetstone or an oilstone, and a butcher's steel are used to sharpen knives. First check the blade of a knife for nicks and remove these by placing the edge of the blade against a grinding wheel. When the nicks have been removed, the knife is ready to be sharpened. The first step in sharpening is to hold the blade of the knife flat against the face of the grinding wheel so that a long bevel and a thin, sharp edge are produced. Move the blade back and forth across the face of the grinding wheel. Grind first one side of the blade and then the other side. A low-speed grindstone is best for sharpening knives. If a high-speed grinder is used, extreme care must be taken to prevent overheating the edge of the blade and ruining its temper. If a high-speed grinder is used, use very light pressure on the knife and dip the blade in water frequently.



(Courtesy Stanley Tools)

Fig. 5.5. A plane blade, showing whetting and grinding angles.

The second step in sharpening a knife is to hone it on an oilstone to produce a sharper edge. Use first the coarse side and then the fine side of the stone. In honing a knife on an oilstone, place the heel of the blade on the stone and then draw the blade forward across the stone with a sweeping motion. At the end of the sweeping stroke, the tip of the blade of the knife should be pulled across the stone. Sharpening a knife takes time and patience. Finish the sharpening process on the oilstone with a "figure-eight" stroke.

The third step in sharpening a knife is the use of a steel. A steel is used to smooth the cutting edge of a knife. Place the heel of the blade at the tip of the steel and on the underneath side of the steel. Bring the blade down and across the steel. If a wire edge develops, hone the blade again until the wire edge is removed and then use the steel again.

Sharpening Axes and Hatchets—Axes and hatchets are used for two purposes: chopping and splitting wood. Hatchets are also used for hewing, forming, or shaping wooden objects. The way an ax or a hatchet is sharpened depends on its intended use. An ax or a hatchet with a long bevel and a thin blade is for chopping.

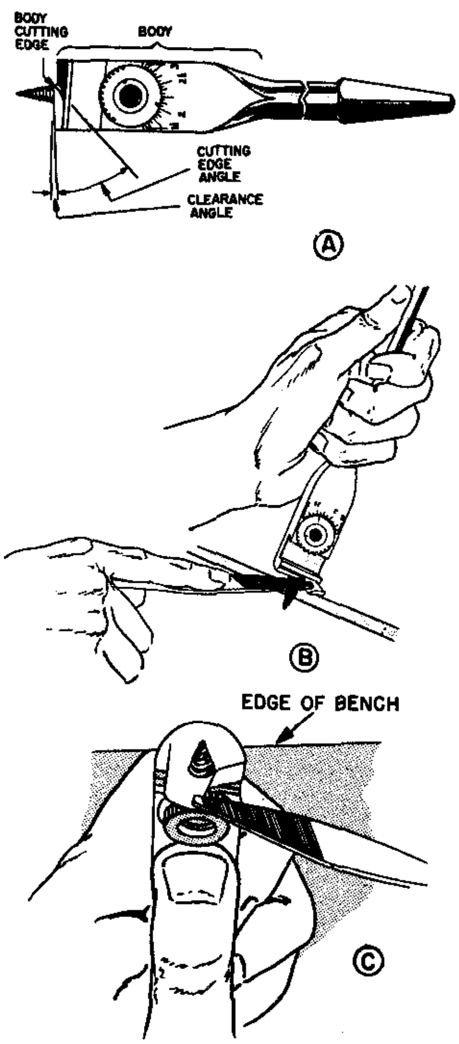


Fig. 5.6. Sharpening the body cutting edge of an expansive bit. Note the cutting edge angle and the clearance angle as shown in "A." In sharpening, maintain these original angles to provide strength behind the cutting edge. File toward the cutting edge, steadying the bit on the edge of the bench as shown in "B." A burr will form on the side opposite the side filed. Remove this burr as shown in "C."

An ax or a hatchet with a short bevel and a thick blade is for splitting. A hatchet sharpened on only one side is for shaping, forming, and hewing wooden objects.

When an ax is being sharpened, its balance must be maintained. See Fig. 5.37 for an illustration of an ax in proper balance. When an ax is set with its cutting edge down, as shown in Fig. 5.37, two-thirds of the blade should be in front of the part of the blade that touches the ground.

The first step in sharpening an ax or a hatchet is the removal of nicks, or jointing, on a grinding wheel. Lay the ax blade on the tool rest of the grinder and push forward lightly to grind out the nicks. Be careful to maintain the original curvature of the blade when jointing. Check the balance of the ax frequently, as shown in Fig. 5.37, to determine whether or not the correct balance is being maintained.

The second step in sharpening an ax or a hatchet is the grinding of the sides of the blade. Again be careful to maintain the original curvature of the blade, and check the balance of the ax frequently. When grinding an ax, swing the handle back and forth in a long arc to maintain the correct curvature of the blade.

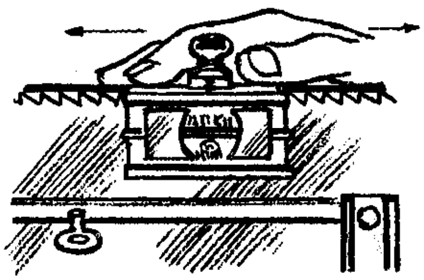
The third step in sharpening an ax or a hatchet is the grinding of a short bevel on both sides of the cutting edge of the blade. When grinding this short bevel, avoid overheating the edge of the blade. Grind the ax slowly and dip it in water frequently.

The fourth step is filing the bevel of the blade with a smooth mill file to finish the job of sharpening. A whetstone may be used instead of a file for finishing the sharpening job on an ax or a hatchet. The whetstone is usually run across the ax or hatchet blade.

Sharpening Handsaws—Handsaws are of two general types, the crosscut saw and the ripsaw, each designed for a particular use. They will give long and satisfactory service if kept in good condition. By keeping them free of rust and by avoiding damage to the teeth on nails and metal, you can maintain them in good condition by an occasional setting and filing. Sharpening a saw is not difficult if attention is given to details. Five steps are usually necessary, especially if the saw is in bad condition: (1) jointing, (2) shaping teeth, (3) setting, (4) filing, and (5) side jointing.

The same general procedure is followed for both crosscut saws and ripsaws, but small differences are necessary and are explained and illustrated here:

1. *Jointing* is the filing of the teeth of a saw until they are of equal height, and it is done with an ordinary flat mill file. Place the saw in a clamp with the handle to the right. Lay a mill file lengthwise on the points of the teeth and pass it back and forth the length of the saw, taking off the high points until the file touches the top of every tooth. Care should be taken not to allow the file to tilt to either side. A patented jointer, into which a file is clamped, will hold the file securely and aid in doing a good job of leveling the height of the saw teeth (Fig. 5.7).
2. *Shaping of teeth* may be necessary if some of the teeth are broken or extremely worn. It consists of cutting new teeth where needed and cut-



(Courtesy E. C. Atkins and Co.)

Fig. 5.7. The use of a patented jointer.

ting the other teeth to the proper size and shape. The new teeth should be uniform and should be, as near as possible, the same size as the original teeth. Note that the shape of the teeth of a crosscut saw is different from the shape of the teeth of a ripsaw. In shaping teeth, place a corner of a three-cornered file in the gullet between the teeth, and file straight across at a right angle to the saw blade until the finished side of the tooth comes to a point. Then go to the next gullet. Hold the file square and level, and press it against the tooth having the largest top until the center of the flat top made by jointing is reached. Do not try to bevel the teeth; cut them out square and pointed.

When the teeth are properly shaped and of uniform height, they are ready to be "set."

(Courtesy E. C. Atkins and Co.)

Fig. 5.8. Jointed ripsaw teeth.

(Courtesy E. C. Atkins and Co.)

Fig. 5.9. Saw teeth jointed evenly.

3. *Setting* consists of bending slightly the points of the teeth, alternately, one to the right, the next to the left. This causes the saw to make a cut which is wider than the thickness of the saw blade, thus giving the blade clearance, and allowing it to run freely without binding or pulling hard. Soft, wet, or green woods require more set than hard, dry woods.

   A patented saw set tool should be used to produce a uniform set. The tool should be adjusted so that only about one-third to one-half of the tooth is bent over. Set a saw one side at a time, setting every other tooth in the same direction. Then reverse the saw in the clamp and set the alternate teeth in the opposite direction.

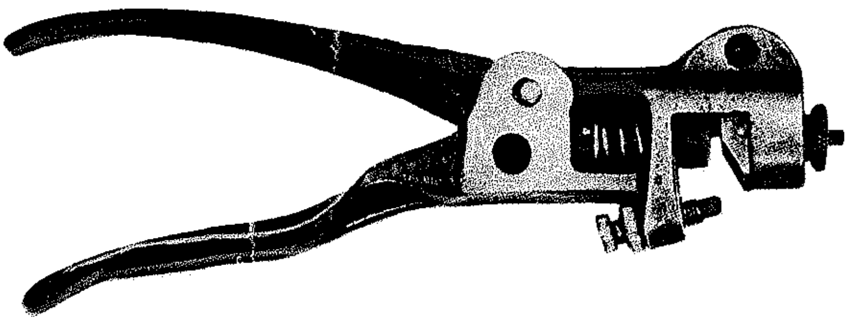
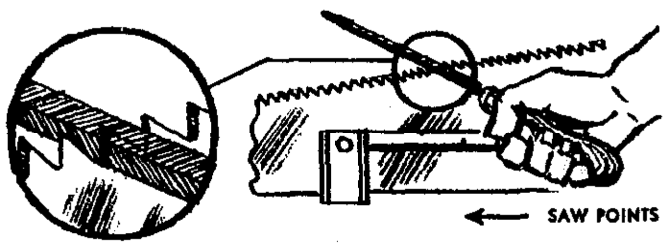


Fig. 5.10. One type of saw set.

4. *Filing* consists of shaping and pointing the teeth so that they will cut the wood easily and cleanly. Taper or three-cornered files are used. The procedures for filing crosscut saws are somewhat different from those used for ripsaws.

Crosscut saw teeth are given beveled edges. Place the saw in the clamp with the handle to the right, the jaws of the clamp being located just below the bottom of the teeth to prevent vibration. Hold the file, as shown in the diagram (Fig. 5.11), so that the handle of the file is at approximately a 45-degree angle to the blade of the saw. The thumb of the right hand is placed on top of the file handle, and the tip of the file is held between the thumb and forefinger of the left hand. Hold the file level and push it evenly through the gullet, bringing the tooth to the right and the tooth to the left of the file to a point at the same time, but beveled in opposite directions. The file should cut only on the push stroke. Continue to file in every other gullet until the end of the saw has been reached. Then reverse the saw in the clamp, placing the handle to the left, and file the alternate gullets which were omitted the first time (Fig. 5.11.). The file must be held at the same angle for all the teeth. File each tooth to a sharp point.

Ripsaw teeth are not beveled. The file is held at a right angle to the saw blade and pushed straight across, making the front edge of the tooth square. Otherwise, the procedure is the same as for crosscut saws. Every other tooth is filed from one side, then the saw is reversed in the clamp, and the remaining teeth are filed. Care must be taken to file the teeth to a uniform size.



(Courtesy E. C. Atkins and Co.)

Fig. 5.11. Position of file and saw for filing teeth.

5. *Side jointing* consists of putting a final touch to the job after the saw has been set and filed. The saw is laid on a flat surface and a worn file or whetstone is run along each side of the saw a few times to remove the wire edge or slight unevenness of the points of the teeth. Two or three strokes without pressure should be sufficient to remove the roughness and produce a fine cutting edge.

(Courtesy E. C. Atkins and Co.)

Fig. 5.12. Views showing a properly filed and set crosscut handsaw. Note the bevel on the front of the teeth.

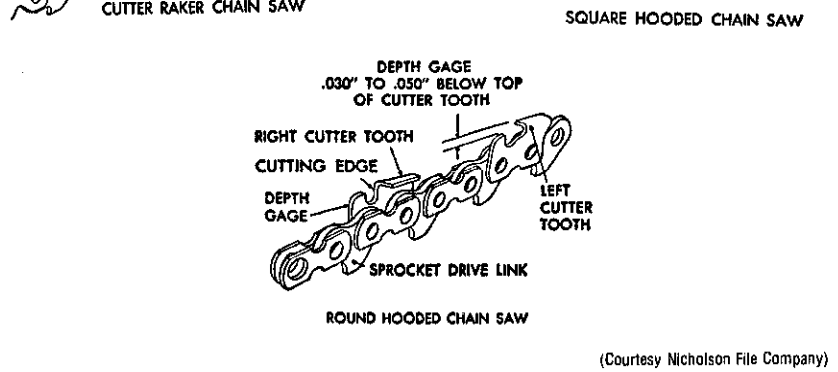
(Courtesy E. C. Atkins and Co.)

Fig. 5.13. Views of a section of a ripsaw which has been correctly filed and set. Note there is no bevel on the front of the teeth. The teeth are filed straight across.

Sharpening Chain Saws—Special files are needed to sharpen chain saws. The type of file needed depends on the type of saw teeth the chain has. The teeth on a chain may be classified into three main types: round-hooded, square-hooded, and cutter-raker. The first step in sharpening a chain saw is determining the type of teeth which the saw has. Fig. 5.14 illustrates the three types of teeth found on chain saws.

A round chain saw file is used to sharpen round-hooded chain saw teeth. Either a square chain saw file or a lozenge chain saw file may be used to sharpen square-hooded chain saw teeth. A flat chain saw file is used to sharpen cutter-raker chain saw teeth.

In sharpening a *cutter-raker chain saw*, joint the cutters that are badly worn. See Fig. 5.14 for an illustration of the differences between cutters and rakers. File the cutters on their faces to sharpen the points of the cutters. File the faces of the rakers. Be sure to maintain the original angles of the cutters and rakers. Check to determine whether the rakers are below the cutters a sufficient amount. The side

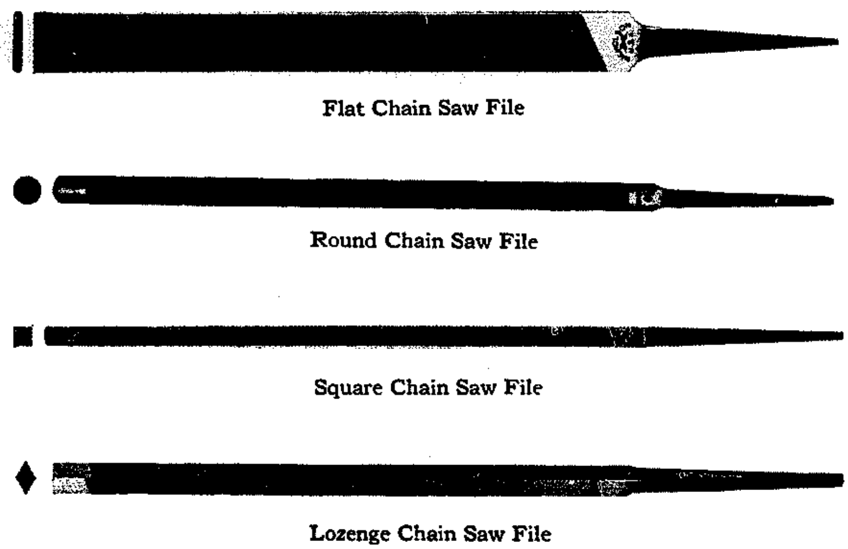


(Courtesy Nicholson File Company)

Fig. 5.14. Three types of chain saw teeth.

rakers should be $^{1}/_{64}$ inch below the tops of the cutters, and the center rakers should be $^{1}/_{32}$ inch below the tops of the cutters. A feeler gauge may be used to measure this clearance when a file or other level object is placed across the top of the cutter teeth.

In sharpening a *round-hooded chain saw*, place the file against the beveled cutting surface of a tooth. The file should be at a 45-degree angle to the saw. File every other tooth. Then reverse the saw and finish filing the remaining teeth. Check the clearance between the depth gauges and the tops of the cutter teeth. This clearance should be 0.025 inch to 0.050 inch and may be measured with a feeler gauge. If sharpening the saw has reduced the clearance too much, file down the tops of the depth gauges.



(Courtesy Nicholson File Company)

Fig. 5.15. The types of files used in sharpening the various types of chain saw teeth.

In sharpening a *square-hooded chain saw*, place the file under the hood so that the adjacent sides of the lozenge or square file contact both cutting edges of the saw tooth. Tilt the file back and down while filing. Be sure to maintain the original shape of the teeth. Check the clearance of depth gauges in the manner recommended for the round-hooded chain saw.

Sharpening Auger Bits—Auger bits are sharpened by filing. It is best to use a specially made auger bit file or a very slim taper file. If the tip or edges of the

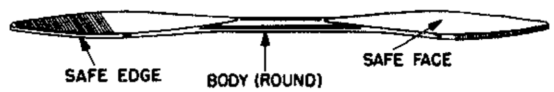


Fig. 5.16. An auger bit file.

screw point of a bit have been nicked or damaged, file away the burred part carefully by passing the tip of the file around the threads. File the cutting spurs on the *inside* only, following the original bevel. Do not file the spurs on the outside edges, as this will decrease the diameter of the bit. Do not change the slant or slope of any of the cutting parts.

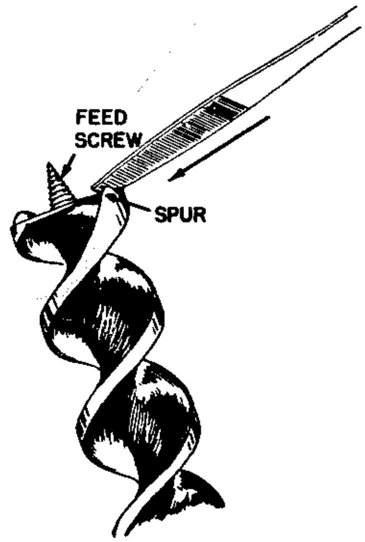


Fig. 5.17. Sharpening the spurs of an auger bit.

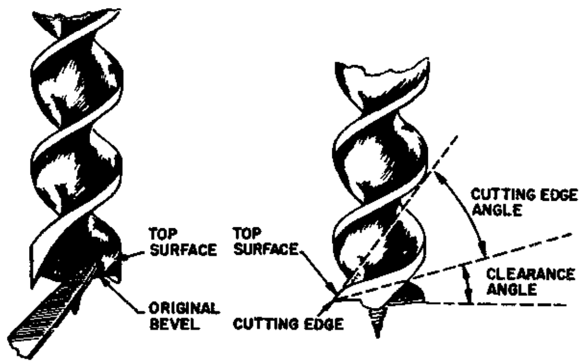


Fig. 5.18. Filing an auger bit.

Sharpening Twist Drills—Twist drills are sharpened by grinding. It is important in grinding a twist drill that the blunt point be kept in the exact center of the drill and that the cutting edges of the bit be made slightly longer than the trailing edges so that the drill will cut properly and have sufficient clearance. The cutting edges of a bit should make a 59-degree angle with the center line of the bit; hence the drill should be held against the grinder at a 59-degree angle. The bit should be slightly rounded from the cutting edge to the trailing edge. This round-

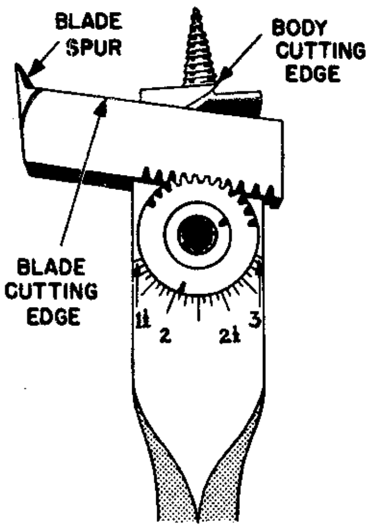
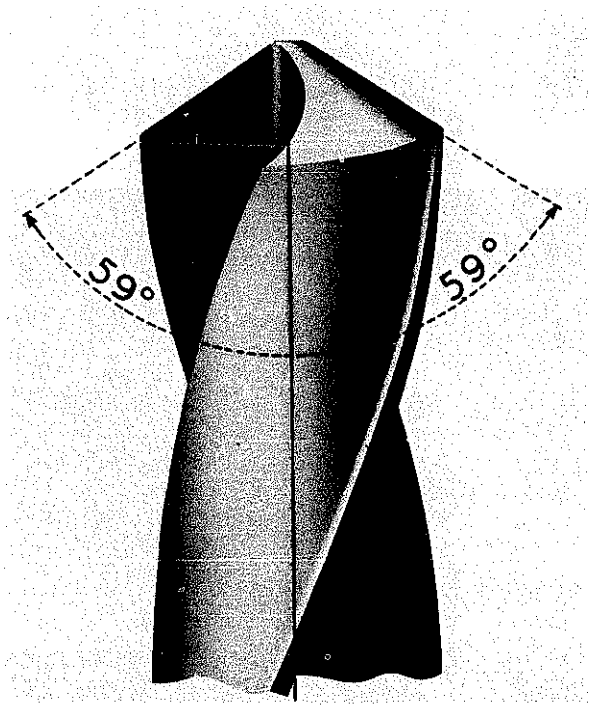
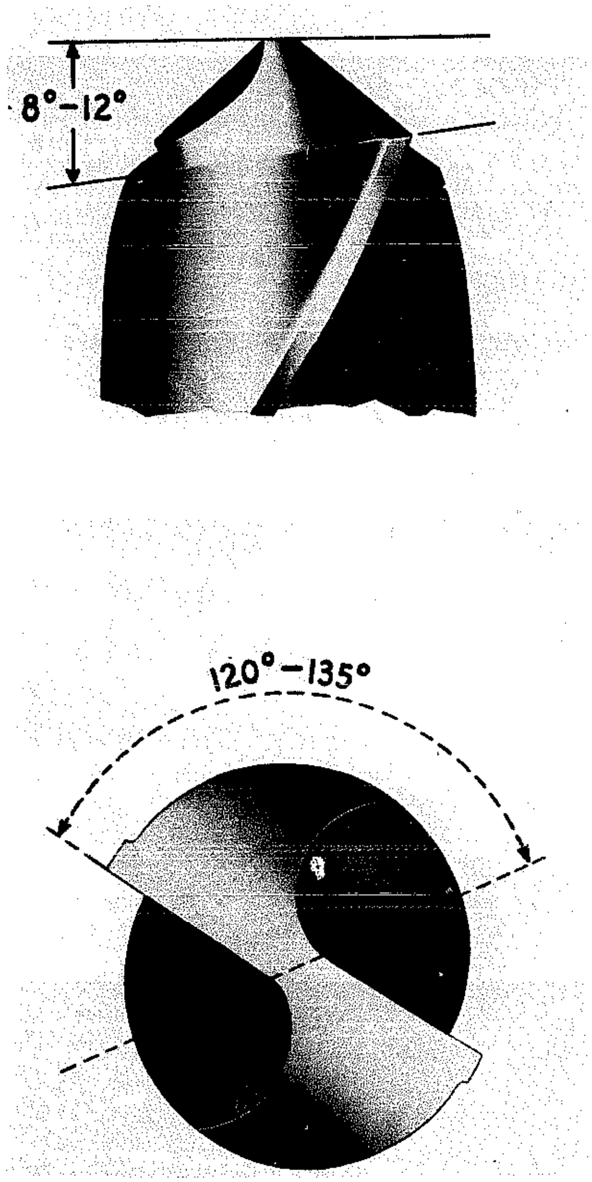


Fig. 5.19. Points to be sharpened on an expansive bit.



(Courtesy Cleveland Twist Drill Co.)

Fig. 5.20. A drill with lips ground correctly. The two lips are the same length, and their angles to the axis of the drill are equal.



(Courtesy Cleveland Twist Drill Co.)

Fig. 5.21. The correct angles of the lips of a twist drill.

ing is obtained by lowering the shank of the drill and rotating the drill clockwise against the grinder.

A gauge for securing the proper angle may be made by cutting a V-notch in a piece of tin at the proper angle for the two cutting edges. Since each cutting edge should be beveled to 59 degrees, the V should be 118 degrees. The drill when properly ground should fit snugly into this V. Each lip of the drill should cut a spiral coil of metal when the drill is used.

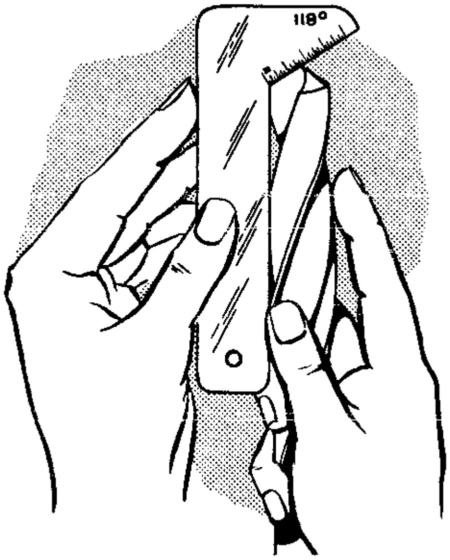
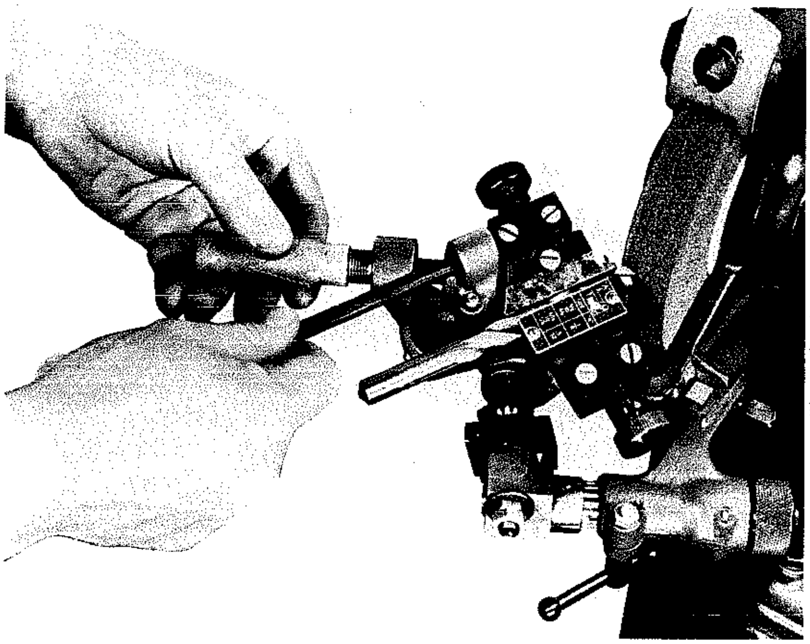


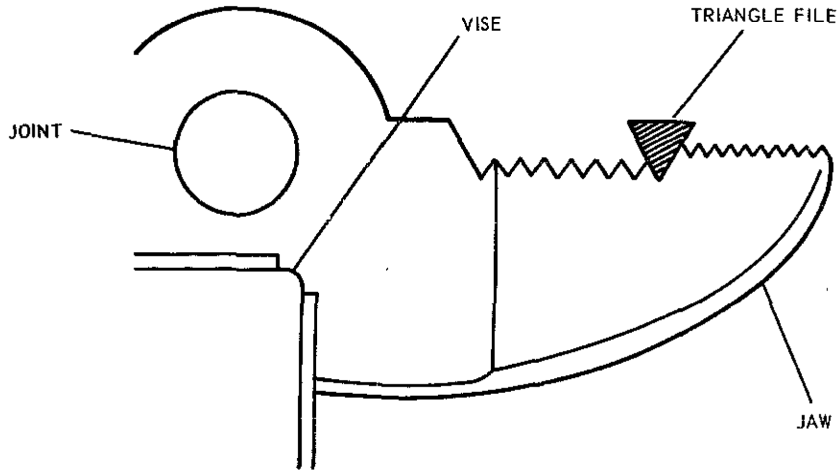
Fig. 5.22. Checking the drill point angle and cutting edge.



(Courtesy Walker-Turner Division, Rockwell Manufacturing Co.)

Fig. 5.23. An attachment for grinding drill bits.

Reconditioning Pliers—The jaws of pliers are serrated. The serrations may become dull. If this occurs, place the pliers in a vise as shown in Fig. 5.24. Then recut the serrations with a triangular file. Also check the pin or bolt at the hinge of the pliers. Keep this pin or bolt just tight enough to hold the two parts of the pliers in contact.



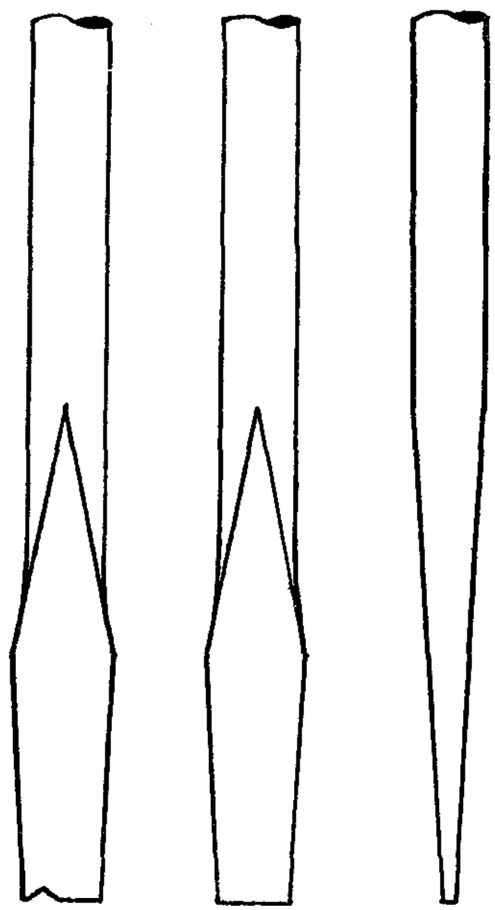
(Courtesy U.S. Department of the Army)

Fig. 5.24. Reconditioning the serrations on the jaw of pliers with a triangle file.

Reconditioning Punches—Mushroomed heads on punches should be removed by grinding, and the heads should be reshaped to resemble the heads of new punches. Grinding is used to reshape the points of punches. After much use the point of a prick punch or a center punch may become dull. When reshaping the point of a prick or center punch, hold the point against the face of the grinding wheel at the correct angle, let the punch revolve in your hand as it is being ground, and move the punch back and forth across the face of the grinding wheel. The correct angle at which to hold a center punch is 30 degress. This will produce a point with a 60-degree angle. If you do not know what a 30-degree angle is to the face of the grinding wheel, obtain a bevel-square and set it at a 30-degree angle with a protractor.

The ends of taper and pin punches become worn or broken with use. When this happens, hold the end of the punch to the face of the grinding wheel and grind the point square.

Reconditioning Screwdrivers—Screwdrivers should have blunt, square, unnicked tips. If the tip of a screwdriver is nicked, rounded, or thin and sharp, it needs to be reconditioned by being ground off or jointed. In jointing, hold the tip at a 90-degree angle against the grinding wheel. Then adjust the tool rest on the grinder so that the screwdriver may be held against the wheel at the proper angle to make the sides of the tip have equal bevels. See Fig. 5.26. Grind the sides of the blade until the tip is the correct thickness and until the sides have equal bevels for ¼ inch from the tip. Do not grind a longer bevel than is necessary, because this weakens the screwdriver. The correct thickness of the tip is determined by the width of the tip. A screwdriver with a wide tip is made for a large screw. The thickness of the tip of a screwdriver should be reduced, therefore, until it fits the slot in a screw whose head size is equal to the width of the blade of the screwdriver.



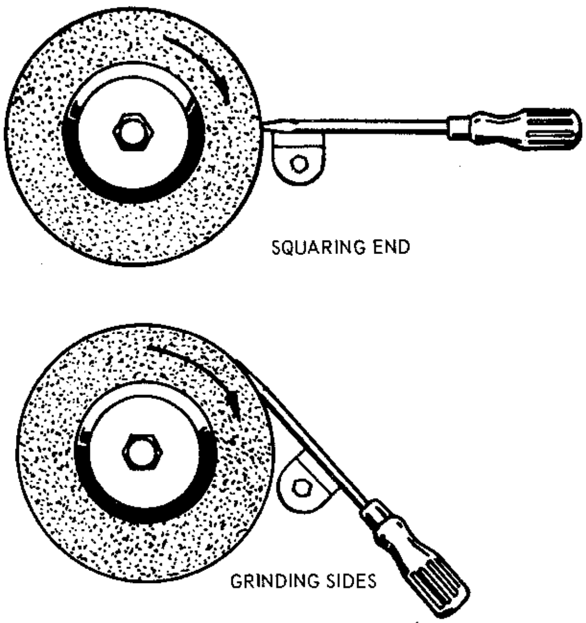
(Drawn by Ronald Ipsen)

Fig. 5.25. The drawing on the left illustrates a nicked screwdriver. The two drawings on the right illustrate a screwdriver that has been reconditioned correctly.

If the sides of the blade of a screwdriver are held flat on the rest of the grinder while being ground, the curvature of the wheel will make it easier to obtain equal bevels on the blade of the screwdriver. See Fig. 5.25 for an illustration of a screwdriver that has been reconditioned correctly.

Sharpening Shears—If possible, take the blades apart, because it makes sharpening easier. A shear blade does not have a sharp edge like a knife. If possible, use a file to sharpen shears, tin snips, and scissors. Clamp the shears in a vise, and draw file with a smooth mill file. Be careful to maintain the same angle the shears had when new. If the shears are too hard to file, use a fine grinding wheel and grind lightly. Hone the shear blades on an oilstone after they have been filed or ground.

Sharpening Hoes, Spades, and Shovels—These tools are easy to sharpen with a file. Clamp the tool in a vise, and push the file across the sharp edge of the tool, being careful to maintain the original angle of the bevel. If these tools need to



(Courtesy U.S. Department of the Army)

Fig. 5.26. Reconditioning a screwdriver.

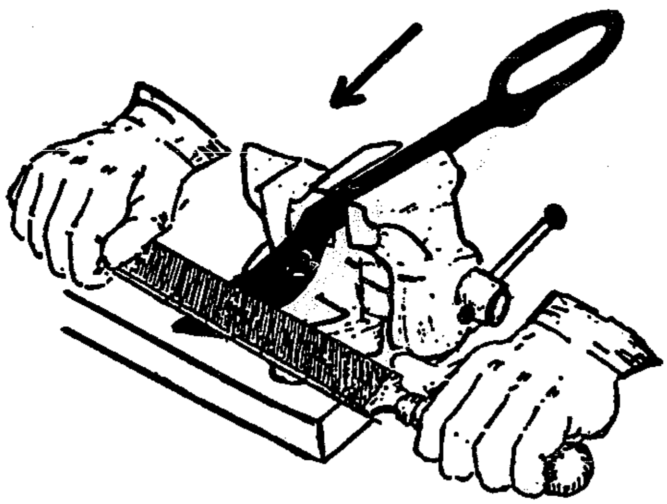


Fig. 5.27. When sharpening shears, tin snips, and scissors, be careful to maintain the same angle the blades had when new.

be sharpened on the job or in the field, wedge them against a post or another stationary object while filing.

Sharpening a Cold Chisel—In sharpening a cold chisel, it should be held against a grinder until all nicks have been removed and until the cutting edge is square. The chisel is then given a short bevel on both sides, grinding first on one side and then on the other. The bevels of a cold chisel should be kept even. The angle of the cutting edge of a cold chisel should be about 65 degrees. A piece of tin with a 65-degree V-notch makes a convenient gauge for determining when the proper bevel has been obtained.

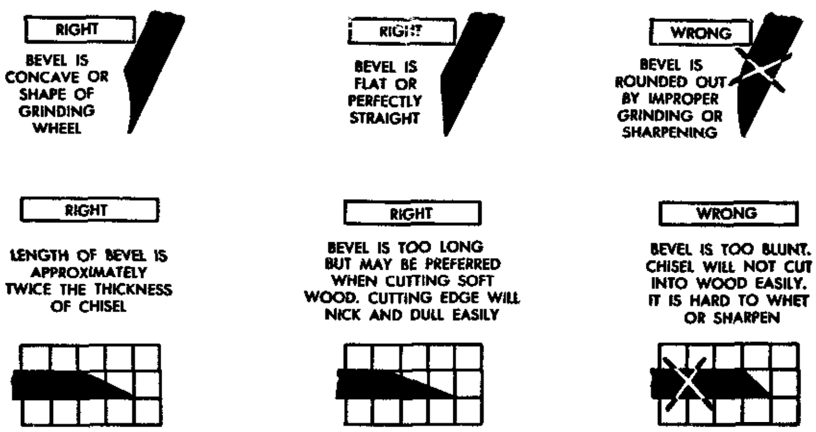
(Courtesy Stanley Tools)

Fig. 5.28. Cold chisels are ground to an angle of 65 degrees for average work.

Sharpening and Reconditioning Wood Chisels—In sharpening wood chisels, grind only when the cutting edge has been nicked or when the correct bevel cannot be restored except by grinding. If grinding is necessary, proceed as follows:

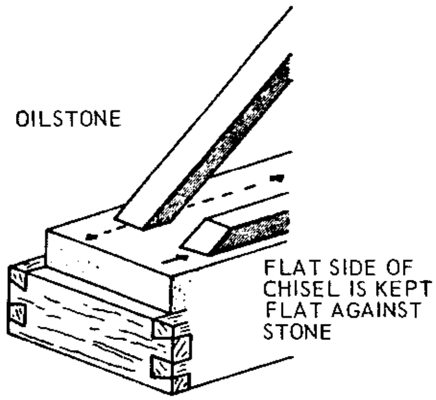
1. With the bevel up, square the cutting edges and remove nicks by moving the chisel across the grinding wheel from side to side.
2. Adjust the tool rest on the grinder so that the bevel of the chisel rests on the grinding surface at the angle needed to provide the correct bevel. See Fig. 5.29. Grind until nicks have been removed and the proper bevel has been obtained.
3. Hone the chisel on a stone, using a slightly steeper angle than the angle at which it was ground. After sharpening, turn the chisel over on the stone to remove the wire edge. Only a few strokes will be needed.
4. For an extra-sharp edge, strop the chisel on a piece of soft leather.

If grinding is not needed, use a hone to obtain a sharper edge. Often the heads of wood chisels become mushroomed. See Fig. 5.31 for the procedure for reconditioning the heads of wood chisels.



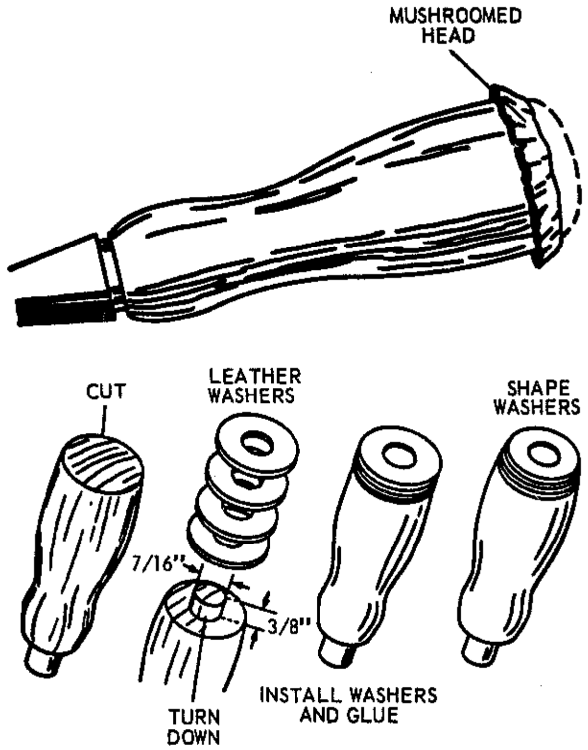
(Courtesy U.S. Department of the Army)

Fig. 5.29. Sharpening a wood chisel.



(Courtesy U.S. Department of the Army)

Fig. 5.30. Honing a wood chisel.



(Courtesy U.S. Department of the Army)

Fig. 5.31. Reconditioning a mushroomed head on a wood chisel.

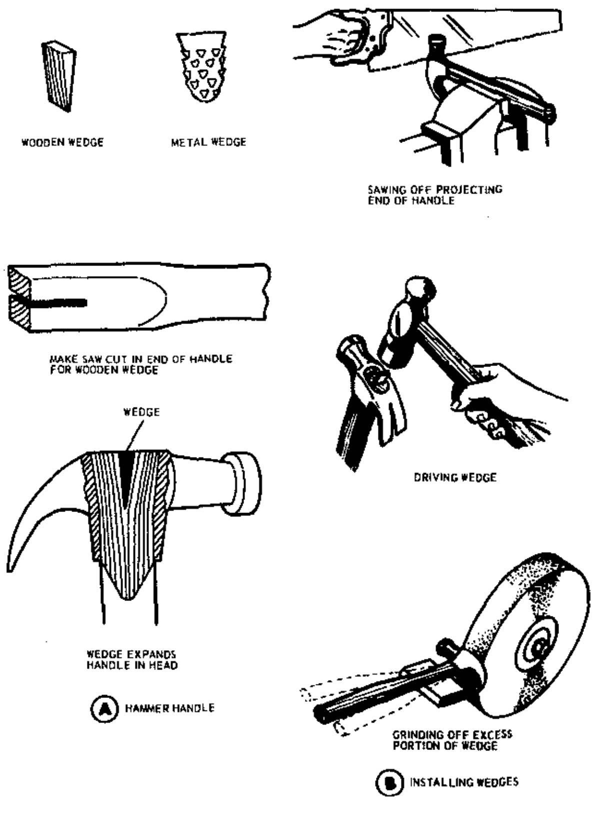
REPLACING TOOL HANDLES

Need for Replacing Broken Tool Handles—Many shop tools on farms and in agricultural businesses have wood handles, and these handles are frequently broken. Often you may repair a split handle by taping it with cloth friction tape, or by tightly wrapping it with a soft wire. These repair methods may also serve temporarily when a handle breaks with a reasonable length of handle stock extending from the tool.

Usually, however, a handle breaks almost flush with the tool eye, making it necessary to fit a new handle into the eye. Occasionally the old handle can be fitted to the eye of the tool, but this shortens the handle, which makes the tool difficult to use.

Well fitted new handles return to a tool its original utility. Most owners like to recondition a tool when a new handle is fitted to it. This is a good practice. When battered, worn, or loose parts of a tool are repaired, the finished tool is materially improved in its utility and appearance.

Securing Tool Handles—Tool handles are not expensive to purchase, and usually it is unwise to make them. Wood tool handles are made from ash, hickory, and sometimes oak. The best handles for shovels, forks, and similar tools are made from select white ash. Handles for hammers, axes, sledges, and other tools used for pounding are made from hickory, usually white hickory or second-growth hickory. Some handles are made of plastic or of metal with a covering.



(Courtesy U.S. Department of the Army)

Fig. 5.32. Handles may become loose and need to be fitted with wedges.

General Instructions for Fitting New Tool Handles—When new handles are fitted to the common tools, such as hammers, axes, shovels, forks, mauls, sledges, and picks, which are used in agricultural businesses and on farms, the following general steps should be observed:

1. Secure the necessary tools and supplies.
2. Cover the vise jaws with sheet metal, or use wood blocks.
3. Remove the old handle.
4. Recondition the tool if necessary, especially the part to receive the handle.
5. Fit the new handle. Do a good job.
6. Place starch or chalk on the portion of the handle being shaped when it is tried into the tool or ferrule. The high points will have the powder removed. Flour may be used if the other products are not available.
7. Wedge the new handle in place, and treat this portion of the handle with boiled linseed oil. Boiled linseed oil dries more rapidly than raw oil and becomes more sticky. Raw oil will remain a lubricant and may allow the handle or wedge to loosen.
8. Do any finishing or conditioning of the tool that is necessary.

The most common tools and materials necessary for fitting a new tool handle are as follows: metal vise, hacksaw, brace and twist drill bits, chain drill, punch, cold chisel, hammer, wood rasp, half round wood file, mallet, ripsaw, ruler, piece of soft pine to make a wedge, boiled linseed oil, and the new tool handle.

Fitting a Hammer Handle—Select a handle like the one the manufacturer fitted into the hammer at the factory. A hammer will not balance correctly if fitted with the wrong type of handle. The shape of the handle of a ball-peen hammer, for example, is different from the shape of the handle of a claw hammer.

A good procedure for fitting hammer handles follows:

1. Refer to the general instructions on fitting tool handles.
2. Place the hammer head in a metal vise. If the jaws are rough, they should be covered to keep them from damaging the tool and later the handle. Note the illustrations showing how vise jaws may be covered.
3. Cut off close to the hammer head, with a hacksaw, the old portion of the handle, then drill it out with the largest metal twist drill that will go through the eye.
4. Drive the remaining wood from the head with a punch and a hammer.
5. Recondition the head if it is damaged or needs polishing.
6. Place the new handle in a vise as shown in Fig. 5.33, and fit the handle by removing with a wood rasp and a half-round wood file the excess wood from the handle. Take care to remove the wood in the right places so that the hammer head will fit.
7. Place the handle in a metal vise, as shown in Fig. 5.34, and with a ripsaw make a saw cut across the long diameter of the top of the handle.
8. Place the sawed end of the handle in the vise and pinch the handle together. Then make another cut as before, but not quite so deep. This produces a tapered cut, allowing room for the wedge.
9. Make a wedge from a block of soft pine, as shown in Fig. 5.35. (See step 8 in the next section, "Fitting an Ax Handle.")
10. Place the handle in the hammer head, holding the handle in one hand, and drive it into the head with a mallet. (See Fig. 5.36.) Bevel the end of the handle that is being forced into the eye of the hammer head to prevent the handle from splintering.

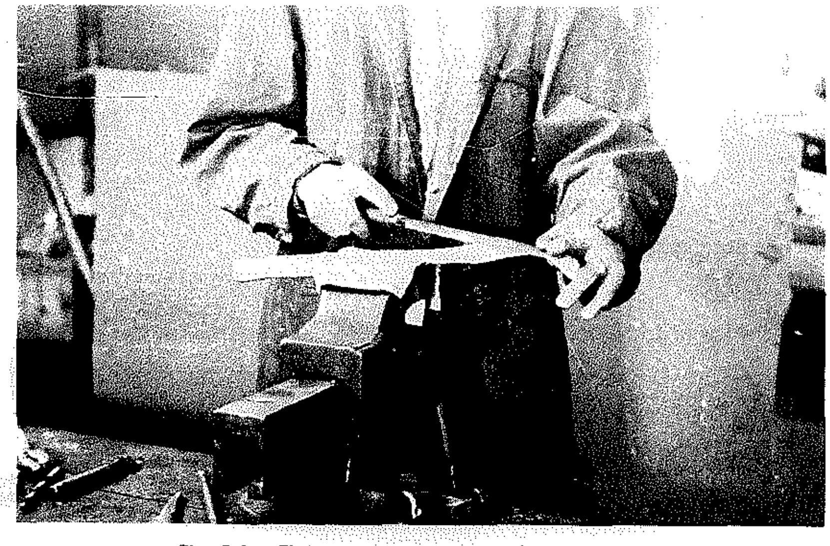


Fig. 5.33. Fitting a hammer handle with a wood rasp.

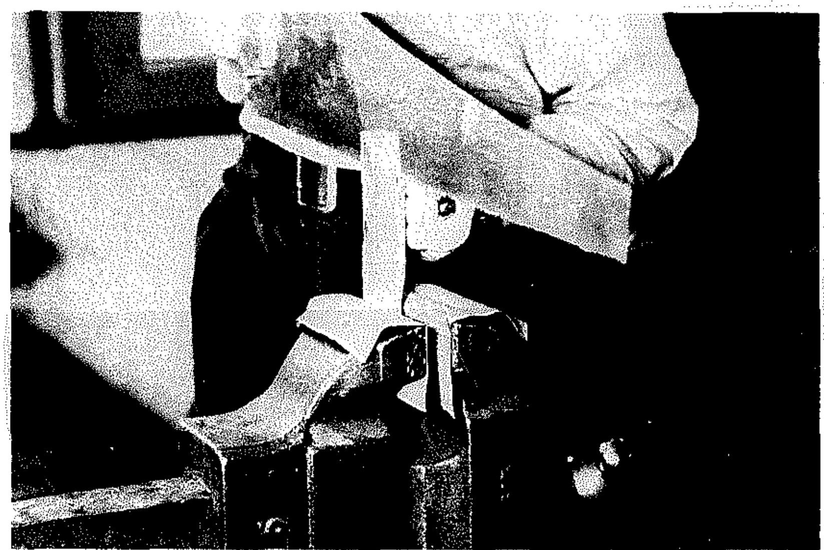


Fig. 5.34. Making the second saw cut across the longest diameter of the top of the handle.

11. Place the wedge in the slot sawed in the handle. Place a slight bevel, if necessary, on the thin edge of the wedge so that it will enter the cut in the end of the handle. Drive the wedge in solidly. (Refer to Fig. 5.38.)
12. Place the hammer in the vise in a horizontal position, and with a hacksaw remove the part of the handle extending through the head. (Refer to Fig. 5.39, which shows this being performed on an ax handle.)
13. Place the hammer in a vise with the head end up. Saturate the wedge and the end of the handle with boiled linseed oil to prevent moisture from going in and out of the wood, which would cause the handle to loosen. A small amount of linseed oil can be rubbed on the handle to polish it. (Refer to Fig. 5.40.)

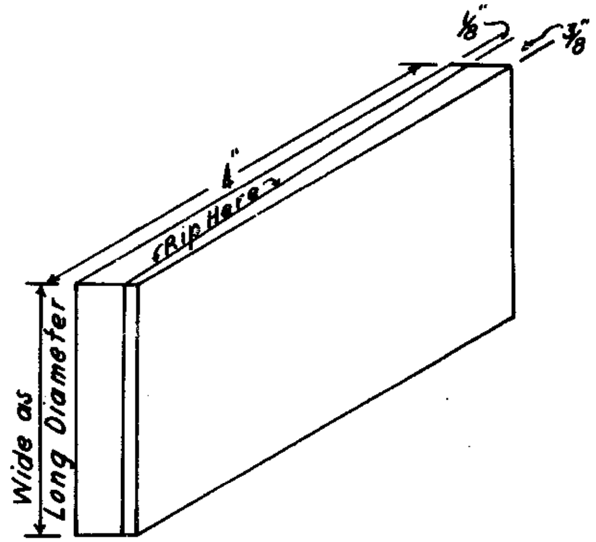


Fig. 5.35. Two wedges made from a 4-inch soft pine board.

Fig. 5.36. Driving the hammer handle into the hammer head.

Fitting an Ax Handle—Read the paragraph on securing tool handles and the general instructions for fitting new tool handles. Then proceed as follows:

1. Place the ax in a metal vise and with a hacksaw remove close to the head any portions of the old handle which extend from the head of the ax.
2. Drill through the old handle in the ax head, using as large a metal twist drill as will go through the eye.
3. Drive the remaining wood from the ax with a hammer and a punch. Measure to determine whether the eye in the ax head is straight.
4. Place the new handle in a vise, in the same way as shown in Fig. 5.33, and fit the handle by removing the excess wood with a wood rasp and a

wood file. The wood should be removed so that the cutting edge of the ax will rest on the bench, when the handle end of the ax rests on the bench, at a point about two-thirds of the width of the bit back of the front tip of the bit. This places the ax head in the proper position for good cutting. If the ax head is hung straight on the handle, most of the cutting is done by the heel of the bit. (See Fig. 5.37.)

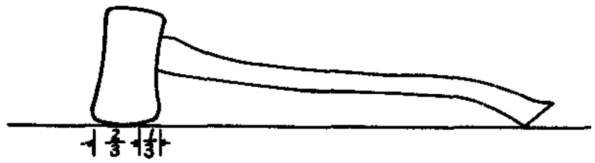


Fig. 5.37. This illustrates how an ax handle should fit to give the proper position to the cutting edge of the ax.

5. Place the handle in a vise with the tool end up, and rip a slot in it across its largest diameter to a depth of about two-thirds the depth of the eye of the ax. The handle should fit into the ax to within 1/2 inch of the swell in the handle.
6. Place the sawed end of the handle in a vise so that the sawed portion is pressed shut. Then saw the handle again to about two-thirds of the depth of the first cut. By doing this, room is made for the wedge to be driven into place after the ax head is on the handle. (Refer to Fig. 5.39.)
7. Place the ax head on the handle. Drive the handle into the ax with a mallet. (Refer to Fig. 5.36.)
8. Make wedges out of a soft pine board 5/8 inch thick, as wide as the long diameter of the ax eye, and 6 inches long. Draw diagonal lines on the edges of the board from which the wedges are to be made. (See Fig. 5.35.) The bottom ends of the wedges should taper to about 1/6 inch, or

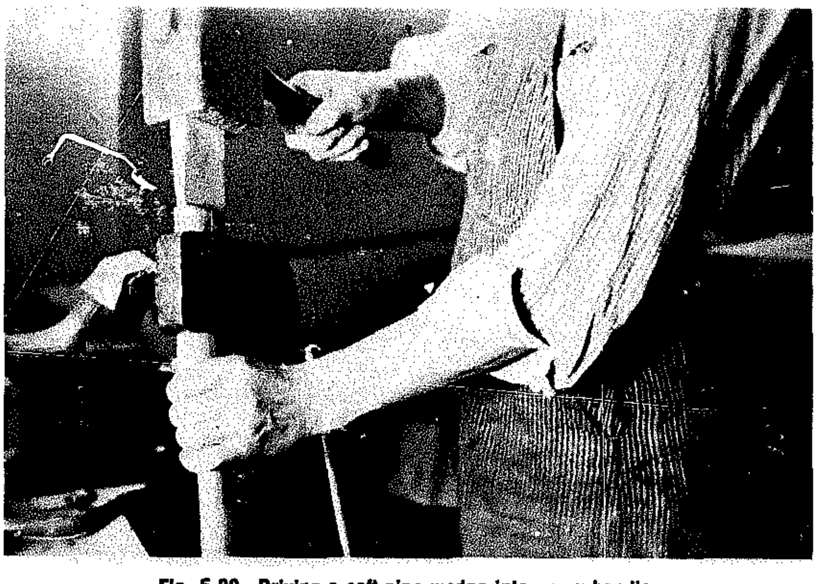


Fig. 5.38. Driving a soft pine wedge into an ax handle.

as thick as the bottom of the saw cut in the handle. Hold the ax as shown in Fig. 5.38 and drive the wedge in place with a mallet. To prevent the wedge from splitting, be sure the mallet strikes over the whole top of the wedge.

9. Place the ax in a vise in a horizontal position, and with a hacksaw remove the part of the handle and wedge extending through the head. (See Fig. 5.39.)
10. Place the ax in a vise with the wedge up, and saturate it with boiled linseed oil to keep the handle and wedge tight. (See Fig. 5.40.)

Fig. 5.39. Removing the handle and wedge extending through the tool head.

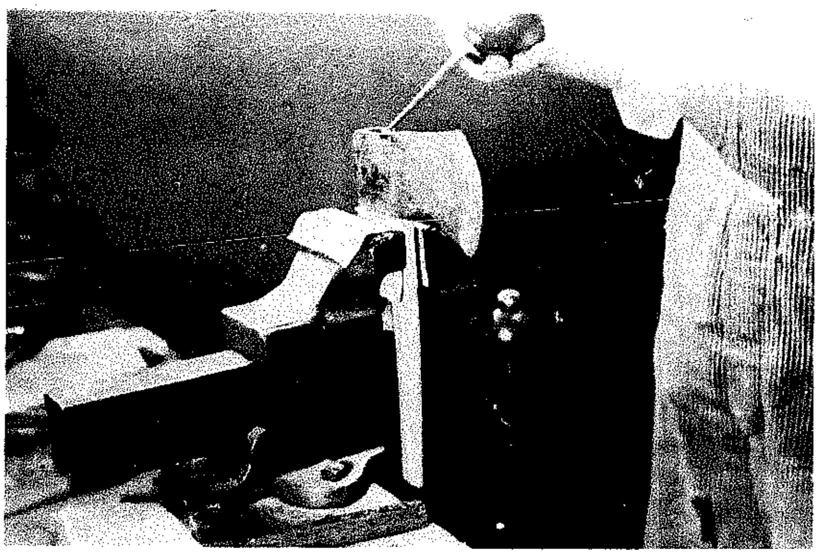


Fig. 5.40. The wedge and handle are being soaked with boiled linseed oil. Note the sheet metal pieces on the vise jaws to prevent damage to the wooden handle.

Fitting Other Tool Handles—Other tools used on farms and in agricultural businesses that need handles replaced are hatchets, adzes, sledges, splitting mauls, double-bitted axes, picks, and spades. Handles can be secured to fit each type of tool. The instructions for replacing handles in the tools in the previous sections also apply for these tools.

Some tool heads slip onto the handle from the hand end of the handle; consequently it is not necessary to remove excess wood on the tool end of the handle. Some mauls and picks are of this type. A double-bitted ax has a straight handle instead of a curved handle of the type used for an ordinary splitting ax.

AGRICULTURAL WOODWORK AND CARPENTRY

Student Abilities to Be Developed

1. Ability to classify, select, and care for lumber properly.
2. Ability to classify, select, and use nails, screws, bolts, and hinges.
3. Ability to use glue in agricultural woodwork and carpentry.
4. Ability to figure bills of materials.
5. Ability to read blueprints and make working drawings.
6. Ability to cut rafters.
7. Ability to construct or repair agricultural woodworking and carpentry projects.

CHAPTER 6

Figuring Bills of Material

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Why should an employee in an agricultural business or a farmer know how to figure bills of materials?
2. What is a bill of material?
3. What is the unit of measure in selling lumber?
4. What is meant by a board foot? Running foot? How are they calculated?
5. How should the number of pieces and the dimensions be written in a bill of materials? How is a smooth surface indicated?
6. Should any extra material be allowed for dressed lumber? Waste?
7. How are shingles and molding sold?

Workers in Agriculture Should Know How to Figure Bills of Material—In order to plan any construction work intelligently, it is necessary to know what kinds of materials are required, the amount of each needed, and what the total cost will be. If agricultural workers can figure bills of material, they will not have to ask the lumber dealer for assistance with this job, and they will be able to check the accuracy of the dealer's bill.

Bill of Material—A bill of material is an itemized list of the number of pieces needed and the dimensions of each. Lumber dealers have paper pads or order books for writing orders for lumber. An order contains the name and address of the buyer, the date, the name of the project, the number of pieces of lumber, the kind of wood, the name of each piece, the dimensions of each piece, the number of board feet, and the cost. A complete bill of materials contains a list of all the necessary materials for building a project. For example, a bill of materials for an individual shed contains a list of all the materials necessary for building it. Students should develop a bill of materials for each shop project before it is started.

Unit of Measure in Selling Lumber—While the unit of measure in lumber is a board foot, lumber is generally priced on the basis of 1,000 board feet (per M.). Lumber for finishing work is sometimes priced by the running foot.

Board Foot and Running Foot—A board foot is a piece of lumber 1 inch thick, 12 inches wide, and 12 inches long—144 cubic inches. To find the number of board feet in a piece of lumber, multiply the thickness in inches times the width in inches times the length in feet and divide by 12. For example, a board 1 inch thick, 6 inches wide, and 16 feet long equals 8 board feet.

$$\frac{1'' \times 6'' \times 16'}{12} = 8 \text{ board feet}$$

If there are several pieces of lumber the same size, find the board feet by multiplying the number of pieces times the width in inches times the thickness in inches times the length in feet and divide the product by 12. For example, 6 pieces 1 inch thick, 4 inches wide, and 12 feet long may be figured as follows:

$$\frac{6 \times 1'' \times 4'' \times 12'}{12} = 24 \text{ board feet}$$

A running foot refers to a foot length of lumber regardless of the thickness and width of the lumber. A board 1″ × 4″ × 12′ = 12 running feet. A board 2″ × 6″ × 12′ = 12 running feet.

Method Used in Writing Dimensions—A bill of materials should be written so that it can be understood easily. Lumber may be either rough or surfaced. Surfaced lumber has been dressed by being run through a planer. When lumber is surfaced on one side, the symbol S1S is used, two sides S2S, one edge S1E, two edges S2E. Four methods of writing bills of materials for lumber follow:

(1)

Pieces	Kinds of Wood	Dimensions	Finish	Bd. Ft.
1	White Pine	1″ × 12″ × 10′	S2S	12
2	White Pine	1″ × 12″ × 12′	S2S	10

(2)

Pieces	Kinds of Wood	Dimensions	Use
2	Fir	2″ × 4″ × 24′	Rafters
10	White Pine	⅞″ × 6″ × 12′	Ends

(3)
6 Pcs. (pieces) No. 1 Yellow Pine 2″ × 4″ × 12′ S2S

(4)
two 1 × 6's, 14 ft. long, fir fencing

Lumber lengths are usually sawed in even feet, such as 10, 12, or 14 feet.

Allowing Extra Materials for Dressed Lumber and for Waste—Dressed lumber is not full-width; consequently, it is necessary to allow for this when figuring a bill of materials. In figuring 6-inch matched lumber, about one-sixth more is needed than would be necessary if the lumber were full-width. One-fifth of the total amount needed should be added when shiplap, drop siding, or framing lumber is used.

It is a good plan to allow for waste when figuring materials. A 5 to 10 per cent allowance for waste should be sufficient. In making plans for shop projects, a student should keep in mind that lumber is sawed in even lengths. Lumber should be purchased so that there will be the least possible waste.

Calculating the Cost of Lumber—In order to determine the cost of a single piece of lumber, figure the number of board feet in the piece, then multiply this number by the cost per thousand and point off three places. The value of a beam 6″ × 8″ × 20′ at $210.00 per M. would be calculated as follows:

$$\frac{6'' \times 8'' \times 20'}{12} = 80 \text{ board feet}$$

$$80 \text{ board feet} \times \$210.00 \text{ per M.} = \$16.80$$

Shingles and Molding—Wood shingles are sold by the thousand or by the square in bundles of 250 each. A square consists of four bundles (standard 16-inch size) or 1,000 shingles. A square of asphalt shingles consists of three bundles. A square of roof is 100 square feet—900 wood shingles being required per square when laid with 4 inches exposed to the weather, 800 when laid with 4½ inches exposed to the weather, and 720 when laid with 5 inches exposed. Some millwork such as moldings or trim is sold by the running foot.

CHAPTER 7

Making Simple Sketches and Reading Blueprints

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Why is the ability to read blueprints and to make simple sketches and drawings of value to a farmer and to workers in nonfarm agricultural businesses?
2. What equipment is needed for making drawings?
3. Why is sketching useful, and when may it be used?
4. How are drawings made "to scale"?
5. What views of a construction project should be shown?
6. What are isometric, oblique, and orthographic projections?
7. How are different kinds of building materials shown in sketches?
8. Why is it important that lines and signs be used in the same way in all drawings?
9. How should drawings be lettered?

Value of Drawings to an Agricultural Worker—All construction work should be made from drawings or sketches. An agricultural carpenter should be able to visualize a project in its different stages and be able to plan all its details before the actual construction work is started. Such planning is essential for economy and efficiency in the work of construction, and as a guarantee that the finished product will be of the desired specifications and standards.

Plans and drawings are available for most of the construction work that the average farmer or worker in a nonfarm agricultural business will do. They range in complexity from simple working sketches to elaborate architectural drawings and blueprints. Some general knowledge of the meaning of the lines and figures and of the general arrangement of the items shown on a drawing is necessary. Drawings are usually made according to a given scale so that all parts will fit together. If a mistake is made in interpreting a figure or in reading a dimension on a drawing, material will be wasted and a "botched" job will result.

The ability to make sketches and drawings of construction and repair projects is worth the time required for developing the ability. For ordinary purposes, drawings do not need to be elaborate, nor in great detail. A simple working sketch, drawn clearly and neatly, is all that is necessary.

The ways in which a knowledge of drawing may be of profit to agricultural workers may be summarized as follows:[1]

1. It aids workers in reading drawings of appliances that they wish to make, or of buildings that they may desire to build.
2. It aids workers in their repair and construction work and also in conveying to others ideas regarding construction and repair work.
3. It makes it possible for workers to make drawings of anything which they desire to produce before they actually construct it, thus making it possible for them to order or buy the necessary material more economically and to eliminate waste in the construction of the project.
4. It makes it possible for workers to plan their buildings on paper.

Skill in drawing and lettering requires practice and careful attention to details. By studying the instructions given in the following pages, the ability to make and use simple drawings may be easily acquired.

Drawing Equipment and Its Use—A drawing board is of value if considerable drawing and lettering are to be done. A board can be made in a shop. Soft pine and basswood are the kinds of wood usually used. The usual size is 18 inches by 24 inches. A drawing board should be square so that the edges may serve as straightedges.

A T square should be provided for use with a drawing board. When a T square is used, the head or short part should be held firmly against the left edge of the board; the blade of the square then extends squarely across the board. From the blade of the T square, paper may be placed squarely on the board. Triangles and a ruler are used for making measurements and drawing lines.

Triangles with 30-, 45-, 60-, and 90-degree angles should be secured for making angles.

Other pieces of equipment needed for simple drawing are a ruler, 2H and 4H pencils, an eraser, drafting tape, a soft cloth or brush, fine sandpaper for sharpening the pencil point, thumbtacks, and paper.

For ordinary working drawings it is not necessary to draw the lines in ink. Special ruling pens are necessary for the inking of drawings. Inked drawings are made in pencil first, then inked. The pencil marks are removed with an eraser or with art gum.

Sketching—A penciled sketch is usually sufficient as a working drawing in constructing simple projects. For practical use a sketch may be of more value from an agricultural worker's viewpoint than a detailed mechanical drawing. A sketch need not be drawn exactly to scale, but it should show the general shape and arrangement of the various parts of the object, with the dimensions of all parts clearly indicated. As many views of the project should be made as are necessary to show clearly the relationship of the different parts. Figures, showing dimensions, and explanatory notes should be provided on the drawings to show clearly what is

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[1]Adapted from Louis M. Roehl, *The Farmer's Shop Book*, Milwaukee: Bruce Publishing Co., p. 408.

to be done. No construction work should be started without a working drawing being prepared first.

Mechanical Drawings—Blueprints and construction drawings made by architects and engineers are very carefully and accurately drawn to scale, showing all parts of the work in their proper perspective and relationship. Architects and engineers are able to show a great many details of construction through the use of certain types of lines, letters, and figures. They make the measurements, lines, and letters correctly and neatly by using drawing instruments.

The accepted form for a mechanical drawing is shown in Fig. 7.1. Drawing paper may be secured in the sizes indicated. Uniform margins should be left on all sides of a drawing. The title block should appear in the lower right corner, showing the title of the drawing, the person doing the work, and other information as indicated.

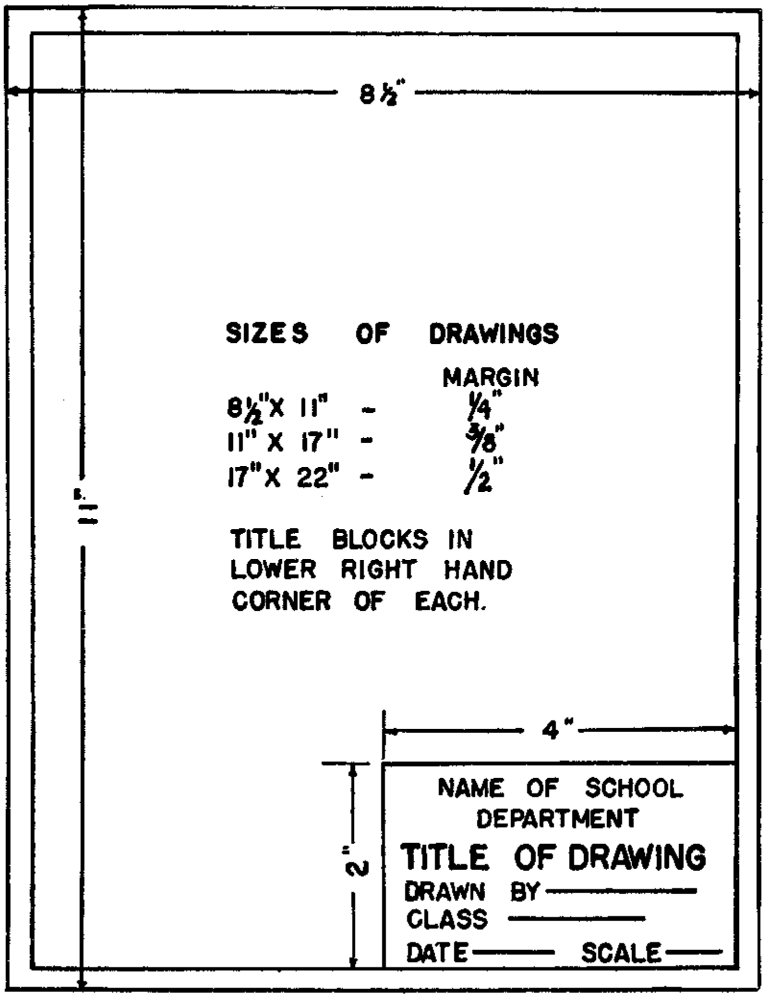


Fig. 7.1. A standard form for mechanical drawings.

Drawing to Scale—Drawings must ordinarily be made on a scale that is considerably reduced from the normal size of the object to be made. To show the proper proportions in a drawing, draw all parts to the same scale. For example, 1 inch on a drawing may represent 1 foot in the dimensions of the project. Any scale which is convenient to use may be chosen, such as 1 inch equals 1 foot, ½ inch equals 1 foot, ¼ inch equals 1 foot, 1 inch equals 5 feet. The scale used should be clearly indicated on the drawing.

Projections—An *isometric projection* discloses the object in a tilted position so that the top, the front, and one side are shown. The "key" to making a drawing of this type consists of getting the proper angles between the vertical line and the two horizontal lines which form the "near" corner of the object. Each of the two horizontal lines must make a 60-degree angle with the vertical line. (Hence, the name "isometric," meaning the same measure or angle.) See Fig. 7.2.

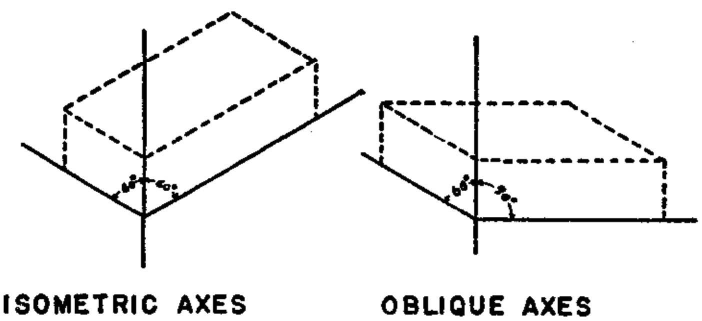


Fig. 7.2. Isometric and oblique projections.

Assuming that the point where these three lines meet is the bottom corner of the object, measure on the line to the right of the vertical line the proper distance to represent the length of the object, using a suitable scale. Measure on the line to the left of the vertical line the width of the object. Measure on the vertical line the depth of the object. This gives the proper dimensions, and the connecting lines are drawn parallel to these three lines (with some allowance for perspective). All perpendicular lines on the object are shown perpendicular in the drawing, and all horizontal lines on the object basically slope in the drawing at an angle of 30 degrees from a base line or 60 degrees from the vertical lines.

An *oblique projection* also shows three sides of an object. It differs from an isometric projection in that the corner angles are not equal, and the scale is accurate for only one side of the object (Fig. 7.2). The line representing the length of the object is drawn at right angles to the vertical corner line, while the width line is drawn at a 60-degree angle. The long side of the object is accurately drawn to scale, but the other sides are usually drawn to a scale of about three-fourths the scale of the first side in order to give better proportions to the drawing.

Another type of projection is that which shows only one face or surface of an object. It is called an *orthographic projection*. Separate drawings are made to show

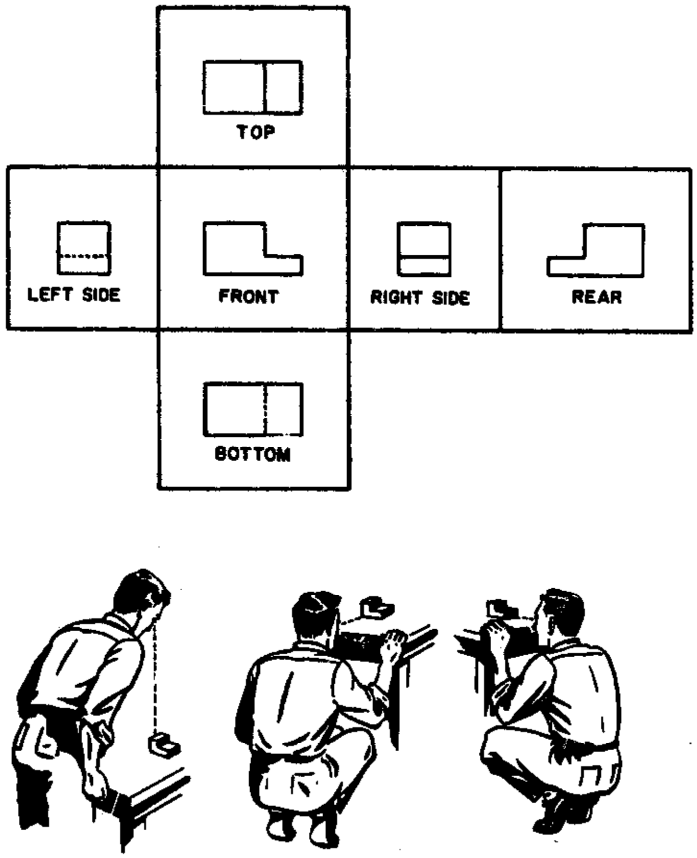


Fig. 7.3. Top—orthographic projections. Bottom—compare the orthographic projections with the model.

each side of the object. The drawings in Fig. 7.3 illustrate orthographic projections.

Conventional Lines and Symbols—The use of certain types of lines, shadings, and symbols to represent certain features and construction materials has been standardized so that a drafter, an architect, or a builder may readily interpret and follow the plans drawn by another person. Figure 7.4 shows the more important lines and their meanings, as well as the conventional symbols for common construction materials. These lines and symbols should always be used in drawings. Figure 7.4 also shows how dimensions are indicated on drawings. Study Fig. 7.4 carefully.

Lettering—Good lettering is an essential part of a good drawing. A well made drawing may be ruined not only in appearance but in usefulness by improper or careless lettering. There are many types of lettering forms in use. Legible, neat, well balanced, and attractive lettering is more important than the type of letters used. Skill in lettering can be acquired by studying carefully the structure and composition of the letters and by practicing.

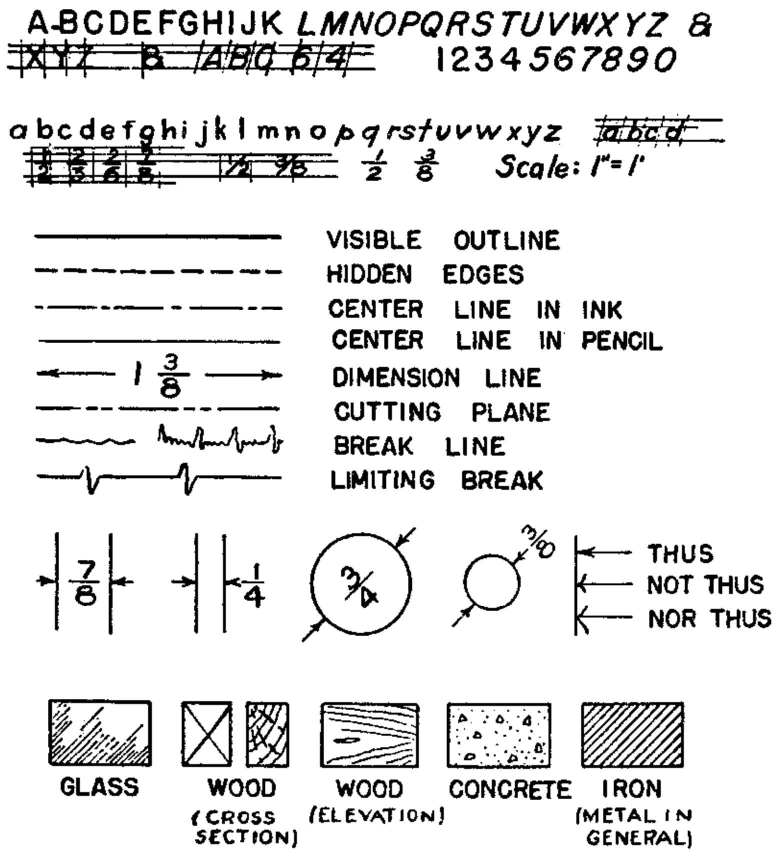


Fig. 7.4. Lettering and conventional signs used on mechanical drawings.

Figure 7.4 shows specimen sets of neat and attractive letters which are simple to make and easy to read. Study the lettering on the drawings in this book, notice the different types used, and select the drawings which in your judgment are lettered most appropriately.

Octagons—In shop work, octagons are often used. Two methods of laying out octagons are illustrated in Fig. 7.5.

1. In "A," the diagonals a c and b d are drawn on the end of a square piece of timber. Points along the edges of the square are located a distance from each corner equal to half the diagonal lengths. By drawing across

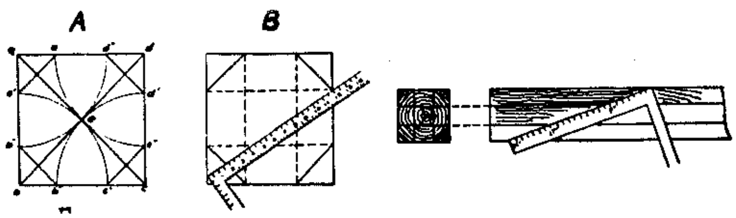


Fig. 7.5. Methods of laying out octagons.

from points a′ to a″, b′ to b″, c′ to c″, and d′ to d″, the octagon can be completed. Arcs may be used as shown for large layouts.

2. On a square stick of timber place the steel square so that 24 divisions on the square will be contained between two parallel sides. Then locate a point 7 divisions in from the right and left sides. As shown in "B," the 3½-inch mark is 7 divisions from the left side and the 8½-inch mark is 7 divisions from the right side. These points locate the lines across the timber parallel to the edges. The octagon sides are obtained by drawing across the ends of these cross lines.

Drawing an Ellipse with a Square—Ellipses are sometimes used in shop work, and it is convenient to know how to draw them. Figure 7.6 shows the steps necessary.

1. Draw the two desired diameters A B and C D.
2. Place the heel of the square at the intersection of the axes so that the blade and tongue of the square lie along the axes.
3. Take a thin strip of wood or a piece of heavy cardboard and lay off *a d* = EC and *a e* = EA.
4. Drive nails through the strip at points "*d*" and "*e*" and make a hole at "*a*" for a pencil point.
5. Move point "*a*" from A to D with the nails at points "*d*" and "*e*" always touching the steel square.
6. Repeat the process in the other quadrants of the figure to secure the completed ellipse.

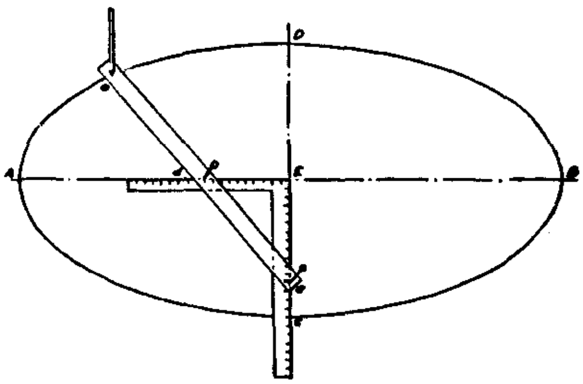


Fig. 7.6. The method of drawing an ellipse with a square.

CHAPTER 8

Selecting and Caring for Lumber

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What are some of the more common woods used in agriculture, and how are they used?
2. What is meant by heartwood? Sapwood?
3. What are the two general methods of sawing lumber?
4. What is meant by seasoning wood, and why is it necessary?
5. What is meant by open- and close-grained woods?
6. Of what significance are knots in lumber?
7. Why is lumber graded, and what are some of the common grades of lumber?
8. How should lumber be stored?
9. What factors should be considered in selecting lumber?
10. What are some desirable insulation materials?

Importance of a Study of the Common Woods—A wise buyer becomes acquainted with the lumber products available. There are vast differences in the various kinds of lumber; consequently, a buyer should know the purposes of the different kinds. Some of the requirements of good lumber are that:

1. It will endure the elements to which it is subjected.
2. It will not crack and dry out.
3. It will nail easily without splitting.
4. It will stay in place.
5. It has the proper strength and durability.

Two Main Classes of Trees—The two main classes of trees are the needleleaf or softwood and the broadleaf or hardwood. There are many varieties of trees in each of these classes. Some of the softwood trees are the pine, fir, cedar, cypress, hemlock, and redwood.

The pines are of two main kinds—the yellow and the white. Yellow pine wood is harder, more pitchy, and heavier than white pine. Because of these characteristics, yellow pine is harder to work and splits more easily than white pine, although it can be given a more durable finish. White pine is fairly light in weight, is low in shrinkage, takes a good finish, and is easily handled. The wood of pines has widespread use and is a popular softwood.

Douglas fir comprises about 70 per cent of the timber of the West Coast and about 25 per cent of the standing timber of the United States. Douglas fir is one of the strongest of the softwoods. It is light in weight, and very resistant to decay. The trees grow to be very large and, consequently, furnish lumber of large dimensions for heavy construction and for the building of bridges. Douglas fir is one of the most popular of the softwoods.

Sitka spruce grows on the North Pacific Coast. It is the largest of the spruces. The wood is light in weight but very strong. It is used for veneering, crating, sashes, doors, and framing.

Western red cedar grows in the Pacific Northwest. The trees are large in size and furnish wood which is especially adapted for cabinet work, veneering, caskets, beehives, sashes and frames, house siding, shingles, posts, and interior finishing. The wood fibers are filled with oils which preserve the wood and give it a pleasant odor.

Cypress trees are found in the South and on the Pacific Coast. The wood is a yellow or reddish color, and very hard and durable. It is used in cabinet work, for fence boards, and for building purposes.

Western hemlock grows on the West Coast. The wood is light, fairly soft, straight-grained, and free from pitch. It is used for inside joists, siding, flooring, lath, and ceilings.

Redwood trees are found chiefly in Oregon and California. The trees are among the largest in existence, often having a diameter of 12 to 15 feet. The wood is reddish in color, very soft, and long-lived, and it takes a good finish. It is used for siding, interior finishing, and furniture.

The hardwood trees do not grow to so great a height as the softwoods. The wood is very hard, beautifully grained, and well adapted to furniture-making or any type of use which requires strength, hardness, and wear resistance. Hardwoods are especially good for floors and interior finishing. Some of the more common trees of this group are the walnut, hickory, oak, elm, maple, and ash.

Common Woods Used in Agriculture—Most of the woods used in agriculture are softwoods. Some repair projects, however, may require hardwoods; consequently, a person should know the characteristics of each type of wood.

Table 8.1 lists, for several common woods used on farms and in nonfarm agricultural businesses, whether each is a hardwood or a softwood, and how each is used.

Meaning of Heartwood, Sapwood—The inner wood of trees is known as heartwood. Some of the characteristics of heartwood are its dark color, resistance to decay, strength, and durability. Since it contains a smaller percentage of moisture than the outer portion of a tree, it shrinks and warps less. Sapwood is the outer portion of trees and is lighter in color than heartwood.

Methods of Sawing Lumber—There are two general methods of sawing lumber: "slash-sawing" and "quarter-sawing." See Fig. 8.1. Most of the lumber

Table 8.1—Hardness and Uses of Common Types of Wood

Name of Wood	Hardness	Uses
White pine	Soft	Lawn and garden furniture; screen, window, and door frames; exterior trim; cabinet work; interior finishing.
Yellow pine	Soft	Benches, stands, and other places where a semi-hard surface is desired.
Fir	Soft	Siding, common dimension materials (2-by-4's, 2-by-6's), shiplap, sheathing, flooring, ceilings, farm gates, hog houses, garages, barns, troughs, feeders.
Cedar	Soft	Fence posts, sills, shingles.
Poplar	Hard	Crates, wagon boxes.
Oak, ash, elm, maple, hickory	Hard	Handles, interior finishing, floors.

used in construction work is "slash-sawed." "Quarter-sawed" lumber is often used in furniture. Some woods, such as oak, have a beautiful grain and do not shrink and warp as much when they are "quarter-sawed" as they do when they are "slash-sawed."

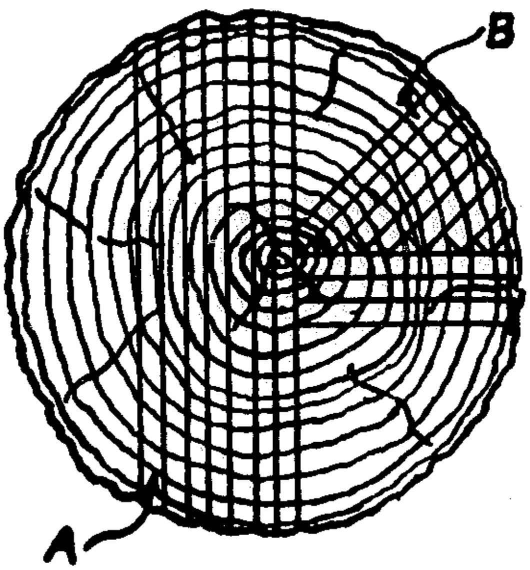


Fig. 8.1. An illustration of (A) slash-sawing and (B) quarter-sawing.

Seasoning Lumber—When a tree is first cut, it contains a large percentage of moisture, which will cause the lumber to shrink and warp if it is not properly dried. The drying process is known as seasoning. Lumber may be seasoned by the following methods:

1. Natural air-drying, which necessitates piling the lumber so that the air can circulate around each piece. This method requires considerable time, varying from a few months to several years.
2. Artificial drying, which is known as kiln-drying.

All lumber should be thoroughly dried before it is used. Green lumber placed in a warm room to dry must be stacked so that the air will circulate around it. It must also be held in place so that it will not warp.

Open- and Close-Grained Woods—Some woods such as oak, walnut, and ash are open-grained and require a wood filler before finishing materials are used. Other woods such as maple, gum, and pine are close-grained, or nonporous. Close-grained woods do not require a wood filler; in fact, some will not absorb wood fillers.

Knots in Wood—A knot is a cross section of a limb of a tree. Knots usually vary in size from ½ inch to 2 inches in diameter and are objectionable for several reasons: (1) they may fall out of place, leaving a hole in the lumber; (2) they weaken the piece of lumber; (3) they are often unattractive; and (4) they are hard to saw.

In selecting lumber which contains knots, observe whether the knots show any indication of decay and whether they are tight.

Grading Lumber—Graded lumber insures a uniform product. Softwood lumber less than 6 inches thick which is used for general building purposes is divided into two main divisions: (1) select lumber and (2) common lumber.

Care of Lumber—Lumber must be stored properly; otherwise it may become badly warped. In storing lumber:

1. Keep it in a dry, well ventilated place.
2. Place it on supports at least a foot above the ground so that air can circulate under it.
3. Pile all pieces of the same dimensions together.
4. Lay each piece flat.
5. Separate the layers one from another with a strip of lumber so that air can circulate between them.
6. Place dividing strips directly above each other.
7. Keep the stacks in neat order.

Factors to Consider in Selecting Lumber—Some of the factors which should be considered in selecting and buying lumber are:

1. The purpose for which the lumber is to be used.
2. The amount of seasoning which the lumber has received.
3. The type of grain the lumber has—especially if it is to be stained.
4. The number of knots and cracks in the wood.
5. The price of the lumber per board foot.
6. The hardness or softness of the wood.
7. The amount of rot and worm holes in the wood.
8. The dimensions of the lumber available.

It is a good plan to go to a lumber yard to select your materials. In this way you can select the kind, dimensions, and quality of lumber you need.

Table 8.2—Basic Grade Classification for Yard Lumber

Total products of a typical log, which are arranged in series according to quality as determined by appearance.	SELECT Lumber of good appearance and finishing qualities.	Lumber suitable for natural finishes.	Grade A—Practically free from defects.
			Grade B—Allows a few small defects or blemishes.
		Lumber suitable for paint finishes.	Grade C—Allows a limited number of small defects or blemishes that can be covered with paint.
			Grade D—Allows any number of defects or blemishes which do not detract from appearance, especially when painted.
	COMMON Lumber containing defects or blemishes which detract from appearance; lumber suitable for general utility and construction purposes.	Lumber suitable for use without waste.	No. 1 Common—Sound and tight-knotted stock. Size of defects and blemishes limited. May be considered water-tight lumber.
			No. 2 Common—Allows large and coarse defects. May be considered grain-tight lumber.
		Lumber permitting waste.	No. 3 Common—Allows larger and coarser defects than No. 2 and occasional knotholes.
			No. 4 Common—Low-quality lumber admitting the coarsest defects, such as decay and holes.
			No. 5 Common—Must hold together under ordinary handling.
	DIMENSION	Lumber suitable for framing (rafters, studs, joists.) Grade based primarily on strength, stiffness, and straightness.	No. 1 Dimension—Used for joists, rafters, scaffolding, and planking.
			No. 2 Dimension—Used for joists, rafters, plates, sills, and other vertical load-bearing members in light construction.
			No. 3 Dimension—Used in cheap and small buildings.

Insulation Materials—Many types of insulation materials are available on the market. Some of these can be used for several purposes other than insulation. Most lumber dealers keep a supply of free literature which describes these materials.

CHAPTER 9

Selecting and Using Wood Fasteners

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What are the common types of nails and their uses?
2. How should nails be placed in wood?
3. How should nails be clinched? Drawn?
4. What are the common types of screws and their uses?
5. What are the common types of bolts and their uses?
6. How may rusted bolts be removed?
7. What are the common types of hinges and their uses?
8. How should glue be used in agricultural woodworking and carpentry?

Importance of a Study of Hardware—It is important for an agricultural worker to become familiar with the different kinds of bolts, screws, nails, and hardware available. A few of the factors to consider in choosing hardware are:

1. The kind of lumber being used—some lumber splits very easily.
2. The location of the hardware—interior work requires hardware which is durable, yet neat and attractive.
3. The permanency and strength desired—heavy lumber requires heavy hardware.
4. The cost of the project.
5. The type of project—a hog feeder would require heavier hardware than a chicken feeder.

Not only is it important to know what hardware to choose, but it is also important to know how much to buy.

NAILS

Common Types of Nails and Their Uses—There are many different kinds of nails, but only a few kinds are frequently used on farms and in nonfarm agricultural businesses. *Common nails and brads are designated by the "penny" system.* Two explanations are given as to why nails were originally designated by the "penny" system in England. One explanation is that six-penny and ten-penny nails were sold for sixpence and tenpence per 100; the other explanation is that 1,000 six-penny nails weighed 6 pounds. The symbol for "penny" is the letter "d." A six-penny nail is designated as 6d. The length in inches of common nails through the ten-penny may be determined by dividing the "penny" by 4 and adding ½. The length of a 6d nail may be found as follows: 6 divided by 4 equals 1½ plus ½ equals 2 inches.

A spike is a nail, 16d size or larger. If a spike is longer than 6 inches, it should be ordered by its length. The thickness of the wire from which nails are made is termed "gauge."

Common Nails—Nails of this type are used on farms and in nonfarm agricultural businesses more than any other type of nail. They are made of wire and may be purchased in any size from a two-penny (2d) to a sixty-penny. The eight-penny nail is the size most frequently used. Common nails all have flat heads. They are generally used for nailing such materials as sheathing, shiplap, fencing, and barn boards.

Box Nails—Box nails are slightly smaller in diameter than common nails, and they are better adapted for use in lumber which splits easily. They may be secured in any size from a two-penny to a forty-penny. The six- and the eight-penny are the sizes most frequently used. They are often used for the nailing of siding.

Finishing Nails—Nails of this type have small heads and are used when the heads of the nails should not show. The heads are usually sunk or "set" in the wood and the holes filled with wood putty. They are used extensively for interior finishing, for ceilings, and for cabinet work. They may be secured in sizes from a two-penny to a twenty-penny.

Common Brads—These nails have small heads similar to the heads of finishing nails, and they are often used for the same purposes as finishing nails. They can be purchased in various sizes. They are often classified according to their length in inches.

Casing Nails—As the name indicates, these nails are used in laying floors. They may be purchased in sizes as large as a twenty-penny.

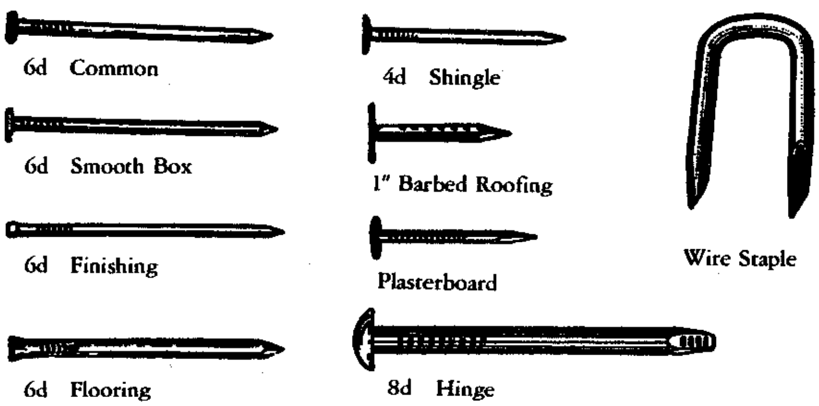
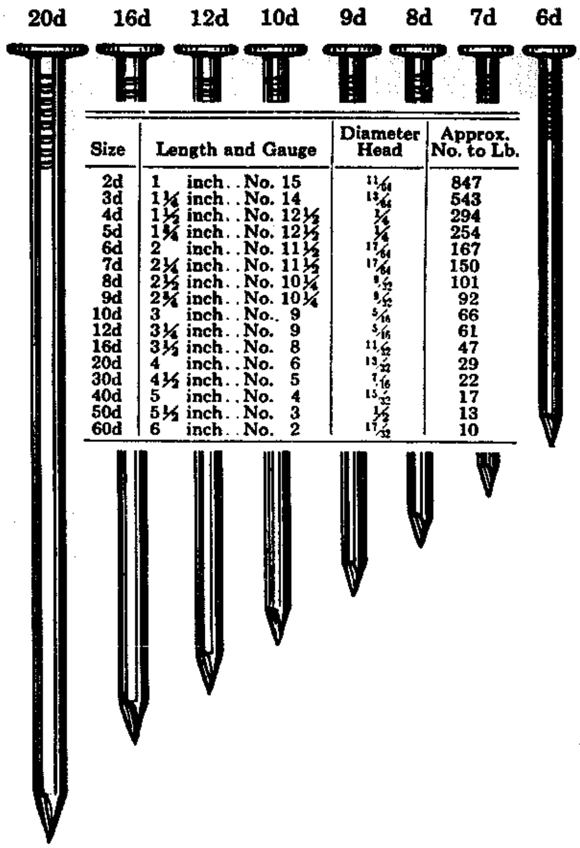


Fig. 9.1. Common kinds of nails.



Size	Length and Gauge	Diameter Head	Approx. No. to Lb.
2d	1 inch . . No. 15	11/64	847
3d	1¼ inch . . No. 14	13/64	543
4d	1½ inch . . No. 12½	¼	294
5d	1¾ inch . . No. 12½	¼	254
6d	2 inch . . No. 11½	17/64	167
7d	2¼ inch . . No. 11½	17/64	150
8d	2½ inch . . No. 10¼	9/32	101
9d	2¾ inch . . No. 10¼	9/32	92
10d	3 inch . . No. 9	5/16	66
12d	3¼ inch . . No. 9	5/16	61
16d	3½ inch . . No. 8	11/32	47
20d	4 inch . . No. 6	13/32	29
30d	4½ inch . . No. 5	7/16	22
40d	5 inch . . No. 4	15/32	17
50d	5½ inch . . No. 3	½	13
60d	6 inch . . No. 2	17/32	10

(Courtesy American Steel and Wire Company)

Fig. 9.2. Common sizes of nails.

Table 9.1—Size, Length, Gauge, and Approximate Number of Nails per Pound[1]

Size	Length in In.	COMMON Gauge	COMMON No. per Lb.	BOX NAILS Gauge	BOX NAILS No. per Lb.	FINISHING Gauge	FINISHING No. per Lb.
2d	1	15	876	15½	1,010	16½	1,351
3d	1¼	14	568	14½	635	15½	807
4d	1½	12½	316	14	473	15	584
5d	1¾	12½	271	14	406	15	400
6d	2	11½	181	12½	236	13	309
7d	2¼	11½	161	12½	210	13	239
8d	2½	10¼	106	11½	145	12½	189
9d	2¾	10¼	96	11½	132	12½	172
10d	3	9	69	10½	94	11½	121
12d	3¼	9	63	10½	88	11½	113
16d	3½	8	49	10	71	11	90
20d	4	6	31	9	52	10	62
30d	4½	5	24	9	46		
40d	5	4	18	8	35		
50d	5½	3	14				
60d	6	2	11				

[1]"Manual of Carpentry," American Steel and Wire Company, Chicago.

Shingle Nails—Nails for wood shingles are galvanized box nails and may be secured in sizes from a three-penny to a six-penny, the four-penny nail being the size most frequently used.

Roofing Nails—These nails can be purchased in lengths from ¾ inch to 2 inches. They may be purchased with several shank styles. In deciding which of the many available types to use, it is best to consult your local roofing supply dealer.

Plasterboard Nails—As the name indicates, these nails are used for nailing plasterboard. They may be purchased in sizes of 1 inch to 1¼ inches in length. The type to use will depend on the type of plasterboard being used.

Hinge Nails—There are two general types of hinge nails—the oval head and the flat countersunk head. They may be secured in sizes from a four-penny to a twenty-penny. They may be smooth or barbed, zinc-coated or blued. Barbed nails have more grip and holding power. A zinc coating retards rusting. Zinc-coated nails are often used in roofing or in lattice work because of their rust resistance.

Placing and Driving Nails—Nails should not be placed in a straight line because they may split the wood. Even two nails may split a piece of wood if they are placed in a straight line. Nails should be arranged in a zigzag line.

Splitting of lumber may be decreased by lubricating nails with paint, wax, or soap. Lubricated nails do not bend as easily as nails that are not.

When a nail is almost driven, the last blow with the hammer should not be so heavy that a hammer mark is left on the wood. Hammer marks are very unattractive and indicate carelessness. A nail set should be used when the head of the nail is to be sunk below the surface of the wood.

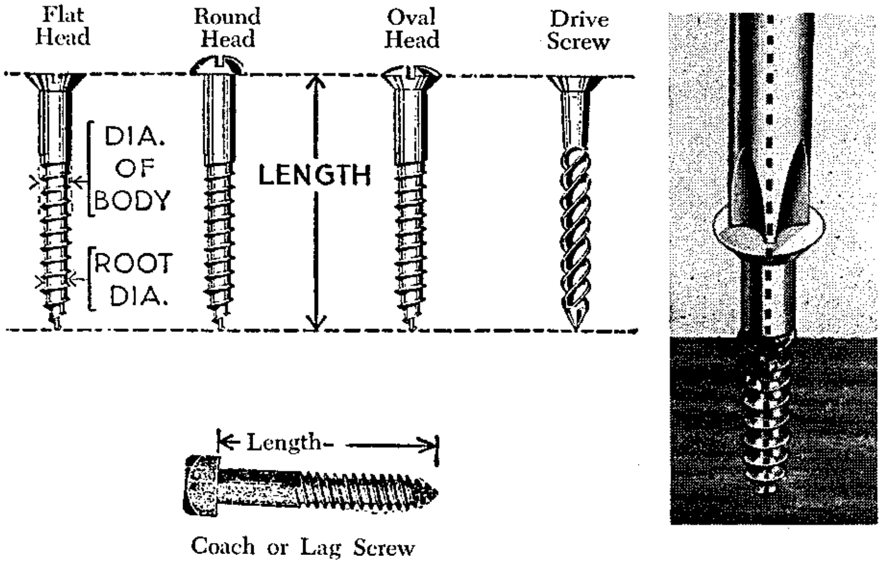
Clinching and Drawing Nails—Nails should never be clinched on outer surfaces but on under surfaces where they will not show and catch everything. In clinching a nail, bend it across the grain; otherwise the wood may be split. On surfaces such as the inside of a door, bend the points of the nails so that they will be driven into the wood when the nails are clinched.

In pulling a nail from a piece of wood, use a claw hammer. A small block of wood may be placed under the head of the hammer to secure a better leverage. If the head of a nail is missing and the claw hammer will not grip the nail, a pair of vise-grip pliers may often be used to pull the nail. Sunken heads may be raised by lifting the board slightly with a pry and then driving it back into place so that the hammer will grasp the nail heads. Clinched nails should be straightened and driven back before they are pulled.

SCREWS

Common Types of Wood Screws and Their Uses—Screws are used for fastening two pieces of wood together when a more secure fastening than nailing is desired, or when the pieces of wood may need to be taken apart later. Screws are made of a metal such as steel or brass. There are four common types of screws used for woodwork: lag or coach, flat head, round head, and oval head. The bright-finished, flat-headed wood screw is the type most frequently used. The size of screws is designated by their gauge and by their length. Length of screws varies from ¼ inch to 6 inches.

Lag screws are often used for fastening wood to a brick or concrete wall. A good way of fastening lag screws to a wall is to drill, with a star drill, a hole in the wall which is slightly larger than the lag screw. The depth of the hole should not be greater than the length of the lag screw, because the heads of lag screws are not ordinarily countersunk. After the hole is drilled, a piece of flat, flexible lead as wide as the hole is deep should be tightly rolled and placed in the hole so that when the lag screw is screwed into it, it will unroll. If desired, an expansion shield may be used instead of the lead.



(Courtesy American Screw Company)

Fig. 9.3. Common types of screws.

In fastening two pieces of wood together with screws, it is a good procedure, especially in hardwood, to drill holes in the wood slightly smaller than the screws. If the under piece of wood is hard, continue the holes into it. If the under piece is soft, it is not necessary to bore into it. In starting a screw, tap it with a hammer before using a screwdriver.

A strong screwdriver which fits the screw head should be used. The head of a screw is usually left flush with the surface of the wood unless stain is to be applied to the wood. If stain is to be applied, the head should be countersunk far enough to permit it to be well covered with plastic wood, putty, or a wooden plug. Flat-headed and oval-headed screws may be countersunk, but round-headed screws should not be countersunk. There is less danger of the wood splitting if the screws are lubricated with soap or wax.

Table 9.2—Bit Sizes for Boring Pilot Holes and Shank-Clearance Holes (for Slotted- and Phillips-Head Screws)[1]

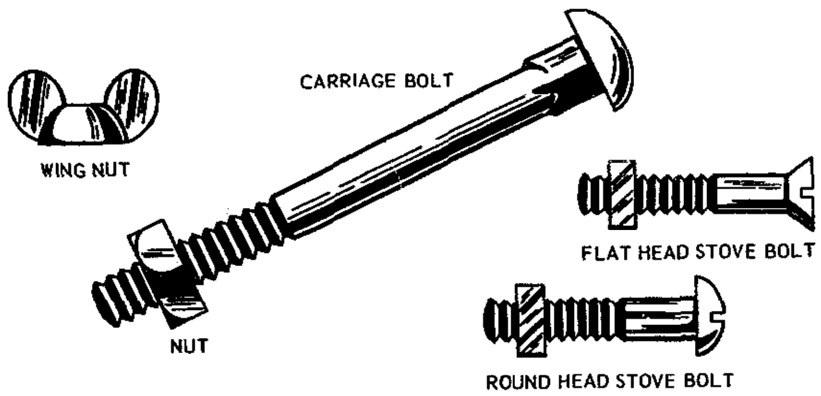
	BIT OR DRILL SIZES										
	FOR SHANK-CLEARANCE HOLES		FOR PILOT HOLES								
			HARDWOODS				SOFTWOODS				
NO. OF SCREW	TWIST BIT (Nearest Size in Fractions of an In.) Slotted & Phillips	DRILL Gauge No. or Letter, to Be Used for Maximum Holding Power Slotted & Phillips	TWIST BIT (Nearest Size in Fractions of an In.) Slot.	Phil.	DRILL Gauge No., to Be Used for Maximum Holding Power Slot.	Phil.	TWIST BIT (Nearest Size in Fractions of an In.) Slot.	Phil.	DRILL Gauge No., to Be Used for Maximum Holding Power Slot.	Phil.	NO. OF AUGER BIT to Counterbore for Sinking Head (by 16ths) Slotted & Phillips
0	1/16	52	1/32	—	70	—	1/64	—	75	—	
1	5/64	47	1/32	—	66	—	1/32	—	71	—	
2	3/32	42	3/64	1/32	56	70	1/32	1/64	65	75	3
3	7/64	37	1/16	1/32	54	66	3/64	1/32	58	71	4
4	7/64	32	1/16	3/64	52	56	3/64	1/32	55	65	4
5	1/8	30	5/64	1/16	49	54	1/16	3/64	53	58	4
6	9/64	27	5/64	1/16	47	52	1/16	3/64	52	55	5
7	5/32	22	3/64	5/64	44	49	1/16	3/64	51	53	5
8	11/64	18	3/32	5/64	40	47	5/64	1/16	48	52	6
9	3/16	14	7/64	3/32	37	44	5/64	1/16	45	51	6
10	3/16	10	7/64	3/32	33	40	3/32	5/64	43	48	6
11	15/64	4	1/8	7/64	31	37	3/32	5/64	40	45	7
12	7/32	2	1/8	7/64	30	33	7/64	3/32	38	43	7
14	1/4	D	9/64	1/8	25	31	7/64	3/32	32	40	8
16	17/64	I	5/32	1/2	18	30	9/64	7/64	29	38	9
18	19/64	N	3/16	9/64	13	25	9/64	7/64	26	32	10
20	21/64	P	13/64	5/32	4	18	1/64	9/64	19	29	11
24	3/8	V	7/32	3/16	1	13	3/16	9/64	15	26	12

[1]Courtesy American Screw Company.

BOLTS

Common Types of Bolts and Their Uses—In heavy construction work in which permanency and strength are desired or in which an object may need to be dismantled frequently, bolts are often used. There are three types of bolts ordinarily used on farms and in nonfarm agricultural businesses: machine, carriage, and stove bolts.

Bolts may be purchased with fine threads or coarse threads. The latter is the more frequently used type in agriculture. The fine thread type is usually used in motors.



(Courtesy U.S. Department of the Army)

Fig. 9.4. Some types of bolts.

Machine bolts have hexagonal heads. Bolts of this type are ordinarily used in assembling machinery. They may be secured in sizes from 1/4 inch by 1 1/2 inches to 1 1/4 inches by 30 inches.

Carriage bolts have a rounded head and a square shank which is supposed to keep the bolt from turning. Since it is impossible to hold the head of a carriage bolt with a wrench, it is often a difficult job to remove bolts of this type, especially after they have become rusted.

Stove bolts have round or flat heads and can be secured in a number of small sizes. They have either slotted or Phillips heads which permit the bolts to be tightened or loosened with a screwdriver. They are used for lightweight structures of either metal or wood. Stove bolts are threaded their full length.

Expansion shields and lag bolts are used in fastening materials to concrete, brick, or stone walls. A star drill is used to drill the holes. When a lag bolt is tightened, the collar around it expands, making it secure. An expansion shield consists of a metal tube with inside threads and a lead collar around the tube. A small bolt screws into the shield.

Toggle bolts are used to fasten objects to walls and ceilings. A hole is drilled in the wall or ceiling and the toggle bolt inserted with the head closed. When the head reaches the opposite side of the wall or ceiling, it opens. The bolt may then be tightened with a screwdriver.

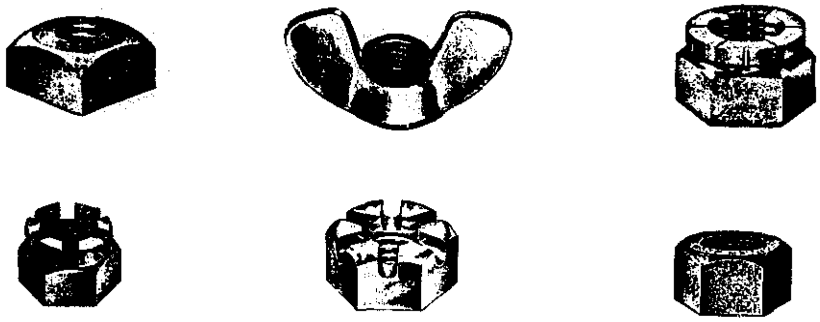


Fig. 9.5. Top row, left to right—square nut; wing nut, used on bolts which need to be changed or adjusted frequently; self-locking nut, no lock washer needed. Bottom row, left to right—castellated hex nut, used on machinery, cotter pin can be inserted through top; slotted hex nut, cotter pin can be inserted; hex nut, used because it will fit in locations with small clearances and is adapted to socket wrenches.

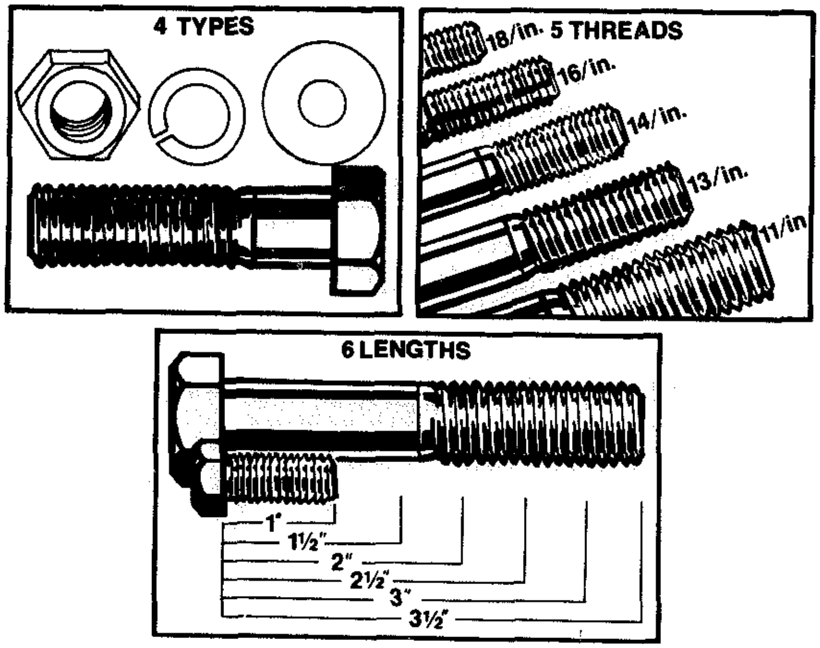
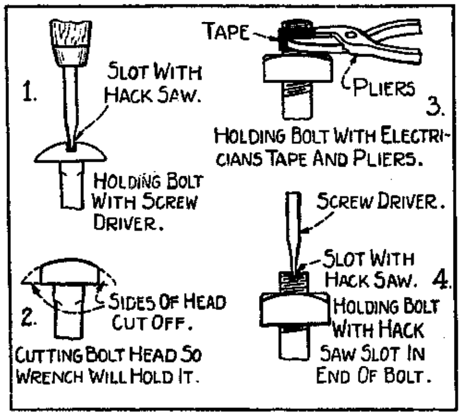


Fig. 9.6. Hex bolts used on agricultural machinery.

Washers—The two common types of washers are (1) plain and (2) lock. Both types may be either smooth or corrugated. The plain type is used frequently in agriculture. When there is danger of a nut coming loose and when permanency is desired, the lock-type washer should be used.

Nuts—Nuts are of the square, hexagon, castellated, slotted, and thumb types. The castellated and slotted types, which may be held in place with a cotter pin, are the best types to use in machinery and tractors where safety is essential. Thumb nuts are often used on bolts which may need frequent adjusting.

Removing Rusted Bolts and Nuts—Removing bolts and nuts which are badly rusted is often a problem. Figure 9.7 shows some of the ways to overcome this problem.



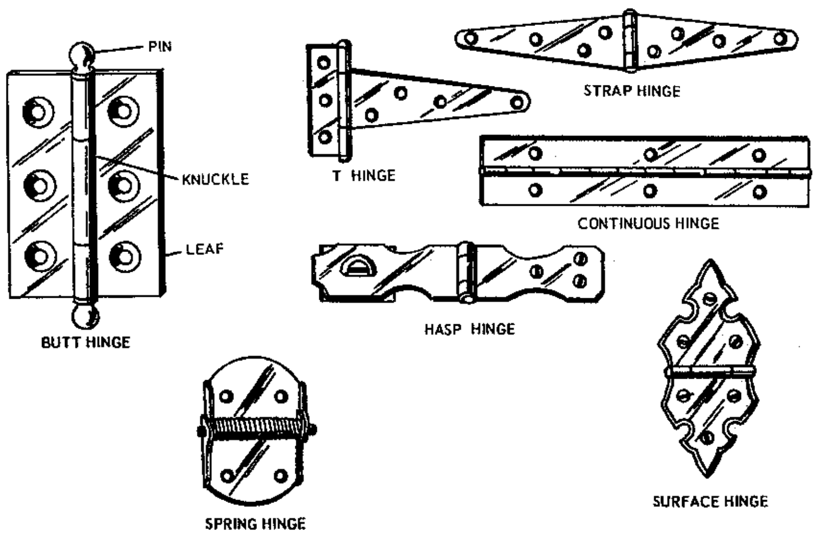
(Courtesy E. C. Atkins and Co.)

Fig. 9.7. Ways to remove rusted bolts and nuts.

HINGES

Common Types of Hinges and Their Uses—Hinges, like other hardware, are of many types. Each type has certain uses. The following types are frequently used:

Strap hinges, because they are durable and have considerable strength, are probably the type of hinge most frequently used in agriculture.



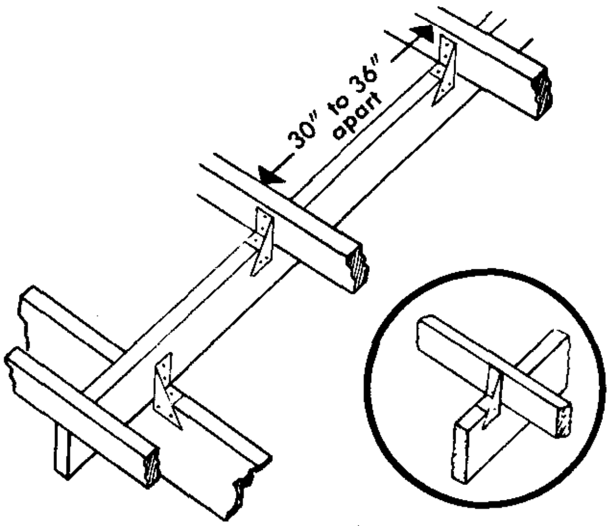
(Courtesy U.S. Department of the Army)

Fig. 9.8. Types of hinges.

T hinges are also frequently used. They are generally used where the butt end of the hinge is to be fastened into a studding.

Butt hinges are of two types—those in which the center pin may be removed and those which have the center pin riveted in place. The first type is frequently used on house or cabinet doors. Butt hinges should be set flush with the parts they hold together when they are used on cabinet-type doors.

Hasp hinges are used for fastening doors, and they provide a place for a lock.



(Courtesy Republic Steel Corporation)

Fig. 9.9. Steel anchors may be used to fasten timbers and give added strength to a building.

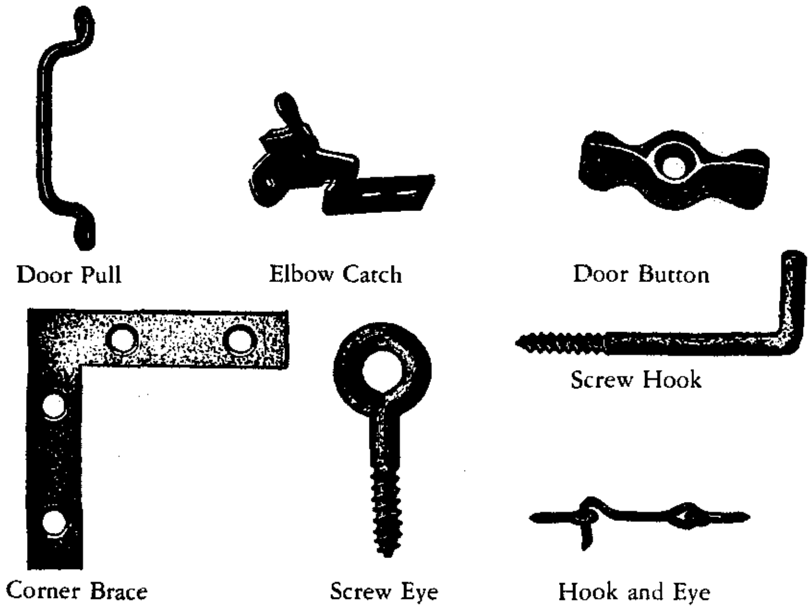
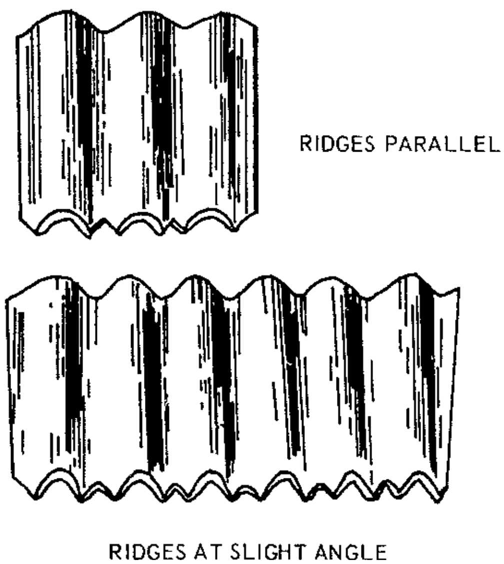


Fig. 9.10. Other types of hardware frequently used in agriculture.

OTHER TYPES OF HARDWARE

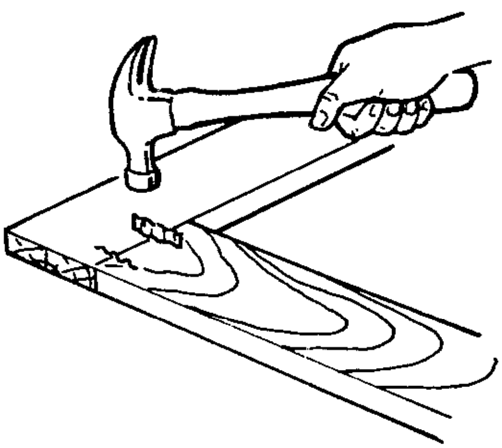
Timber or steel framing anchors are often used to increase the strength of buildings. See Fig. 9.9 for an illustration of the use of steel framing anchors to strengthen a roof. The hardware shown in Fig. 9.10 needs little explanation. The use of each is apparent.

Corrugated fasteners are used for making joints in such projects as boxes, screen doors, and screen windows. They may be purchased in various sizes from 1/4 inch to 1 inch in depth, with two to seven corrugations.



(Courtesy U.S. Department of the Army)

Fig. 9.11. Corrugated fasteners.



(Courtesy U.S. Department of the Army)

Fig. 9.12. Using corrugated fasteners.

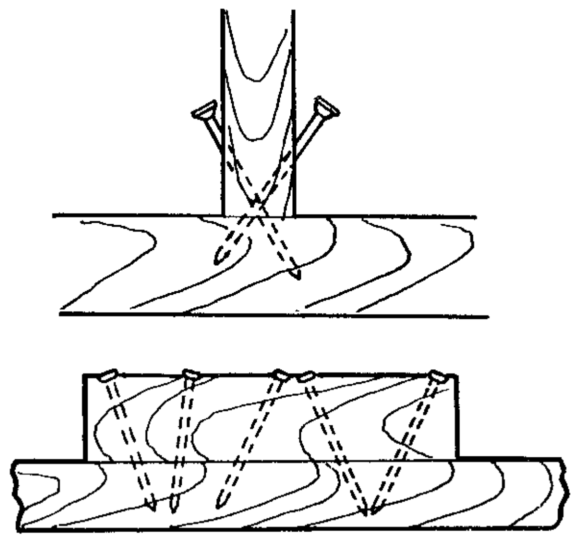
GLUE

Value—Glue may be used to strengthen agricultural buildings, especially portable buildings. It is used to supplement the use of nails, bolts, screws, steel plates, crosstie rods, and metal straps. In some situations, glue is used as a substitute for these materials. When glue is used to fasten two boards together, the bond is often stronger than the wood itself. When two pieces of wood in a building are joined together with glue, the bond is several times as strong as it is when the pieces of wood are nailed together.

Type of Glue—In agricultural woodworking and carpentry a glue is needed that is highly water-resistant, capable of being handled at a relatively wide range of temperatures, and usable on rough lumber where the only pressure applied results from nailing.

Casein glue is resistant to heat, cold, and moisture and meets the other requirements of a glue for use in the construction of agricultural buildings and equipment. It is not waterproof, however, and is not suitable for exterior use. For wood exposed to the weather—exterior use—the glue that should be used is resorcinol resin. It is the type of glue recommended as the structural adhesive for agricultural service buildings. Casein glue and resorcinol resin glue may be obtained from most hardware stores and lumber yards.

How to Use—Glue may be spread with a brush on the pieces of wood being joined together. The pieces of wood should then be nailed or bolted to hold them together until the glue sets. When the glue sets, the wood is held by both the glue and the nails or bolts. In putting up small portable buildings which must withstand much strain when moved, glue and nail or bolt all braces and joints.



(Courtesy U.S. Department of the Army)

Fig. 9.13. Toe-nailing. Toe-nailing is often used with glue to secure and strengthen glued joints.

Table 9.3—Characteristics of Some Types of Glue for Wood[1]

Type of Glue	Source	Mixing	Apply	Drying Time	Strength	Shop Uses	Water Resistance
Animal.		Soak in cold water, then heat in glue pot to 140° F; takes all day.	Hot.	Sets rapidly.	Very strong.	Joint work not exposed to water.	Low.
Cold liquid animal.	Animal or fish.	Ready-mixed.	Cold or warm.	Varies with type.	Medium.	Repair work.	Low.
Casein, powdered.	Milk.	Water-soluble; takes 20 min. to mix for each use.	Cold.	4–5 hrs.	Good on oily woods. Works when cool, too.	For semi–water-resistant joint work and as a filler.	Good.
Plastic.	Plastic resin.	Mix in cold water; ready immediately.	Cold.	Sets up hard enough to work within 5–6 hrs. Clamping is necessary.	Very strong.	Joint work.	Very high.
Epoxy.	Resin.	Resin and hardener, easily mixed.	Cold.	Clamping not necessary. Hardens overnight.	Strong. Resists heat.	Wood, masonry, metal, china, glass.	Waterproof.
Resorcinol resin glue.		Liquid resin and powdered catalyst to be mixed.	Cold.	8–10 hrs. Clamping necessary.	Strong at any temperature.	Outdoor furniture, boats, etc., where dark color does not matter.	100 per cent waterproof.
Powdered resin.	Resin.	Mix for each use.	Cold.	Clamping necessary.	Strong if joint fits well.	Not good for poor joints or oily surfaces.	Good.
Contact cement.		Liquid ready-mixed for use.	Cold.	Bends on contact when dry.	Light duty.	Leather. Good for large surfaces like wall paneling.	High.
White glue.		Liquid ready-mixed for use.	Cold.	Sets in 20–30 min. with moderate pressure.	Moderate strength.	Paper, fabric, canvas, felt, and cork to wood.	Moderate.

[1]Courtesy U.S. Department of the Army.

CHAPTER 10

Cutting Rafters

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Is a study of rafter cutting important?
2. What tools are necessary?
3. What is the meaning of the following: plumb cut, plate, seat cut, span, run, rise, and pitch?
4. What is the procedure for laying out a rafter?
5. How may rafter lengths be determined?
6. What are some of the common types of roofs?

Importance of Rafter Cutting—Rafters in the buildings on farms and on the premises of nonfarm agricultural businesses often do not fit. Agricultural workers often have had little, if any, training in how to lay out and cut a rafter. Rafters which do not fit together have less strength than those which fit properly. An amateur carpenter often tries to hold the rafters in place while marking where to saw. A little knowledge of rafter cutting makes the job simple and easy.

Tools Necessary—The following tools are used in rafter cutting:

1. A steel square for measuring the correct angles.
2. A sharp, pointed pencil or knife for marking the rafters.
3. A crosscut saw.

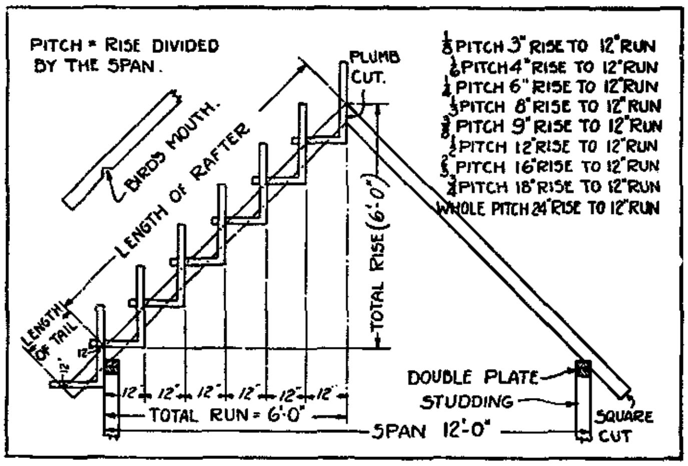
In addition to these tools, a pair of sawhorses may be used.

Definition of Terms—The following terms are often used in rafter cutting:

1. *Plumb cut*—the vertical cut at the top end of the rafter.
2. *Plate*—the base on which the lower end of the rafter rests. The plate usually rests across the top of the studding.
3. *Seat cut*—also known as the bird's mouth; the cut at the end of the rafter which rests on the plate.
4. *Span*—the distance from the outside edge of one wall plate to the outside edge of the opposite wall plate.
5. *Run*—one-half of the span.
6. *Rise*—the vertical distance from the top of the plate to the ridge.
7. *Pitch*—the slope or slant of the roof of a building. It is the proportion of the rise to the span. A roof having a 24-foot span and an 8-foot rise

would have a one-third pitch. The pitch may be determined by dividing the rise by the span.

Laying Out Rafters—In laying out rafters, the smaller part of the square, the tongue, is used for the run and the larger part of the square, the blade, is used for the rise. Figure 10.1 shows that with a run of 6 feet and a rise of 6 feet, the square is placed on the rafter using 12 inches on the tongue and 12 inches on the blade. For a one-fourth pitch, place the steel square on the rafter and use 12 inches on the tongue and 6 inches on the blade. An experienced carpenter usually measures from the top or peak end of the rafter. Apply the steel square as many times as there are feet in the run. Since the first pair of rafters is usually used for a pattern in cutting other rafters, it is essential for all measurements to be correct.

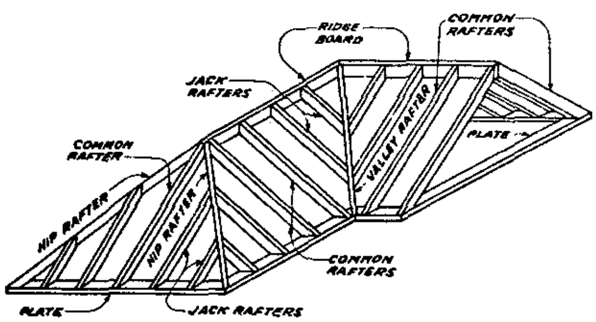


(Courtesy E. C. Atkins and Co.)

Fig. 10.1. The principle involved in the use of a framing square in the laying out of rafters.

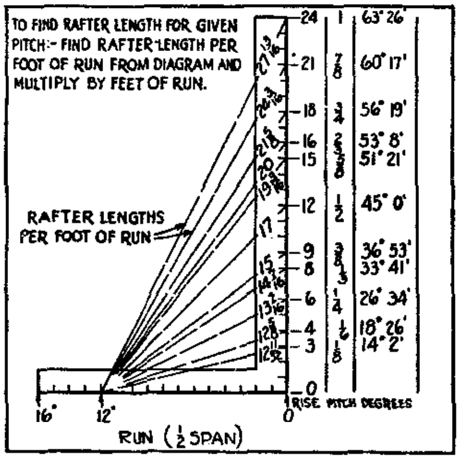
Determining Rafter Lengths—Rafter lengths may be computed by applying the square as indicated in the previous paragraph, by using a steel square, or by using a table. The length of a rafter is the hypotenuse of a right angle. The rise and run of the rafter are the other two sides of the right angle. For a half pitch roof, the steel square is placed on the rafter using 12 inches on the tongue and 12 inches on the blade as previously explained. The diagonal distance or hypotenuse between these points is 17 inches. The 17 inches is read from the rafter table on the square. (See Fig. 10.4.) The length of the rafter is 17 inches times each foot of the run. In a building with a span of 20 feet and a run of 10 feet, the rafter length would be 10 times 17 inches, or 14 feet 2 inches for a half pitch roof. (Fig. 10.3.)

Rafter lengths may also be computed by using a table such as Table 10.1. To find the length of a common rafter, look at the point in Table 10.1 where the column representing the width of the building intersects with the row representing the rise in inches per foot. For example, what is the length of a common rafter for a building 20 feet wide, having a roof sloping 8 inches per foot? Answer: 12′¼″.



(Courtesy Stanley Tools)

Fig. 10.2. The kinds of rafters.

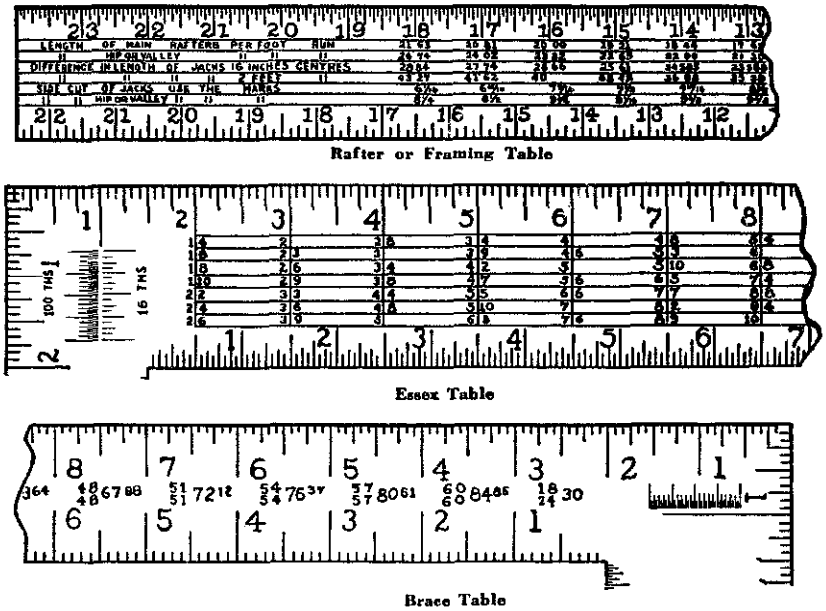


(Courtesy E. C. Atkins and Co.)

Fig. 10.3. How to figure pitch and rafter lengths with a framing square.

The tail length of the rafter beyond the side of the building must be added to the dimensions given in the table to give the overall length of the rafter. If a ridge board is used, the rafter length is shortened half the thickness of the ridge board.

Rafter or Framing Table—The rafter or framing table found on a square is used to determine (1) the lengths of common, hip, valley, and jack rafters and (2) the angles to cut these rafters. The length of a common rafter may be found by multiplying the "length given in the table" by the number of feet in the run of the building. To find the length of a common rafter for a building with a run of 9 feet and a roof with a one-third pitch—8 inches of rise per foot of run—proceed as follows: *First,* find on the "inch line" on the top edge of the blade of the square the figure just below the figure 8. Note that the figure is 14.42, which is the length of the rafter in inches per foot of run. *Second,* since the run of the building is 9, multiply the 14.42 by 9, which will give 129.78 inches. *Third,* 129.78 divided by 12 equals 10'9¾". The length of hip or valley rafters is found in the same way as common rafters, except you use the figures found on the second line of the square.



(Courtesy Stanley Tools)

Fig. 10.4. Framing square tables.

Table 10.1—Handy Table of Rafter Lengths for a Gable Roof

Rise in Inches per Foot	Width of Building in Feet 10'	12'	14'	16'	18'
4"	5'3 1/4"	6'3 7/8"	7' 4 1/2"	8' 5 2/12"	9'5 10/12"
6"	5'7 1/12"	6'8 1/2"	7' 9 11/12"	8'11 4/12"	10' 3/4"
8"	6' 1/2"	7'2 1/2"	8' 4 11/12"	9' 7 3/8"	10'9 10/12"
10"	6'6 1/8"	7'9 3/4"	9' 1 4/12"	10' 4 11/12"	11'8 7/12"
12"	7'7 7/8"	8'5 10/12"	9'10 3/4"	11' 3 3/4"	12'8 3/4"

Rise in Inches per Foot	Width of Building in Feet 20'	22'	24'	26'	28'
4"	10'6 1/2"	11'7 1/8"	12' 7 3/4"	13' 8 5/12"	14'9 1/12"
6"	11'2 2/12"	12'3 7/12"	13' 5"	14' 6 5/12"	15'7 10/12"
8"	12' 1/4"	13'2 5/8"	14' 5 1/12"	15' 7 1/3"	16'9 11/12"
10"	13' 1/4"	14'3 10/12"	15' 7 5/12"	16'11 1/12"	18'2 8/12"
12"	14'1 8/12"	15'6 8/12"	16'11 5/8"	18' 4 5/8"	19'9 7/12"

Essex Table—This table is on the back of the blade of a square. It is used to determine the number of board feet in a piece of lumber 1 inch thick. Lumber less than 1 inch in thickness is figured as 1 inch. The first step in using this table is to find the figure 12, which is the starting point for all calculations, on the outer edge of the blade of the square. To find the board measure for a board 10 feet long and

9 inches wide, find 10 in the column under 12 and glance along the line containing the 10 until you come to the figure in the column below 9. This figure will be 7-6 or 7½, which is the number of board feet in the board.

Brace Table—This table is on the back of the tongue of a square. It is used to show the length of common braces. The figures which are written one above the other represent the rise and run. Note in Fig. 10.4 the numbers $^{51}_{51}72^{12}$ under the number 7. These numbers mean that when the rise and run are 51 inches each, the brace will be 72.12 inches long.

Roof Types—The roofs that are frequently used on structures are gable, curb, shed, two-third span, gambrel, half monitor, and monitor. If the principles governing the laying out of common rafters are understood, it will be possible to frame any of these roof types, as only modifications of common rafter construction are involved.

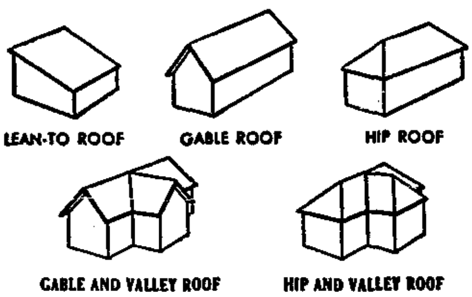


Fig. 10.5. Roof types.

PAINTING AND GLAZING

Student Abilities to Be Developed

1. Ability to appreciate the importance of using good paint and wood preservatives.
2. Ability to prepare a surface for painting.
3. Ability to mix and apply paint.
4. Ability to mix and apply whitewash and calcimine.
5. Ability to measure and cut glass.
6. Ability to prepare a sash for fitting and fastening the glass.

CHAPTER 11

Painting

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What are some common kinds of paint?
2. What ingredients are found in paint, and what is the use of each?
3. What factors should be considered in selecting paint?
4. How many square feet will a gallon of paint cover?
5. How many coats of paint should be applied to new wood?
6. How should paint be mixed?
7. How should paint be stored?
8. What kind of a brush should be selected? How should it be cleaned?
9. How should a new surface be prepared? Primed?
10. How should paint be applied?
11. What causes blistering? Crawling? Alligatoring? Peeling?
12. How may old paint be removed?
13. How should repainting be done?
14. What are whitewashing and calcimining?
15. What precautions should be observed in painting metals?
16. What are the advantages of wood preservatives, and how should they be used?

SELECTING AND USING PAINTS AND PAINT BRUSHES

Safety Precautions—Paints, varnishes, and lacquers may be fire hazards, and may poison a user of them. When paints are used, adequate ventilation should be maintained because the volatile ingredients such as turpentine and acetates are toxic. The use of chemicals to remove paints from the skin may cause a rash, or a chapping of the skin. Before eating or drinking, persons using paint should thoroughly clean their hands with solvents and with soap and water. Paints containing lead, mercury, and chromates are poisonous when taken into the system. When spray painting is done, wearing a suitable respirator will help prevent poisoning.

Importance of a Knowledge of Painting—A knowledge of paints and painting is important because paint is used for decorating and for protecting such surfaces as wood, metal, and masonry. There are many different kinds of paints, and a knowledge of paint ingredients is necessary to select paints intelligently. The durability of paints depends to a large degree upon how they are applied; therefore, a knowledge of how to apply paint is very important. In buying paint the amounts needed are estimated. Consequently, an understanding of how to figure the quantity of paint required for a job is essential.

It is poor economy to wait until buildings are badly in need of paint before painting. Buildings will require less paint and last longer if a good covering of paint is continuously maintained on them.

Common Kinds of Paint—There are numerous kinds of paint on the market, each manufactured for a given purpose. Different types of paint are required for wood, metal, concrete, and masonry surfaces. In selecting paint it is advisable to choose the kind that is suited for the use intended.

The common kinds of paint used on farms and in nonfarm agricultural businesses are:

1. Outside paint
2. Interior flat finish paint
3. Enamel paint, which is used chiefly for interior woodwork and furniture
4. Floor paint
5. Metal paint
6. Roof paint
7. Concrete and masonry paint

Additional information regarding paints may be secured from paint stores.

Ingredients Found in Paint—Paint is composed of a pigment and a vehicle. Linseed oil is often used as the vehicle in high-quality oil base paints. It acts as a material for binding the pigment particles together to form a paint film. Linseed oil may be "raw" or "boiled." If boiled linseed oil is used, a drier is not added to the paint. Boiled oil has been heated, and certain chemicals have been added which hasten drying. It is usually darker in color than "raw" oil.

In purchasing linseed oil, be sure it is in the original container sealed at the factory. This prevents the substitution of an inferior grade of oil.

Pigment is composed of the solid, finely divided particles of the paint such as white lead, zinc oxide, and titanium dioxide.

In oil base paints, turpentine may be added to thin the paint, to make it penetrate better, and to make it dry more quickly. It may also improve the spreading qualities of the paint, but when used it reduces the thickness of the paint film.

Extenders add bulk and cheapen the cost of manufacturing paint. They have very little hiding power, and they lessen the durability of the paint film. The following is a partial list of ingredients known as extenders:[1]

[1]C. H. Van Vlack, "Selecting and Applying Paints," Iowa State University Extension Service Circular 261, p. 7.

1. Calcium carbonate (also known as whiting, chalk, or pulverized limestone)
2. Silica (also called siliceous matter, quartz, or sand)
3. Barium sulfate (barytes)
4. Calcium sulfate
5. Magnesium silicate (talc, china clay, or soapstone)

Liquid drier is a chemical that may be added to raw linseed oil to hasten drying. Boiled linseed oil contains a drier.

Latex Paints—Latex paints are becoming more popular and are used as both interior and exterior paints. Modern paint chemistry has made it possible for paint manufacturers to produce latex paints that will compete successfully with oil paints, and they are usually considered to be easier to apply.

Synthetic latex paints are of two types: the latex-solution type and the latex-emulsion type. In the latex-solution type, the synthetic latex is emulsified so that it mixes with water.

The following discussion will refer to latex paint that has water added as a vehicle. Latex paint that mixes with water is the type being used primarily in agriculture. An important advantage of latex paint that mixes with water is the ease with which paint brushes, rollers, and sprayers may be cleaned. They may be cleaned with water or with water and detergents.

Latex paints may be made with polyvinyl acetates or with acrylics. The acrylic latex paints are often more expensive. However, the acrylic latex paints are considered to be superior for certain surfaces such as wood, with alternating hard and soft layers, and cement surfaces. For concrete surfaces that contain salts, the acrylics are often superior in covering the salts that emerge on the surface.

Latex paint has had a wetting agent added. This wetting agent causes the paint to foam. Care must be taken to select latex paints that do not foam excessively, because this makes their use more difficult.

Latex paints should also be selected that have a bactericide and a fungicide added. The bactericide is needed to combat the growth of bacteria that will break down and destroy the paint. A fungicide is needed to prevent mildew, especially if the paint is used on exterior surfaces.

An antifreeze additive is needed if the paint is to be stored in freezing conditions. An antirust additive is needed to prevent the rusting of the can.

Characteristics of Latex Paints—A very desirable characteristic of latex paint is the ease of cleaning painting equipment. It has excellent brushability but should be flowed on and not brushed out too much. If brushed out, the coat of resin will be too thin. It is easy to apply too thin a covering of latex paint.

Latex has a mild odor compared to oil paint and is preferred by many painters because of its mild odor. It dries rapidly, which is often an advantage, in a temperature range of from 50 to 90 degrees Fahrenheit. It should not be applied when the temperature is below 50 degrees Fahrenheit.

If applied properly, flowed on, it provides a good film, but often not as heavy a film as oil paints. With improper application it is possible to obtain a film that is too thin. An advantage of latex paint is its safeness. It gives excellent results on both wood and concrete. It gives excellent service under normal exposure. It gives fair service under marine exposure, and it is not recommended for use under corrosive exposure conditions.

Latex paints provide excellent initial color. They do not yellow, and their fade resistance is excellent. Their hardness and adhesion abilities are usually rated as excellent.

Latex paints are rated as good resistors of abrasion, detergents, acids, alkalies, strong solvents, and heat. They are rated fair in their resistance to water. They have a high moisture permeability rating, which may be an important advantage in many situations.

In selecting latex paints, remember that in good paints, 14 to 15 per cent of the volume is water. It is easy to reduce the cost of the paint by increasing the percentage of water. However, this decreases the thickness or consistency of the paint, which makes it more difficult to apply and decreases the area a gallon of paint will cover.

Cement-Water Paints—Cement-water paints are used on masonry surfaces. The binder for these paints is cement. They may be safely used on porous, masonry walls or walls that are subject to dampness. The film of cement-water paint is hard, strong, and brittle. It has a tendency to develop fine checks.

Cement-water paints weather by erosion. They have good decorative qualities and may be tinted various colors. They are applied with a stiff brush and "scrubbed" onto the surface.

Aluminum Paint—Aluminum paint is made by mixing an aluminum powder in a spar varnish. Metal surfaces should be painted with a rust-inhibitive paint such as red lead or blue lead before aluminum paint is applied.

Aluminum paint is used to stop the bleeding through of creosote or red paint. It is also used as a priming coat for resinous woods. It is often used as an interior moisture barrier. However, aluminum paint is not a "cure-all" for paint failures caused by moisture's getting behind the paint film.

The cost of aluminum paint is usually greater than the cost of a good grade of white paint.

Metallic Zinc—Metallic zinc is a rust-inhibitive metal paint. Other types of rust-inhibitive paints are red and blue leads, asphalt, and zinc chromate. For rusty roofs, metallic zinc paint is the most satisfactory of the rust-inhibitive paints.

Two coats of a metallic zinc paint will provide a coating equivalent to the galvanizing found on new galvanized roofing sheets. Two coats will last 12 or more years. One coat over rust will last 5 or 6 years.

Metallic zinc paint may be brushed or sprayed. Surfaces should be dry and clean when the paint is applied.

Whitewashing—Common whitewash may be made by adding water to hydrated lime. Whitewash is often used for basement walls, sheds, and dairy barns. Whitewash provides a white coat to surfaces, but it is not very durable. It also may be used as a carrier of disinfectant. Following is a formula for whitewash which is more durable than common whitewash:

38 pounds of quicklime, slaked (strain the paste while thick through a wire fly screen).
4 gallons of hot water (stir vigorously).
12 pounds of salt } (dissolve in 4 gallons of hot water).
6 ounces of alum }
1 quart of molasses (added to above).

Thoroughly mix all ingredients together and thin with water. If a disinfectant is desired, add 1 to 2 quarts of crude carbolic acid to the whitewash.

Calcimining—Calcimine is a mixture of such ingredients as whiting, china clay, and glue. Calcimining is one of the cheapest methods of finishing inside walls, but the finish is less permanent than paint because it cannot be washed. Calcimine can be purchased as a powder ready to be mixed with water. Generally it should be mixed the night before it is used. The directions for mixing, as given on the box, should be followed. It should be spread on a wall with a large brush, and with rapid strokes. Make sure that all the surface is well covered. A coat of sizing should be applied to a wall before it is calcimined.

Selecting Paint—There are a number of factors to consider before buying exterior paint, such as:

1. *Opacity* or hiding power, ability to cover the surface.
2. *Durability.* Since three-fourths of the cost of a paint job is labor, a durable paint should be used. It is the cheapest in the long run.
3. *Painting Surface.* Will the paint film fail by peeling, cracking, scaling, or alligatoring? (See Figs. 11.6 to 11.9.)
4. *Bulking of Pigments.* Some pigments such as calcium carbonate (limestone) and magnesium silicate cost considerably less than high-quality pigments.

Before purchasing exterior paint, study the formulas on different can labels to determine the composition of the paints. High-grade white or tinted exterior paints should not contain more than a total of 10 per cent of the extenders such as calcium carbonate, magnesium silicate, and silica.

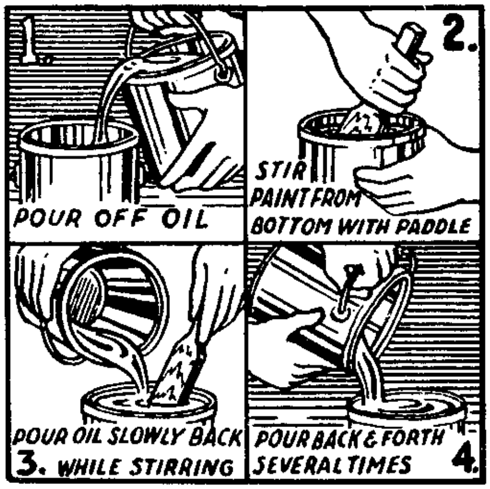
Examine the formula labels on paint cans and purchase only a high-quality, durable paint made by a reliable manufacturer and sold by an established dealer. It often requires more time to apply a low-grade paint than one of a higher quality. Low-grade paint often cracks or peels, leaving an expensive job of surface preparation before repainting.

Number of Square Feet a Gallon of Paint Covers—If a factory-prepared paint is used, the recommendations of the manufacturer should be consulted regarding the number of square feet a gallon of that company's paint will cover. Rough surfaces require more paint than smooth surfaces.

Number of Coats to Apply—In painting new wood, apply three coats. The first coat should be a thin, penetrating, priming coat, the second a body coat, and the third a finish coat. Three thin coats of paint are much more desirable than one coat of paint which produces a film of the same thickness as the three coats. Thick paint will not penetrate the wood properly, and it is difficult to spread evenly. Two coats of paint are sufficient on surfaces which have been painted previously and on surfaces where the old paint is in good condition.

Mixing Oil Paints—It is very important for paint to be mixed properly before it is applied. A portable electric drill with a paint-stirring attachment is a very useful tool for this purpose. In mixing oil base paint, follow these steps:

1. Pour off part of the liquid.
2. Stir the remaining liquid and paste until it is free from lumps and is of uniform texture.
3. Pour oil slowly back while stirring the mixture.
4. Pour the mixture back and forth from one container to another until all the paint is of a uniform color and consistency.
5. Follow the directions on the container as to the amount of thinner to use. When a thinner is used, only a small amount should be added at a time, and it should be thoroughly mixed with the paint before more thinner is added.

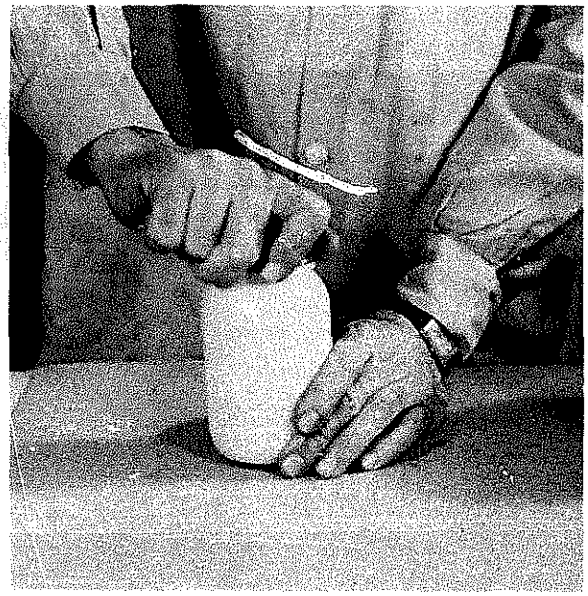


(Courtesy Lead Industries Association)

Fig. 11.1. Factory-prepared paints should be thoroughly mixed before they are applied.

Skins in Paint—When paint is left in a closed container which is not completely full or when it is left in an open container for some time, a scum-like covering forms over the top. This scum is known as skin. It may be removed after it is cut loose from around the inner edges of a container. If paint is stirred before the skin is removed, it will break into small pieces and become mixed with the paint. Small particles of skin in paint may be removed by straining the paint through a cheesecloth or screen wire. Skin, however, will not form on paint that is properly stored.

Storing Paint—To prevent the formation of skin on paint, fill containers completely and seal them tightly. The formation of skin may also be avoided by sealing a partially full container and turning it upside down.



(Courtesy Lead Industries Association)

Fig. 11.2. To prevent the formation of skin on leftover paint, turn the container upside down or fill the container completely and seal it tightly.

Selecting and Cleaning Brushes—Good brushes of the correct size and construction are necessary for good work. A 3½- to 4-inch brush is usually the best size of brush for painting large surfaces. Brushes 2 to 2½ inches wide are suitable for small surfaces, while 1- to 1½-inch brushes are needed for narrow surfaces.

A good paint brush is expensive. Bargain-priced paint brushes usually lack the qualities desired in a good paint brush. A good brush has a metal ferrule, ring, or cap, securing the bristles which are anchored in a tough material, such as rubber, to the handle. The metal ferrule should be nailed to the handle.

The bristles should "toe-in," forming a wedge shape. When the brush is pressed on a smooth surface, the edge of the brush should be even and sharp. Open the bristles and check the "heel" of the brush. Good brushes have two base plugs instead of one. Check the bristles. They should be springy. Pull on the bristles. They should not come out. Check whether or not the brush has a mixture of long and short bristles. It should have. Check individual bristles to determine whether or not the ends are split or frayed. They should be.

Good brushes have hair bristles or nylon bristles. The hair bristles are superior for oil paints. They will take up more paint than nylon bristles. With latex paints, nylon bristles are satisfactory.

The following procedure for cleaning brushes is recommended:

1. Clean excess paint from the brush by wiping it over the edge of the paint paddle. Avoid wiping it over the edge of the bucket, as this may cause paint to run down the outside of the bucket.
2. Wipe any remaining excess paint from the brush with a cloth or piece of paper.

(Courtesy Lead Industries Association)

Fig. 11.3. After cleaning a paint brush, remove the liquid in the brush by twirling the handle between your hands.

3. Clean oil paint, enamel, or varnish brushes in turpentine. Mineral spirits may be used for cleaing oil-paint brushes. Brushes used to apply water-soluble latex paints may be cleaned with water.
4. Whip out liquid by whirling the handle between hands, keeping the bristles inside the container. (See Fig. 11.3.)
5. Remove the brush from the container and place it in a paper wrapper to keep the bristles clean and wedge-shaped. (See Fig. 11.4.)
6. Fasten the wrapper in place with a rubber band or string, and lay the brush flat to keep the bristles straight. (See Fig. 11.4.)

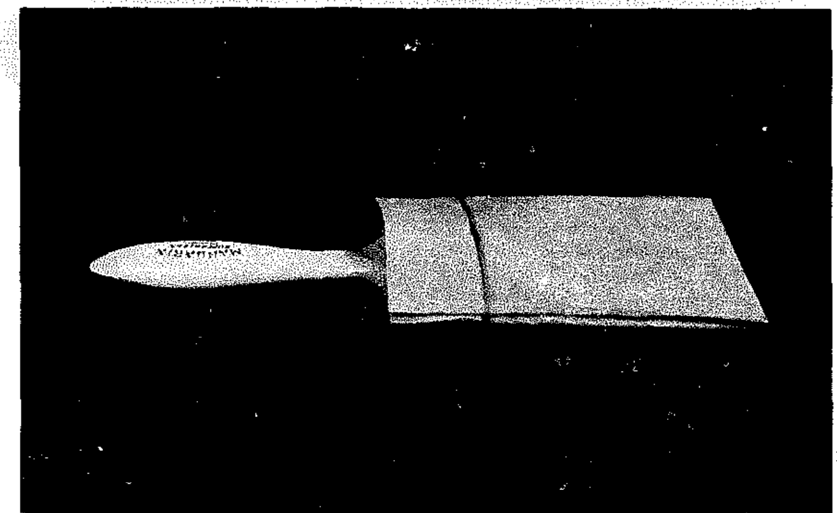
A brush should always be cleaned immediately after the painting job is finished, because it can then be cleaned easily. A clean brush is always ready for immediate use. To redeem old, hard brushes, soak them in a lacquer thinner, which will often dissolve the dried paint. Lacquer brushes should be cleaned with a lacquer thinner, preferably a thinner made by the manufacturer of the lacquer used. Shellac or alcohol stain brushes should be cleaned in alcohol.

Applying Paint

Paint may be applied by brushing, dipping, rolling, or spraying. It may be applied with a regular brush, or with a sponge or a sponge-type applicator.

Brushing—When using a brush, follow these procedures:

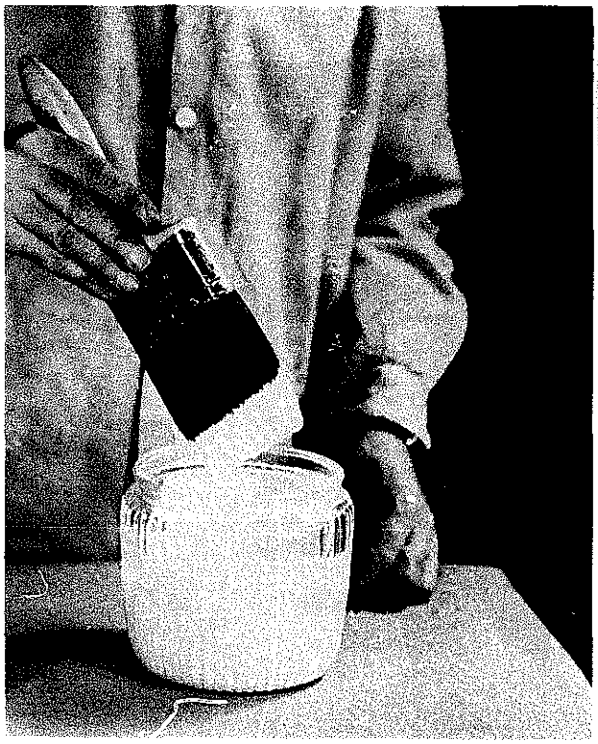
1. When painting floors and breast-high vertical surfaces, hold the brush between the thumb and forefinger similar to the way a pencil is held. The position of the brush in the hand should be changed to suit the positions necessary in painting. Hold the brush lightly, keeping the arm and wrist muscles relaxed to avoid fatigue.



(Courtesy Lead Industries Association)

Fig. 11.4. After a brush has been thoroughly cleaned, wrap it in heavy paper as illustrated to keep the bristles clean and wedge-shaped. Store the brush on a flat surface to keep the bristles in their proper position.

2. Dip the brush into the paint about one-third the length of the bristles.
3. After dipping, tap the brush gently against the inside surface of the container to remove the excess paint. Avoid rubbing the bristles over the edge of the container. This causes paint to run down the outside of the container.
4. First paint the edges of the trim.
5. Do not redip the brush in the paint until the paint in the brush has been used.
6. Begin at the highest point to be painted and work downward.
7. Apply the paint with the grain, when painting wood.
8. Brush out well to prevent brush marks. Any paint which is accidentally dropped, soiling the surface below, should be removed with a clean cloth



(Courtesy Lead Industries Association)

Fig. 11.5. In painting, dip the brush in the paint about one-third the length of the bristles.

wet with turpentine for oil base paint and with water for a latex base paint.

9. Do not carry more than 1 to 2 quarts of paint at a time.

Rolling—Paint rollers are handy for applying paint. Rollers can be used with most types of paint, but latex paints are more easily applied with rollers than some of the other types.

Rollers with long handles are used to paint the exterior of buildings. A long-handled roller can be used to reach high points that are difficult to reach with a brush.

The speed of painting is greater with a roller than it is with a brush. Rollers are of two types: the fill type and the dip type. The fill type of roller is handy, but it is more difficult to clean. In using a roller, do not roll fast. If a roller is rolled fast, the paint film will not be even because bubbles will be produced.

Spraying—Spray painting saves about two-thirds of the labor required to brush paint. The equipment for spray painting is considerably more expensive than the equipment for brush painting, but the saving in labor will pay for the equipment if there is much painting to be done. A spray gun, if used correctly, will apply either a thin or a thick coat of paint more evenly than it can be applied with a brush.

The tools required for spray painting are:

1. Spray gun. A spray gun may be of the suction type or of the pressure type. The pressure-type gun is usually considered to be superior to the suction-type gun.
2. Material pressure tanks.
3. Hose lines.
4. Air compressor.

In spray painting, the spray gun is held at right angles to the surface being painted. The distance to hold the gun from the surface depends on the type of paint being used. The distance most frequently used is from 8 to 10 inches. An operator of a spray gun should experiment to determine the best distance to hold the gun when using different kinds of paint.

In order to keep the gun at right angles to the surface being painted, the entire arm and body should be moved with the gun. Failure to move the entire arm and body with the sweep of the gun will cause the distance of the gun from the surface being painted to vary.

Not holding a spray gun at a right angle and at the same distance from the surface being painted will produce "patchiness" and an uneven coat of paint. When the gun is held at an angle of less than 90 degrees, the surface nearest to the gun is flooded with paint and the surface farthest from the gun is insufficiently covered. The surface that is flooded may sag or run.

Failure to hold a spray gun at a 90-degree angle to a surface being painted is caused by a pivoting at the end of a sweep or by a twisting of the wrist. Holding a gun at an angle to the surface of less than 90 degrees also increases the paint mist in the air, which increases the amount of paint used. A beginner may have difficulty keeping the gun the same distance from the surface when it is directly in front of the body as it is at the ends of the sweeps.

Manufacturers have developed several different nozzles for use with the various kinds of paints. For best results the correct nozzle for the type of paint being used should be secured. Adjustment of the nozzle to produce a wide fan spray gives the best results when walls are being painted. A round cone spray is best for small articles.

If the nozzle of a spray gun becomes clogged, a split or distorted spray is produced. To prevent this, clean the nozzle with the thinner recommended for the type of paint being used. A discarded toothbrush makes a good brush for cleaning nozzles.

The trigger on most spray guns must be pulled back completely to release both air and paint. When the trigger is pulled back only part way, air alone is released. The air alone can be used to clean the surface to be painted. Pull the trigger back completely when ready to paint so that there will be a proper mixture of air and paint from the start. Release the trigger promptly at the end of a stroke to prevent oblique painting angles and to avoid the waste of paint.

The pressure to use in spray painting depends on the type and kind of paint being used. When spray painting, regulate the pressure until a steady spray stream is produced.

Spray equipment needs to be cleaned thoroughly, carefully, and completely after it has been used, or it will not work the next time. For oil base paints, a thinner may be used to clean the equipment. A suction gun may be cleaned by pouring out the paint and partially filling the gun with the thinner. The thinner may also be forced around in the gun by closing with the fingers, simultaneously and repeatedly, the tip of the nozzle and one of the air intakes.

If work is stopped for only a short time, the nozzle of the spray gun should be removed and cleaned.

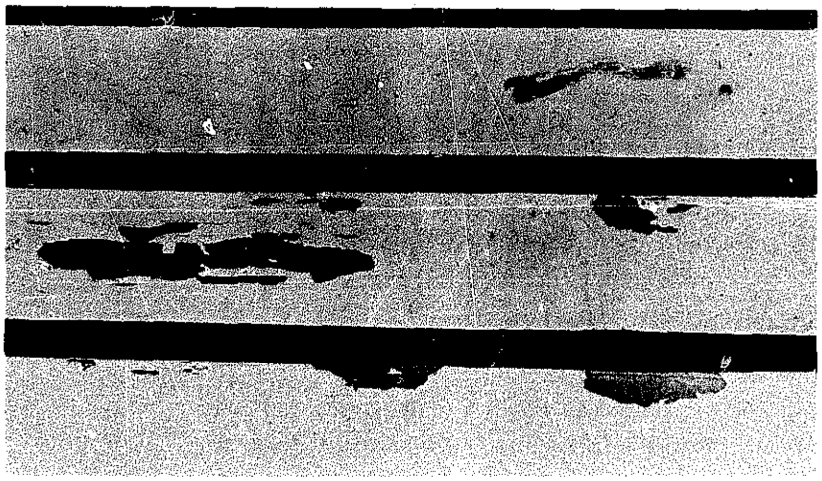
A spray gun should not be left immersed in thinner or water for long periods of time, because the thinner or water may be injurious to the gun.

A spray gun is especially useful for painting farm machinery. The pressure of the spray forces the paint into parts of a machine that are almost impossible to paint with a brush.

Avoiding Paint Failures

Time to Paint—Many paint failures result because the paint was applied when the weather was too cold or too wet. For best results do not paint during wet, foggy weather. Also, do not paint too early in the spring or too late in the fall when the weather is cold, or cold and wet. The temperature should be 65 degrees or higher for painting. It is not advisable to paint surfaces while they are in the direct sunlight. Do not apply a second coat of paint until the first coat is dry. Do not paint too early in the morning or too late in the day, when the surface being painted is moist with dew.

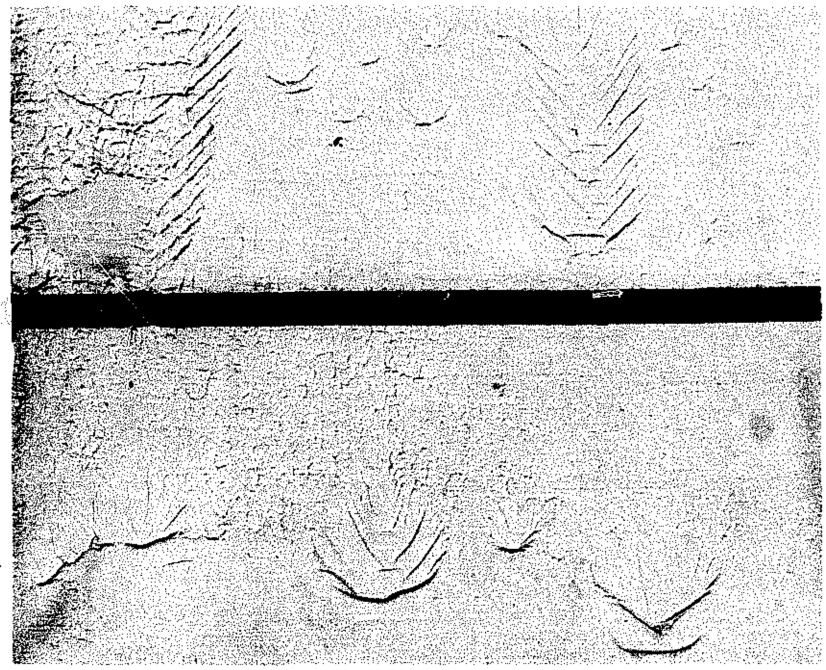
Blistering and Crawling—When paint is applied to a surface containing moisture, it may blister. (See Fig. 11.6.) Blistering may also be caused by heat. The



(Courtesy Lead Industries Association)

Fig. 11.6. The most common cause of blistering is moisture, which comes through the wall in back of the paint film. Peeling naturally follows blistering. Blistering may be prevented by providing ventilation within the walls or by lowering the humidity within the building.

sun will sometimes cause newly painted surfaces to blister. Crawling is the wrinkling or "running and sagging" of the paint film soon after the paint is applied. It often occurs when paint is applied over glossy, greasy, or cold surfaces. (See Fig. 11.7.) If oil base paint has a tendency to "crawl" when being applied, add 1 tablespoonful of ammonia per gallon of paint.

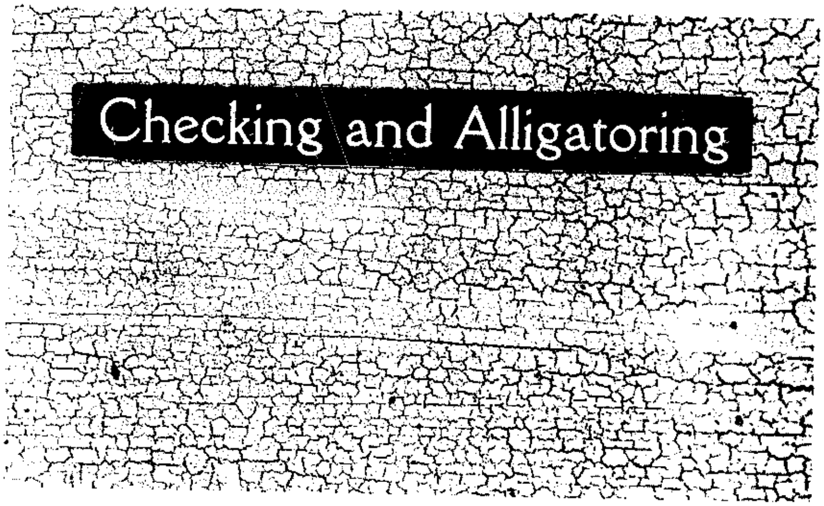


(Courtesy Lead Industries Association)

Fig. 11.7. Running and sagging may occur when the paint contains too much oil or when it is applied too thickly. Any condition which retards drying, such as painting in cool weather or late in the evening, may cause this defect. When painting is done in the late afternoon or in cool weather, the addition of a small amount of turpentine in an oil base paint will cause the paint to set more quickly.

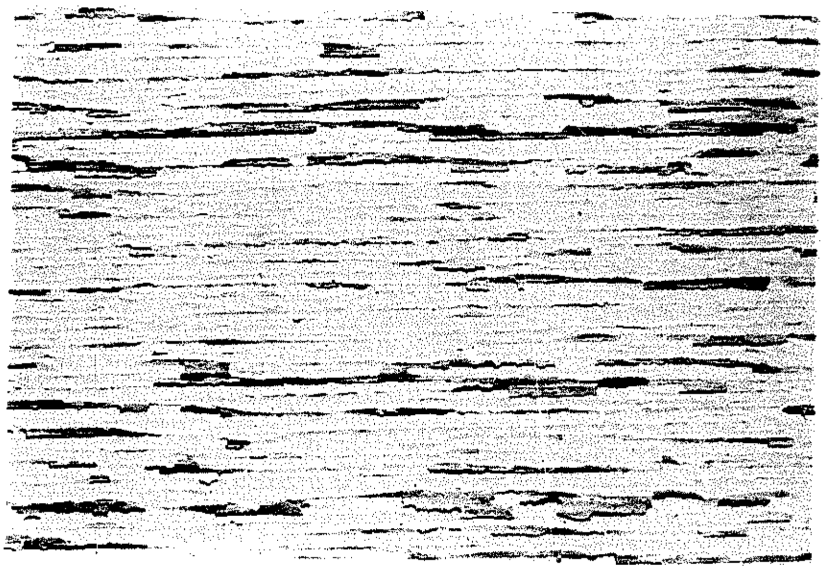
Preparing and Priming a New Surface—In preparing new wood surfaces for painting, it is important for the wood to be dry and clean. If grease is present, it should be removed with a cleaning compound. Wood should not be painted when damp. If the wood has been exposed to rain, it should not be painted until it is thoroughly dry. Wood should be primed with a thin coat of paint. Otherwise, difficulty may be experienced with the paint cracking, peeling, or scaling. The following procedure for preparing and priming the surface of new wood is suggested:

1. Clean, smooth, and prepare the surface.
2. Apply the priming coat of paint, brushing it out well.
3. Cover the knots and pitch streaks with shellac thinned with an equal amount of denatured alcohol after the priming coat is dry. The shellac seals all pores and prevents pitch from coming through the paint.
4. Putty all holes and cracks after the surface is primed.



(Courtesy Lead Industries Association)

Fig. 11.8. Alligatoring may result when a hard-drying coat of paint is applied over a soft undercoat. Alligatoring may also be an indication that inferior or slow-drying oils have been substituted for linseed oil. If a smooth finish is desired, the old paint must be removed from the alligatored surface before it is repainted.



(Courtesy Lead Industries Association)

Fig. 11.9. Wood expands and contracts with the changes in moisture content of the wood. Cracking is a defect caused by the use of paints that contain pigments and oils that form hard, brittle paint films. Such paint cannot stretch and shrink with the expansion and contraction of the wood, so the paint film breaks and allows water to get into the wood under the paint, which causes scaling and flaking.

More paint is required for the priming coat than for the succeeding coats, because more paint is needed to fill the pores in the wood.

Removing Old Paint—Old paint may be removed by either of the following methods:

1. By using a liquid paint remover, which is satisfactory, but rather expensive.
2. By using a propane torch, a putty knife, and a scraper or sandpaper.

Repainting—When repainting is done, the following procedure is recommended:

1. If the old paint is not badly checked, prepare the surface by dusting, washing, and sanding.
2. If the paint is badly cracked, remove it before applying the new paint. All loose, scaling paint should be removed with a hand scraper, putty knife, or wire brush.
3. Replace broken boards and repair all damaged woodwork.
4. Do any reglazing necessary.
5. Tighten all bolts or screws on hinges and other hardware.
6. Scrape or brush all rust scales from metal surfaces, and prime them with a suitable rust-resistant paint.
7. Sand or wash glossy surfaces with a solution of ½ pound sal soda to each gallon of water.

Painting Metal

Painting increases the life and improves the appearance of farm machinery, metal roofs, and other metal objects found on a farm or in a nonfarm agricultural business. Special precautions must be taken in painting metal, however. A special rust-inhibiting primer coat is required to stop rust. Ordinary paint will not inhibit the formation of rust. Rust-inhibiting paints of the following types must be used: (1) metallic zinc, (2) red lead, (3) blue lead, or (4) zinc chromate.

Before a rust-inhibiting primer coat is applied to metal, all dirt, grease, and rust should be removed. A steam cleaning machine may be used for this job. If a steam cleaning machine is not available, the grease, dirt, and rust may be removed with a safe solvent sold by most oil companies. Do not use gasoline. A wire brush, a scraper, or sandpaper may be used to remove rust from metals that are rusted badly.

When applying a rust-inhibiting primer coat to metal, be sure that the paint gets into all the cracks, crevices, and seams, and around the bolts, because these are the places where rusting often starts. A rust-inhibiting metal paint may also be used as the primer coat for wooden parts of metal objects. If a finish coat is used, spraying is often an easy method of application.

Painting Galvanized Roofing

Galvanized roofs rust after a few years but may be protected if painted properly. Painting experiments have shown that the best protection is achieved by painting with a first coat of rust-inhibiting paint and a second coat of aluminum paint prepared for use on metals. Equally good is a first coat of gray metallic zinc paint and a second coat of aluminum paint prepared for use on metals.

The less rust on galvanized roofs before painting, the longer the paint job will last. Wire brushing a rusty roof does not seem to increase the life of a paint job.

Wood Preservatives

Wood preservatives are very popular. Preservatives such as pentachlorophenol (penta) protect wood from rot, fungi, and termites, and repel moisture. Wood preservatives are easy to apply and are relatively cheap. They are often used to preserve fence posts, wooden runners on portable agricultural buildings, wagon box floors, and so forth. They are superior to paint for certain situations because there is no blistering, peeling, or cracking.

They may be applied with a brush, or the wood being treated may be soaked in the preservative. Wood that has been pressure treated with a wood preservative is often available from lumber companies. Pressure treating of wood with a wood preservative is the best method of application, but it cannot be done on the job.

Several types of wood preservatives are used. The two main types are (1) oil-soluble preservatives and (2) water-soluble preservatives. The oil-soluble preservatives are usually preferred by farmers and nonfarm agricultural workers, the most popular ones being penta, coal tar creosote, and copper naphthenate. Penta is a popular wood preservative because it does a good job of preserving wood, it does not "bleed" like creosote when painted, and it is easily obtained.

Some types of wood preservatives are toxic and should not be used for feed troughs and so forth. Wood treated with creosote cannot be painted later. Paint may be used on wood that has been treated with penta or copper naphthenate.

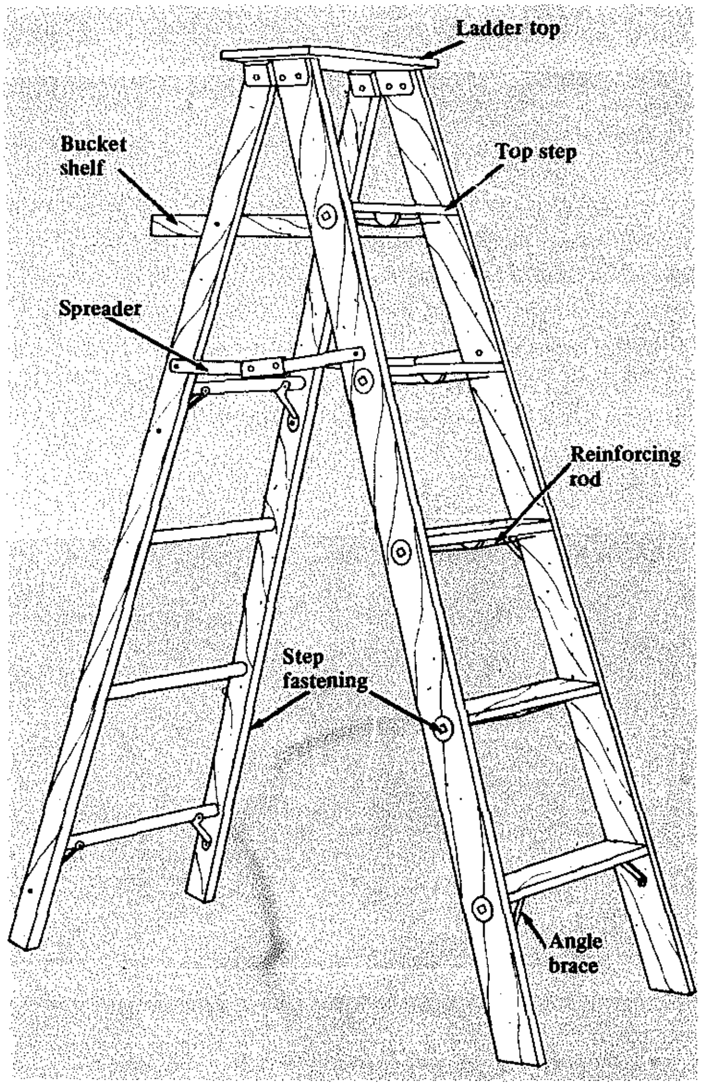
Ladders

Ladders have many uses on farms and in agricultural businesses. One of the uses is in painting. In purchasing a ladder, consider strength, durability, safety, and use as well as price. A metal ladder, for example, that lacks strength and is not sufficiently rigid is not safe and is a poor buy at any price. In purchasing a ladder, look to see whether or not it has the seal of approval of the American National Standards Institute (ANSI) or the Underwriters' Laboratories (UL).

Wood Ladders—Wood ladders are preferred by some because of their sturdiness. They often do not bend as much as metal or fiberglass ladders. However, they are heavier than metal ladders and are, therefore, often harder to handle. Wood ladders are durable and will last a long time if protected from moisture and sunlight. If left unprotected, they may be weakened by insects or by rot. They may also split or crack as a result of the action of the sun and rain. If weakened by any of these actions, they may break and be unsafe. Wood ladders should not be painted, because the paint hides weaknesses that may be unsafe.

Metal Ladders—Substantial, safe metal ladders are often more expensive to purchase than wood ladders. However, they will last longer than wood ladders. The aluminum and magnesium ladders have an advantage of being light in weight. Because of the safety factor, metal ladders should not be used around electrical cables.

There are several types of ladders such as step ladders, platform ladders, and extension ladders.



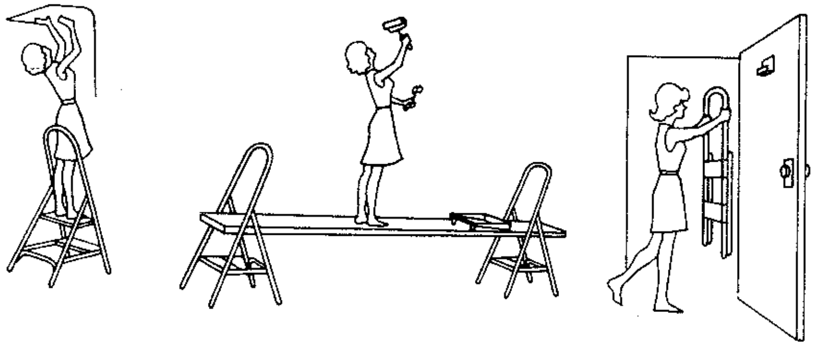
(Courtesy U.S. General Services Administration)

Fig. 11.10. Parts of a step ladder.

Step Ladders—A step ladder is portable and self-supporting, but its length is not adjustable. A step ladder's length is measured by the distance from the bottom to the top of the front side of the side rails. Step ladders are often used in painting and other low jobs where a self-supporting ladder is needed.

The steps of a step ladder should be flat and parallel when opened, and the distance between steps should be no more than 12 inches. The steps should be a minimum of 3½ inches wide. (See Fig. 11.10.)

Platform Ladders—The platform ladder is closely related to the step ladder and may often be used in agriculture. A platform ladder is easy to store, and two platform ladders may be used to form a low platform for painting and other work. (See Fig. 11.11.)



(Courtesy U.S. General Services Administration)

Fig. 11.11. Some of the uses of platform ladders.

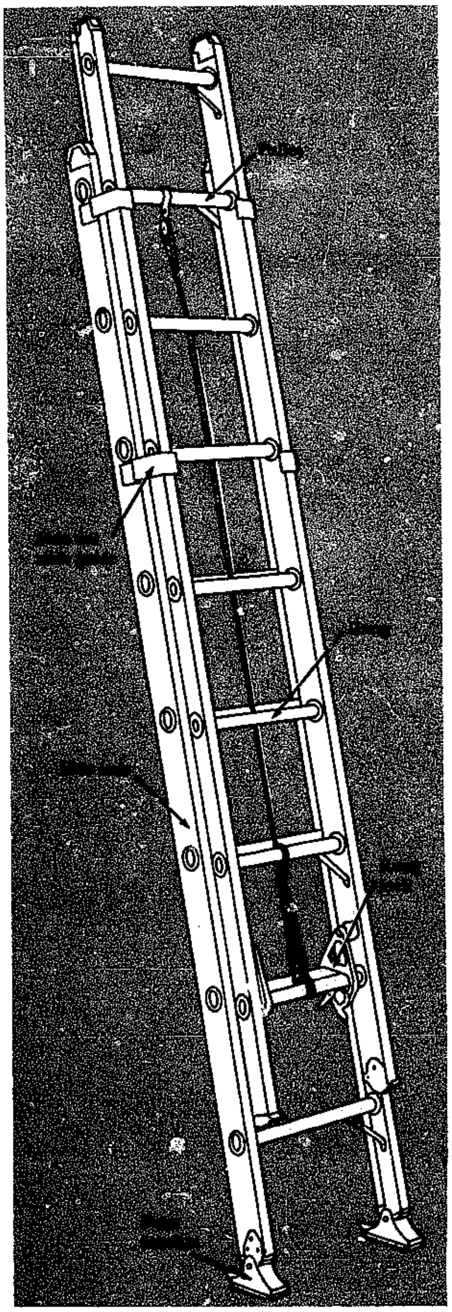
Extension Ladders—An extension ladder is a straight ladder that is adjustable in length. Its size is its extended length. (See Fig. 11.12.)

An extension ladder should be equipped with positive stops to prevent it from being extended too far. A 36-foot extension ladder should have a 3-foot overlap when fully extended. A 48-foot ladder should have a 4-foot overlap, and a 60-foot ladder should have a 5-foot overlap.

An extension ladder needs to be considerably longer than the height to be reached. For example, a 36-foot ladder is needed to reach a height of 29 feet.

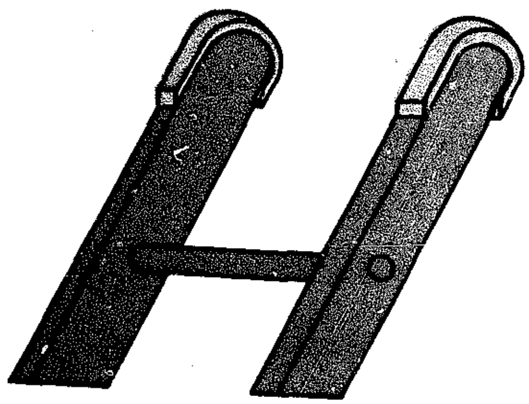
The feet of an extension ladder should have safety shoes to prevent slippage of the ladder at the bottom.

In setting up an extension ladder, place the lower end against a solid object. Then grasp the uppermost rung with both hands, raise the top of the ladder, and move forward under the ladder, grasping each rung as you proceed, until the ladder is upright. When you place the ladder against a wall, the bottom of the ladder should be one-fourth of its working length, not its total length, from the wall. Make certain that the ladder has a firm and level footing.



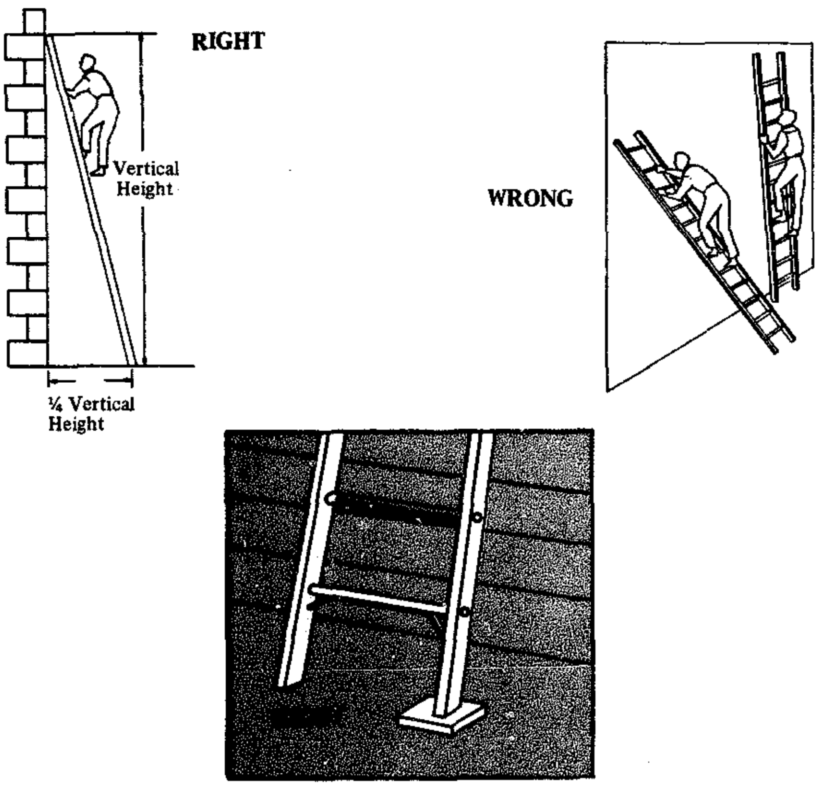
(Courtesy U.S. General Services Administration)

Fig. 11.12. Parts of an extension ladder.



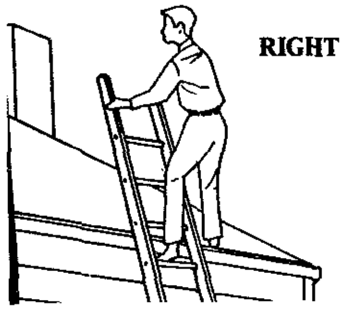
(Courtesy U.S. General Services Administration)

Fig. 11.13. Safety wall grips on top of a ladder.



(Courtesy U.S. General Services Administration)

Fig. 11.14. Right and wrong ways of using a ladder.



(Courtesy U.S. General Services Administration)

Fig. 11.15. The right way of getting off a ladder onto a roof.

CHAPTER 12

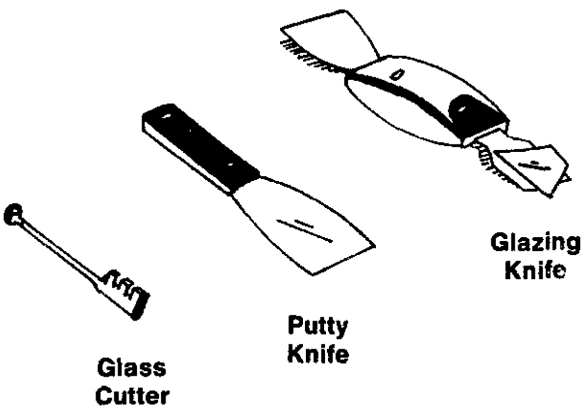
Glazing

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. How should glass be measured?
2. How should glass be cut?
3. How should a sash be prepared for glass? How should glass be fastened?
4. Why is glazing compound used?
5. How should glazing compound be applied?

Importance of Glazing—Windows of agricultural buildings frequently become broken and should be repaired. Glazing does not require a great amount of skill or equipment. Following is the equipment needed:

1. A smooth bench top
2. A framing square or straightedge
3. A glass cutter
4. A wax pencil or piece of soap
5. A putty knife
6. A chisel for removing glazing compound
7. A lead pencil and paper
8. A pair of pliers



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 12.1. Tools for glazing.

Glass may be purchased in single strength, which is $^1/_{12}$ to $^1/_{10}$ inch thick, or in double strength, which is $^1/_9$ to $^1/_8$ inch thick. Single-strength glass is generally used in small panes, while double-strength glass is best for large windows or in any place where considerable strength is needed. Triple-strength glass is also available.

Measuring Glass—Glass must be handled carefully to avoid breakage. It is very important to measure glass carefully so that it will fit properly after it is cut. The following procedure for measuring glass is recommended:

1. Lay out the desired measurements on a piece of paper.
2. Place the paper on a smooth surface and the glass to be cut over the paper so that the lines on the paper will show through.
3. Lay the glass with the concave side uppermost.
4. Mark the glass $^1/_{16}$ to $^1/_8$ inch smaller than the frame in which it is to be placed. This allows for small projections that may be on the edges of the frame.
5. Mark the glass with a wax pencil or a sharp piece of soap.

Cutting Glass—Care must be exercised in cutting glass; overwise breakage will result. The following procedure is recommended:

1. Wear safety glasses to protect eyes from glass chips or slivers.
2. Clean the glass of all dirt and grease.
3. Place the glass on a smooth surface or over several layers of newspaper.
4. Start cutting at the far edge.
5. Hold the cutter perpendicular to the glass, with the notched side leading in the direction of travel.

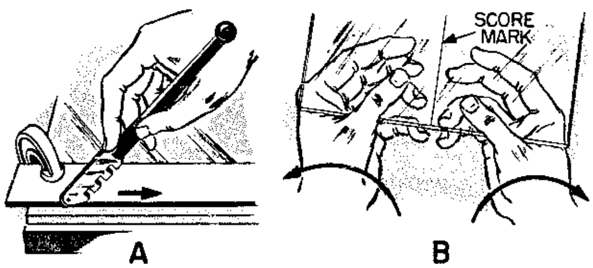


Fig. 12.2. Using a glass cutter.

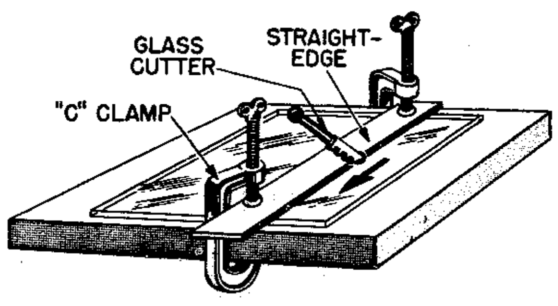
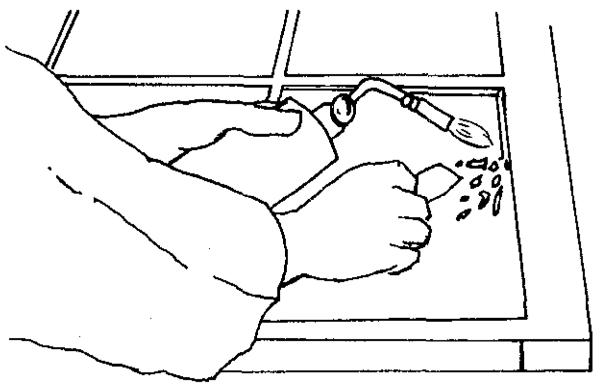


Fig. 12.3. Using a straightedge when cutting glass.

6. Press the cutter firmly and pull it along the straightedge toward you. One stroke across is enough. *Never go over a scratch the second time.* This damages the cutter and may cause the glass to break unevenly.
7. Place the glass over the edge of the bench so the scratch is slightly past the edge. Tip the projecting glass down slightly. Tap lightly directly under the scratch with the notched edge of the glass cutter. Start tapping at the center and work toward the edges.
8. Remove irregularities on the cut edges by chipping them off with the notches on the glass cutter.
9. Smooth the edges of the glass by filing.

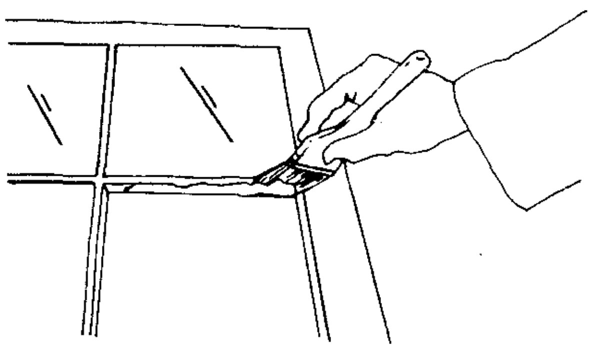
Preparing a Sash and Fitting Glass—Glass is held in a sash by glazier's points, which are triangular or diamond-shaped flanged pieces of galvanized metal. A sash should be prepared as follows before a glass is put into it:

1. Remove the old glazing compound with a putty knife or chisel, being careful not to chip away any of the wood of the sash. A propane torch



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 12.4. A propane torch may be used to soften the old glazing compound. Remove all of the old glazing compound. Use a pair of pliers to remove the glazier's points. Then remove the broken glass from the sash.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 12.5. After the old glazing compound, glazier's points, and glass have been removed, and after the rabbet has been smoothed, it is usually advisable to treat wooden frames with linseed oil or a primer coat of paint to reduce the absorption of the oil from the glazing compound.

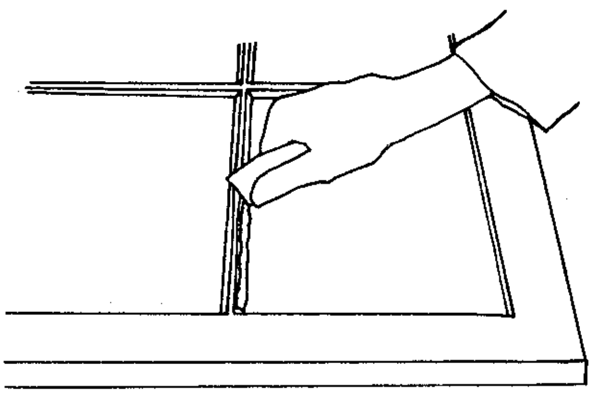
may be used to soften hardened glazing compound, if you are careful not to burn the wood frame.

2. Remove old glazier's points.
3. Remove broken glass.
4. Smooth both sides of the rabbet (the groove cut for the glass).
5. Give the rabbet a priming coat of paint or linseed oil.
6. Apply glazing compound to the rabbet, and put the glass in place.
7. Fasten the glass, using No. 1 or No. 2 glazier's points. Place the glazier's points 6 inches apart. Place points near the corners.
8. Drive glazier's points with a 1- or 1½-inch chisel. Hold the bevel of the chisel flat against the glass. A special tool for driving glazier's points is available.

Glazing Compound and Its Uses—Glazing compound seals the glass and the sash and makes a window weatherproof. It is also used for filling cracks, holes, and crevices in wood. It may be colored with either stain or paint to match the finish where it is used. Glazing compound, a chemically manufactured product, is rapidly replacing putty for glazing.

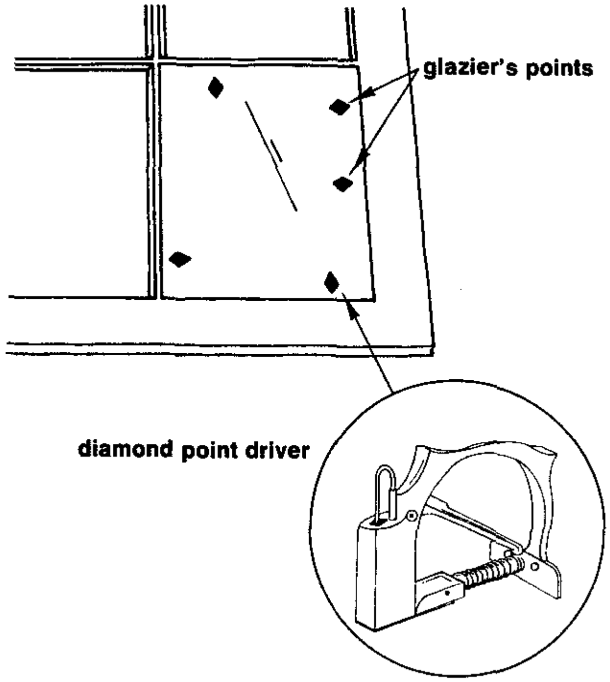
Applying Glazing Compound—Glazing compound should not be applied to bare wood, because the wood absorbs the oil in the glazing compound, leaving it dry. The surface of the wood should be painted, oiled, or shellacked before the glazing compound is applied. In applying it to glass, the following procedure is suggested:

1. Knead the glazing compound in the palm of the hand until it is soft and pliable.
2. Roll the glazing compound into a long pencil-like roll, and lay it over the glass along the rabbet.
3. Spread evenly and firmly with a putty knife, using sufficient glazing compound and smoothing a bevel from the glass to the top of the rabbet.
4. Wipe excess glazing compound from the glass and the sash.
5. Fill marred or damaged places in the rabbet with glazing compound.
6. Paint the sash after the glazing compound is thoroughly dry.



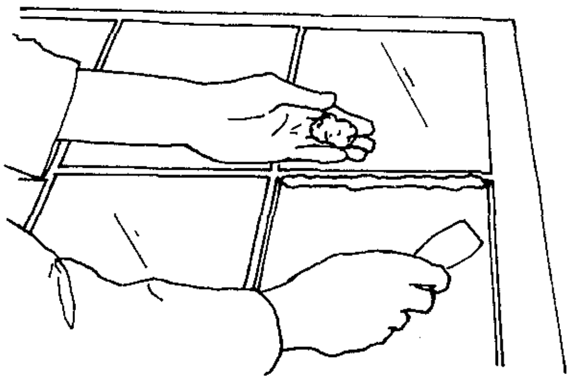
(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 12.6. After applying a coat of linseed oil or primer paint, apply a thin layer of glazing compound to the wood frame before inserting the new glass. This thin layer of glazing compound will seal and bed the glass in the frame.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 12.7. After the new glass has been placed in the frame, fasten it with two or three glazier's points per side.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 12.8. After the new glass has been installed, apply glazing compound to the depth of the frame.

WELDING

Student Abilities to Be Developed

1. Ability to appreciate the importance of arc, mig, tig, spot, and oxyacetylene welding.
2. Ability to use the proper safety precautions in welding.
3. Ability to select equipment for welding.
4. Ability to handle welding equipment.
5. Ability to perform the ordinary welding jobs on a farm and in a nonfarm agricultural business.
6. Ability to maintain welding equipment.

CHAPTER 13

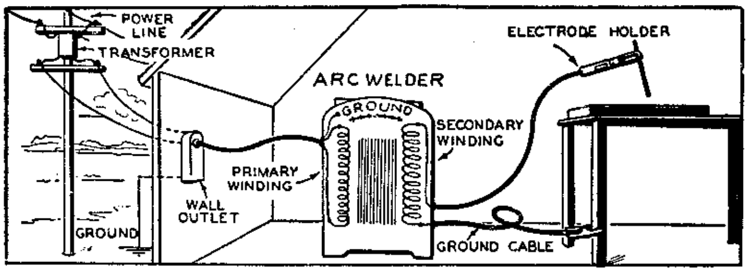
Welding with Electric Arc, Mig, Tig, and Spot Welders

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is electric arc welding? Mig welding? Tig welding? Spot welding?
2. What safety precautions should be observed in the various methods of welding?
3. What factors should be considered in selecting, installing, and maintaining arc welding equipment?
4. What is an electrode, and what determines the correct size and type of electrode to use?
5. How should parts be prepared for welding?
6. What are the essentials of running a good bead?
7. How should an electrode be weaved in welding?
8. What is padding, and how is it done?
9. What are the welding positions and the common kinds of joints and welds?
10. What procedures should be followed in making the various kinds of welds?
11. How can distortion be controlled?
12. How is an electric arc welder used for cutting metal?
13. What procedures are used in welding sheet metal, cast iron, and high-carbon steels?
14. How may different metals be identified?
15. What are the uses of a carbon arc torch?
16. How is brazing done?
17. How is hard facing done?
18. How is tig welding done?

ELECTRIC ARC WELDING

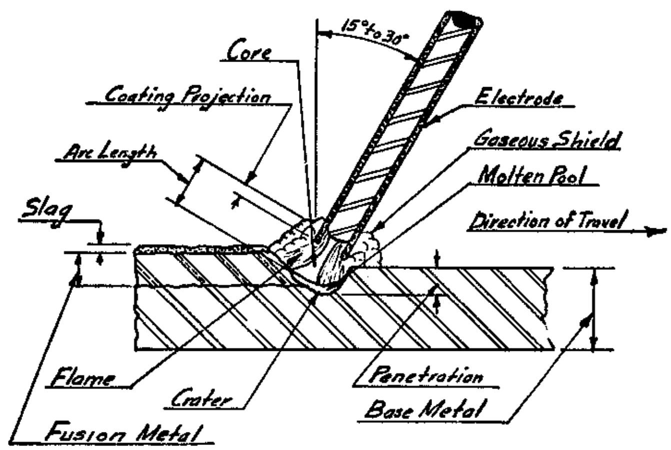
Meaning of Arc Welding—*Arc welding is a melting together of two pieces of* *metal, or a fusion process. The heat is obtained from an electric arc which is formed between a base metal and an electrode.* An electrode is shaped like a wire or rod and is held in an electrode holder, which is attached to an electric arc welder. When this electrode is properly brought into contact with the metal to be welded, an electric arc is formed. The heat of this arc, which is approximately 6,500 degrees Fahrenheit, fuses the metal being welded and melts the electrode or filler metal.



(Courtesy The Lincoln Electric Co.)

Fig. 13.1. The welder transforms power from the line to proper current for the arc.

Metallic Arc Welding—In metallic arc welding a metal electrode is used. This is the most common kind of arc welding done in agricultural mechanics. With the metallic arc it is possible to weld in any position, such as flat, horizontal, overhead, or vertical. Metallic arc welding often produces a weld which is stronger than the base metal.



(Courtesy Marquette Manufacturing Co., Minneapolis)

Fig. 13.2. A diagrammatic sketch showing metallic arc welding.

Carbon Arc Welding—The original arc welding process was done with a carbon arc. This process involves the use of a carbon electrode in a holder. The carbon electrode makes contact with the base metal to form an arc flame. A filler

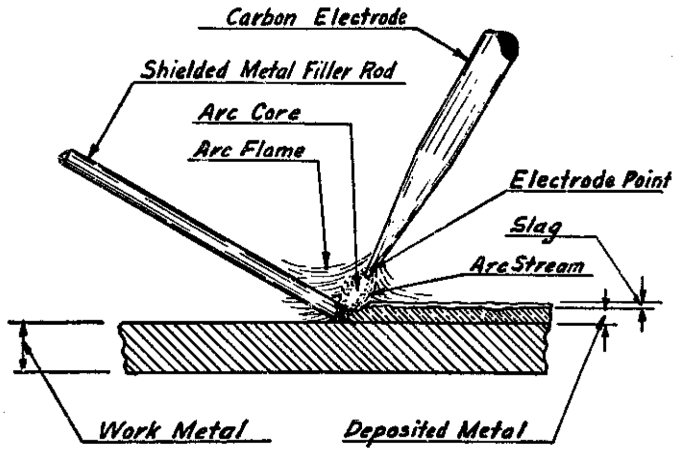


Fig. 13.3. A diagrammatic sketch showing carbon arc welding.

rod is melted in the arc flame and into the puddle formed in the metal with the flame. It is difficult to weld vertically or overhead with a carbon arc because of the large puddle of molten metal which is formed. The welds produced are usually not as strong as the base metal.

Importance of Welding—The welder has become an important piece of equipment on farms and in nonfarm agricultural businesses throughout the United States. It is especially desirable for use in machinery maintenance. It may be used to rebuild surfaces that become worn and to weld broken parts. It can also be used in the construction of labor-saving equipment.

Safety Precautions—The importance of safety precautions in electric arc welding cannot be overemphasized. Arc welding is not a dangerous job if the proper precautions are used. *It is especially important, however, to protect properly the eyes, the skin, and the body. Protection from spattering molten metal is also essential. In a school shop or other places where several persons work at the same time, arc welding should be done, as a protection to others, in a booth or behind a fireproof portable screen designed for that purpose. Be sure to use a shield at all times.*

The following is a partial list of safety precautions:

1. Do not strike an arc until your helmet is in place. Check to see that all observers are using the proper protective equipment. *Never look at the arc with the naked eye.*
2. Make sure the helmet and lenses are in good condition. *Be sure to use the proper lenses.* Number 10 shade lenses are recommended.
3. Wear gauntlet-type leather gloves while you are using a welder.
4. Wear suitable clothing to protect all parts of the body from the rays of the arc and the spatter of hot metal. Keep shop clothes clean. Oil-soaked clothes are ignited easily.
5. Wear trousers without cuffs. Sparks may fall into the cuffs and burn the trousers.
6. Keep the booth or screen closed to protect other workers from the arc rays.
7. Wear safety glasses when you are chipping or grinding metal.

(Courtesy Hobart Brothers Company)

Fig. 13.4. The correct clothes and protective equipment such as a leather apron, leather gloves, and a helmet are essential for the safety of the welder.

8. Grasp the electrode holder by the insulated handle.
9. Use tongs or pliers to handle metal or electrode stubs—they might be hot. Avoid touching hot metal with the hands or body.
10. Place the electrode holder, when it is not being used, on a hanger instead of laying it on a welding table or a grounded metal surface. It might cause a short in the circuit.
11. Avoid welding near flammable or combustible materials.
12. Avoid adjusting the welding machine while it is in operation. Make sure the main switch is open before you start to repair a welder.
13. Keep tools and metal in their proper location so they will not fall on your feet.
14. Provide adequate ventilation while you are welding. This is especially important as a protection against exhaust fumes when an engine-driven welder is used. Avoid breathing the fumes from an arc.
15. Avoid using cables which are worn or poorly connected.
16. Avoid working on line circuits or conductors.
17. Avoid operating the polarity switch while the welder is operating under load.
18. Avoid welding while you are standing in water or on a damp floor.
19. *Protect cables from damage. Do not allow cables to be run over.*

Eye Burn—If persons look at an electric arc without protecting their eyes properly, they may receive eye burns, commonly called "hot sand in the eyes." The pain may be intense for a few hours, but it does not usually cause a permanent eye injury. Aspirin or acetaminophen may be taken to relieve the pain.

Selecting, Installing, and Maintaining Equipment

Common Types of Arc Welders—There are two types of electric current used in arc welding: D.C. or direct current, and A.C. or alternating current. The following types of arc welders have been developed:

1. D.C. welders, which operate with a direct-current generator which may be driven by a gas engine or an electric motor.
2. A.C. welders, which operate with an alternating-current generator driven by a gas engine or an electric motor.
3. A.C. transformer-type arc welders.

The D.C. welders and the A.C. transformer-type welders are the most popular. Both types have their advantages. The A.C. transformer-type welders have no rotating or moving parts; consequently, they operate at a low cost, and their initial cost is usually less than the cost of the D.C.-type welders. Some inexperienced operators prefer a D.C. arc welder because they believe it is easier to strike an arc with this type of machine. Some prefer the engine-driven, direct-current, generator-type welders, because they can be used for either field or shop work.

The A.C. transformer-type electric arc welders are popular because of their lower cost and because they are easy to use.

Arc Welding Equipment and Supplies—The equipment illustrated in the figures in this chapter indicates the items usually included in an arc welding outfit. The following are other pieces of equipment and supplies that are needed:

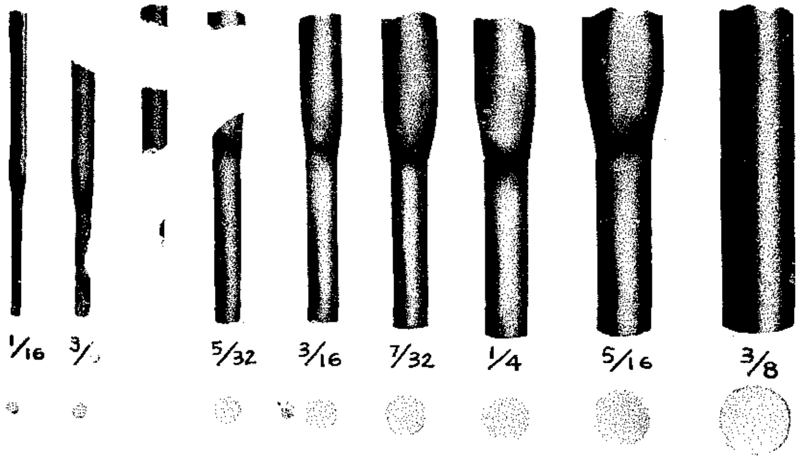
1. Welding booth or portable screen.
2. Gloves, gauntlet type, preferably of leather.
3. Helmet and safety glasses.
4. Machinist's bench vise.
5. Power grinder with 8-inch to 10-inch wheel.
6. Cold chisels and punches.
7. Hammers, peening and chipping.
8. Soapstone or chalk for marking.
9. Wire brush.

Installing an Arc Welder—Before attempting to install an arc welder, read the manual of instructions supplied with the welder carefully.

The suggestions, procedures, and practices which should be followed in the installation of an arc welder are:

1. Secure the services of a qualified electrician to supervise the work.
2. See that the requirements of the National Safety Code and the National Electrical Code are met.
3. Use No. 8 or heavier wire from the service entrance to the switch for a 240-volt-ampere A.C. welder.
4. Make sure that the wiring to the welder is properly grounded.
5. Locate an A.C. welder in a dry place so that the transformer unit will not come in contact with oil or moisture, which is injurious to the windings. Keep the welder at least 3 inches above the floor to provide for ventilation underneath it.
6. Connect properly to the power system. An A.C. welder is built to operate on alternating current only. Be sure that a 240-volt machine is connected to a power supply line with a voltage of 240. Be sure that the welder is connected to operate on the correct phase current, such as single phase or three phase. See instructions with the welder.

Selecting Electrodes—An electrode is a metal rod which is usually covered with a coating of flux. See Figs. 13.2 and 13.5. The flux carries the slag from the metal to the top of the weld and keeps the air from the weld until the metal cools. The slag can then be removed.



(Courtesy Hobart Brothers Company)

Fig. 13.5. Actual sizes of electrodes.

Electrode size is measured by the diameter of the electrode. The 1/8-inch electrode is the size used most frequently in agricultural mechanics. The 5/32-inch, 3/32-inch, and 3/16-inch electrodes are also used. The size of the electrode influences the amperage or current required for welding. When welding mild steel, a 3/16-inch electrode requires an amperage range of 140 to 240. For a 5/32-inch electrode an amperage range from 120 to 170 is required. For a 1/8-inch electrode an amperage range from 70 to 120 is required, and for a 3/32-inch electrode an amperage of 30 to 80 is needed.

The Marquette Manufacturing Company recommends the electrode diameters given in Table 13.1 for use with its A.C. Farm Welder.

Table 13.1—Plate Thicknesses and Electrode Diameters

	Electrode Diameter (Inches)		
Plate Thickness	Horizontal	Vertical	Overhead
20 gauge	1/16–3/32	3/32	3/32
18 gauge	3/32	3/32–1/8	3/32–1/8
1/16 inch	3/32–1/8	1/8	1/8
1/8 inch	1/8	1/8	1/8
3/16 inch	1/8–5/32	5/32	1/8
1/4 inch	1/8–5/32	5/32	1/8
5/16 inch and up	5/32–3/16	3/16	5/32

Identification of electrodes is by a number code and a color code established by the American Welding Society (A.W.S.) and the American Society for Testing Materials (A.S.T.M.). A colored mark on an end and a side of each electrode is used. For example, the color code for the mild steel electrode frequently used in agricultural welding is brown, and the number code is E6013. To avoid confusion some manufacturers are now stamping the number code near the grip end of the electrode. See the electrode manufacturer's literature for the code designations and the use of the electrodes available.

Polarity is involved in classifying electrodes for direct current or D.C. welders, and it refers to the direction the current flows. With alternating current or A.C. welders polarity is not involved.

The direction of current or polarity may be changed on a D.C. welder. If the electrode is connected to the negative terminal of a welder and the ground to the positive terminal, it is called direct current straight polarity (DCSP), and an electrode with a flux for straight polarity works best. If the connections are reversed, it is called direct current reversed polarity (DCRP). The crater during welding has less depth with reversed polarity. An electrode for reversed polarity, therefore, usually is best for welding light materials and for welding materials which should not be overheated, such as cast iron.

When selecting electrodes, keep the following in mind:

1. The kind of metal to be welded.
2. The kind of weld and the type of joint.
3. The type of welding machine.
4. The position of the welding: flat, horizontal, vertical, overhead.
5. The thickness of the metal.
6. The required strength of the weld.
7. The speed of welding.

Many parts on machinery and labor-saving devices used in agricultural activities are under considerable strain and in continual use over a long period of time. Consequently, only the best electrodes for the job to be done should be used.

Maintaining Arc Welding Equipment—The length of service of welding equipment is dependent on the care given to it. Care is also closely associated with the performance of a welder. The following suggestions are given for the care of arc welding equipment:

1. Keep the machine in a dry, well ventilated place.
2. Keep the machine at least 3 inches above the floor to permit proper ventilation under it.
3. Keep the machine away from the welding sparks and the spattering of hot bits of metal.
4. Keep the machine as free from dust as possible by wiping it off occasionally.
5. Blow dust from transformer coils frequently.
6. Have the machine serviced occasionally, checking all working parts.
7. Check the electrode holder frequently to see whether or not it is worn or in need of repair.

8. Check cables and cable plugs occasionally.
9. Keep all supplies in a well protected cupboard or cabinet.

Welding Operations

Preparing Parts to Be Welded—It is very important to prepare metals properly before they are welded. This results in stronger welds, a neater appearance, and less consumption of electrodes. Preparation of metals involves the cleaning, forming, and cutting of parts.

The following suggestions for the preparation of metals to be welded are offered:

1. Clean the metal of all dirt, oil, grease, rust, scale, water, and other foreign matter before welding. Rust and scale may be removed with a chisel or wire brush.
2. Fit joints together before starting to weld.
3. Bevel all materials over $^1/_8$ inch thick.
4. Make a V-groove on both the top and bottom of thick pieces of metal.
5. Separate the parts to be welded about $^1/_{16}$ inch to permit a satisfactory penetration of the weld.
6. Place the work in a position which will be the most comfortable for the welder.

(Courtesy Hobart Brothers Company)

Fig. 13.6. A wire brush is an essential tool for removing the slag from a weld.

Adjusting the Current—A wide range of current is necessary for the various sizes and types of electrodes and for the different kinds of metals and welds used. Consequently, arc welding machines are constructed so that the current may be adjusted. The manufacturer's instructions for using the welder suggest the correct current settings to use. These instructions should be followed. It is important to use the proper welding current in order to obtain a satisfactory weld.

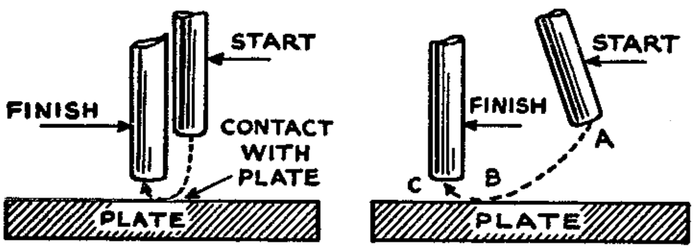
In using a D.C. welder, set it to the polarity suggested by the manufacturer of the electrode being used. The machine is set on *straight polarity* when the electrode is connected to the negative terminal and on *reverse polarity* when the electrode is connected to the positive terminal. An A.C. transformer type of arc welder does not have polarity.

Striking an Arc—The following procedure for learning how to strike an arc is suggested:

1. Select a piece of mild steel plate.
2. Clean the piece thoroughly and prepare for welding.
3. Make good ground connections.
4. Select a suitable electrode, knock off the flux from the tip, and place it in the electrode holder.
5. Wear proper clothing, including leather gloves.
6. Inspect your helmet and place it on your head.
7. Turn on the machine and adjust the current.
8. Get in a comfortable position for welding, preferably seated directly in front of the practice plate.
9. Put yourself at ease.
10. Lower the helmet and strike the arc.

There are two methods used in striking an arc. They are known as the *scratching method* and the *tapping method.* In the scratching method the electrode is moved at an angle across the plate, similar to striking a match. The electrode is struck on the metal and pulled forward with a sweeping motion to the starting point of the weld. After the electrode touches the metal, it is raised slightly as it is drawn across the plate. In the tapping method the electrode is kept perpendicular to the work. It is lowered slowly and tapped lightly on the work. It is then moved up until there is a ⅛-inch gap between it and the work.

One of the difficulties often experienced in striking an arc is that the electrode may stick to the work. This is known as *freezing.* When this happens, the electrode should be freed immediately by bending or twisting it back and forth and by pulling at the same time. If the electrode cannot be freed in this way, disengage the holder at once or stop the machine. Beginners should continue to practice striking arcs until they can do it successfully.

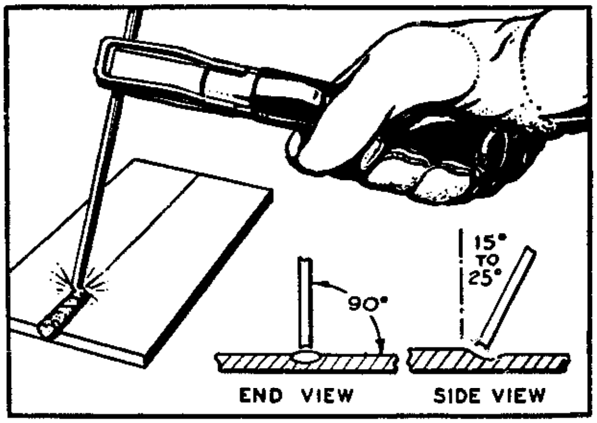


(Courtesy Hobart Brothers Company)

Fig. 13.7. Two methods of striking an arc. The tapping method is illustrated on the left, and the scratching method is illustrated on the right.

Correct Rate of Travel of Electrode—It is necessary to use the correct speed or rate of travel of the electrode in order to (1) secure a smooth, uniform bead of the proper width, (2) prevent the waste of materials, and (3) obtain a strong, neat-appearing weld. If the travel of the electrode is too fast, not enough metal will be used, the bead will be small, and a weak weld will result. If the travel of the electrode is too slow, there will be too much time consumed, and there will be an excessive use of welding metal, resulting in a wide bead and excessive cost. (See Fig. 13.9.)

Maintaining the Proper Length of Arc—The arc length is the distance between the surface of the molten metal and the electrode. The length of arc to use varies with the welding heat, the size and type of electrode, and the material being welded. In general, the length of the arc should be approximately equal to the diameter of the electrode used. Since the recommended length of arc may vary between brands of electrodes, it is desirable to read the manufacturer's recommendations which are supplied with the electrodes. The arc should be slightly longer when you are welding with an A.C. machine than when you are using a direct current welder.

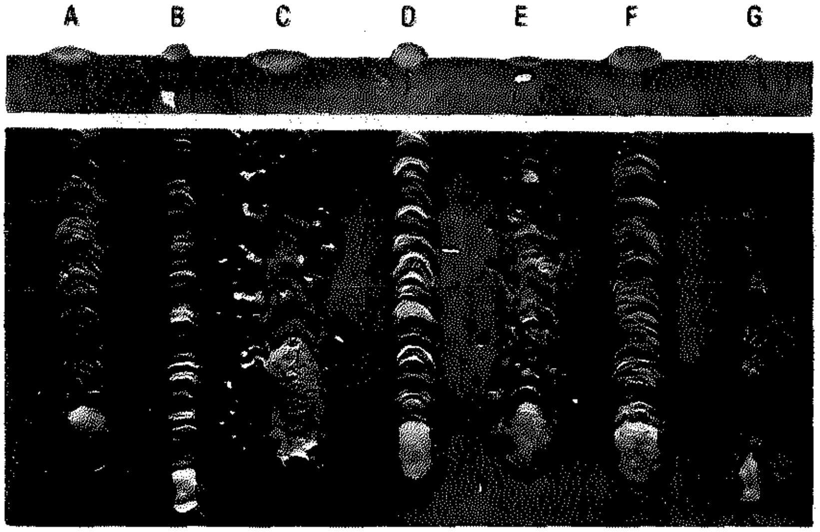


(Courtesy The Lincoln Electric Co.)

Fig. 13.8. The angle of an electrode for downhand welding.

Too short an arc has a tendency to produce a narrow, high bead, and it may cause the weld to be porous. Too high an arc results in a flat, wide bead, often irregular in shape, and an excessive spattering of molten metal. (See Fig. 13.9.)

In order for the correct arc length to be maintained, the tip of the electrode must be held at the proper distance from the work surface, and as the end of the electrode melts, it must be gradually and continuously lowered. Skill in maintaining the correct length of arc can only be developed by practice. The operator should continually keep the eyes focused on the work while welding and observe the appearance of the arc and the weld being produced. The sound of the welding machine is also an indication of the kind of arc being produced. That is, if the



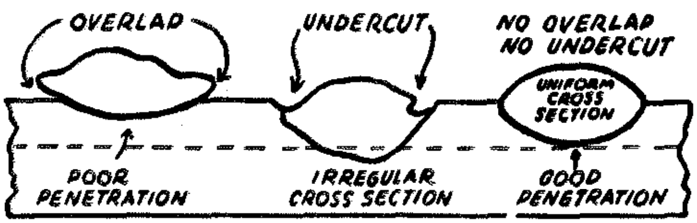
(Courtesy The Lincoln Electric Co.)

Fig. 13.9. Top and elevation views of welds made with a shielded-arc electrode under the following conditions: (A) current, voltage, and speed normal, (B) current too low, (C) current too high, (D) voltage too low, (E) voltage too high, (F) speed too low, (G) speed too high.

correct length of arc is used on an A.C. machine, there will be a steady *humming* sound. A *frying* sound is produced by a D.C. welder when a desirable arc is being used.

Running a Bead—The running of clean, dense beads of uniform size is extremely important in welding. They are necessary for a strong and neat-appearing weld. The following procedure for running a bead is suggested:

1. Place a steel plate on the welding table and clean it with a wire brush.
2. Select a suitable electrode and place it in the holder.
3. Wear proper clothing, including leather gloves.
4. Inspect and put on the helmet.
5. Turn on the machine and adjust the current.
6. Seat yourself in a comfortable position at the table, and be at ease.
7. Lower the helmet over your face.

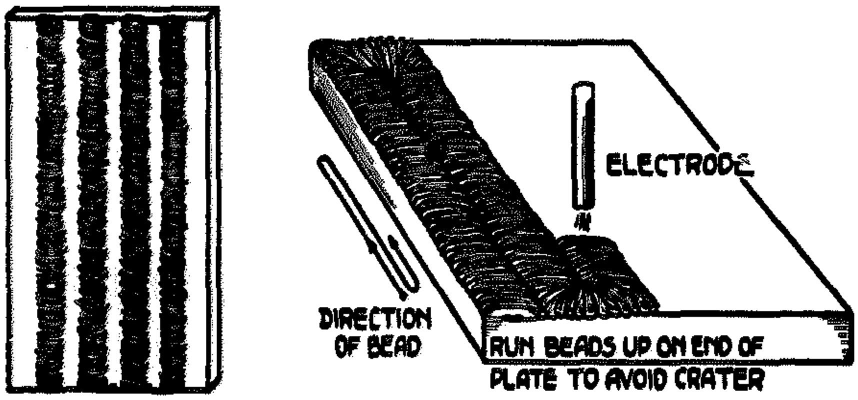


(Courtesy Hobart Brothers Company)

Fig. 13.10. Cross sections of beads.

8. Strike the arc. In holding the electrode holder, it is best not to grip it too tightly, as this will tire the hand and wrist, making proper movement of the electrode difficult.
9. Hold the electrode in a nearly vertical position, leaning the top at a 15- to 30-degree angle toward the direction of welding.
10. Hold the electrode at the proper distance from the surface of the work to form the correct arc.
11. Move the electrode slowly and steadily in a straight line along the surface of the metal, from left to right across the metal for a right-handed person. A left-handed person should move the electrode from right to left across the metal. Be careful not to let the electrode touch the welding surface. Also, do not allow the arc to go out while running a bead. However, "feed" the electrode into the metal continuously to compensate for the melting of the electrode.
12. Break the arc at the end of the bead by holding the electrode in one place until the crater in the metal is filled. Then lift it from the work. (Remove the slag from the bead with a chipping hammer after the bead has cooled.)

Beginners should practice running straight beads until they are proficient in moving the electrode at the correct speed and in maintaining the proper length of arc.



(Courtesy The Lincoln Electric Co.)

Fig. 13.11. After beginners have become proficient in welding beads as shown in the illustration on the left, they should practice welding to the end of the plate, to the side, and back to the other end, as shown in the illustration on the right.

Weaving the Electrode—"When steel is melted, some gas and slag are usually present. In order to allow the gas to escape and to float the slag to the surface for a sound weld, it is necessary that the metal be kept molten for a short period of time. In order to accomplish this . . . a slight oscillation or movement of the electrode parallel to the line of travel is necessary. This oscillation also helps to secure penetration at the edge of the weld."[1] Weaving is necessary when a large molten weld crater is being used and when a wide area is being covered with weld metal.

[1]"Lessons in Arc Welding," The Lincoln Electric Co., Cleveland, p. 23.

After beginners have learned to strike an arc and to run a straight flat bead, they are ready to start using a weaving or oscillating motion of the electrode in welding. There are a number of different weaving patterns which may be used, as illustrated in Fig. 13.12. The "A" weave in Fig. 13.12 is used frequently. It is considered one of the easiest oscillating motions to learn; consequently, its use is recommended for a beginner. It is more of a short, lengthwise, back-and-forth motion than it is a sidewise motion.

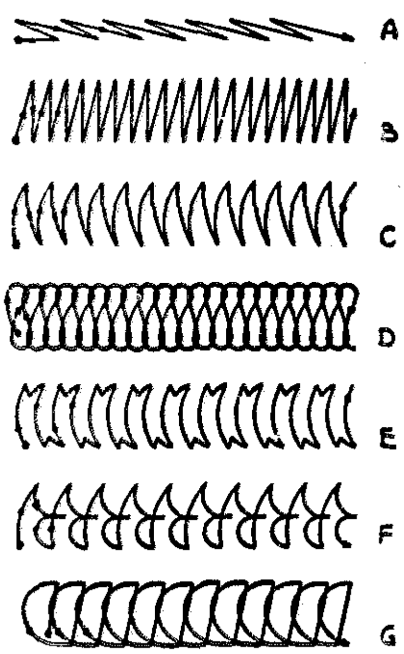
For making a wide bead, it is necessary to weave the electrode slightly from side to side, at the same time proceeding forward along the line where the bead is to be made. Such a weave is shown in B.

For accomplishing various purposes, variations of the B weave are widely used. Some students will find it much easier to weave in a crescent motion such as shown in C. The purposes accomplished by both these motions are substantially the same, and their use is largely a matter of preference. A figure-eight motion such as shown in D is preferred by some welders.

While the student has not yet attempted to make any kind of joints or actual welds, certain weaving motions are desirable to accomplish certain results. One such weave is shown in E. The purpose of such a weave is to allow a slight hesitation at each side of the weave. The purpose of this is to allow a slight building up or working of the metal into the edges of the joint.

Perhaps the most commonly used weave is that of C.

Many welders have their own ideas of the best type of weave for various purposes. Two such weaves are shown in F and G.



(Courtesy The Lincoln Electric Co.)

Fig. 13.12. Different ways of weaving or oscillating electrodes.

Padding—Padding is used in building up worn surfaces. Several layers of beads are run in straight lines until the surface is sufficiently built up.

The following practices in padding are suggested:

1. Place a steel plate on the welding table and clean it for welding.
2. Follow the procedure previously suggested for getting ready to weld.
3. Strike the arc at one corner of the steel plate and lay a straight bead near the edge of the plate, using a weaving motion.
4. Clean the bead with a wire brush or chipping hammer. (See Fig. 13.6.) An entire layer may be cleaned at one time.
5. Lay a second bead parallel to the first bead, fusing it to the first bead and to the plate. Also make sure that the second bead is of the same height as the first bead.
6. Clean the second bead with a wire brush, and continue to lay beads until the desired number have been deposited.

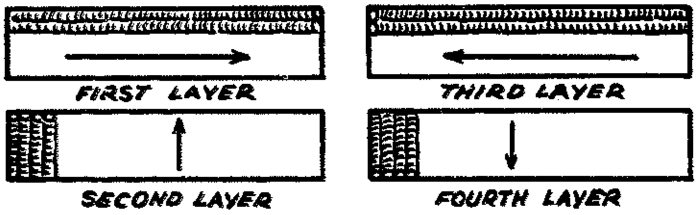
7. Clean thoroughly the layer of beads of all slag, oxide, or scale with a chisel, wire brush, or chipping hammer. (See Fig. 13.6.)
8. Weld a second layer of beads across the first layer.
9. Continue layering beads until the desired thickness is secured.

Table 13.2—Tabulation of Resultant Weld Characteristics

Obtained When Welding Is Done on Mild Rolled Steel with Heavily Coated Shielded-Arc Electrodes and When Proper Welding Procedure Is Used, Except As Indicated

Operating Variables	Resulting Weld Characteristics			
	Arc Sound	Penetration—Fusion	Burn Off of Electrode	Appearance of Bead
Normal amps, normal volts, normal speed. A.[1]	Sputtering hiss plus irregular energetic crackling sounds.	Fairly deep and well defined.	Normal appearance; coating burns evenly.	Excellent fusion—no overlap.
Low amps, normal volts, normal speed. B.	Very irregular, sputtering, few crackling sounds.	Not very deep or defined.	Not greatly different from above.	On top of plate. There is not the overlap as on bare rod.
High amps, normal volts, normal speed. C.	Rather regular explosive sounds.	Deep-long crater.	Coating is consumed at irregular high rate—watch carefully.	Broad, rather thin bead—good fusion.
Low volts, normal amps, normal speed. D.	Hiss plus steady sputter.	Small.	Coating too close to crater; touches molten metal and results in porosity.	Sits upon plate but not as pronounced as for low amps.
High volts, normal amps, normal speed. E.	Very soft sound plus hiss and few crackles.	Wide and rather deep.	Drops at end of electrode flutter and then fall into crater.	Somewhat broader, wide, splattered.
Low speed, normal amps, normal volts. F.	Normal.	Crater normal.	Normal.	Wide bead; overlap large; base metal and bead heated to considerable area.
High speed, normal amps, normal volts. G.	Normal.	Small, rather well defined crater.	Normal.	Small bead—undercut. The reduction in bead size and amount of undercutting depend on ratio of high speed and amps.

[1]Letters in the first column correspond to those which appear in Fig. 13.9.



(Courtesy Hobart Brothers Company)

Fig. 13.13. Arrows show the direction of the arc movement and the layers of beads in the padding.

Welding Positions—There are four general positions used in welding: (1) *flat downhand welding*, (2) *horizontal welding*, (3) *vertical welding*, and (4) *overhead welding*. See Fig. 13.14 for illustrations of these various positions. Flat welding is the easiest. When welding in any of the other positions, some of the molten metal may drop to the floor because of the pull of gravity. The overhead weld is the most difficult. Ability to weld in all positions is important, because some machinery parts may have to be welded in place on machines due to the inadvisability of removing them.

Common Kinds of Joints—The kind of joint to use on a particular job depends on the nature of the work. There are five kinds of joints frequently used, namely (1) *butt*, (2) *tee*, (3) *lap*, (4) *edge*, and (5) *corner*. (See Fig. 13.15 and Chapter 14 for illustrations of these different joints.) It is important that these joints be properly prepared, including the fitting together of pieces, before starting to weld.

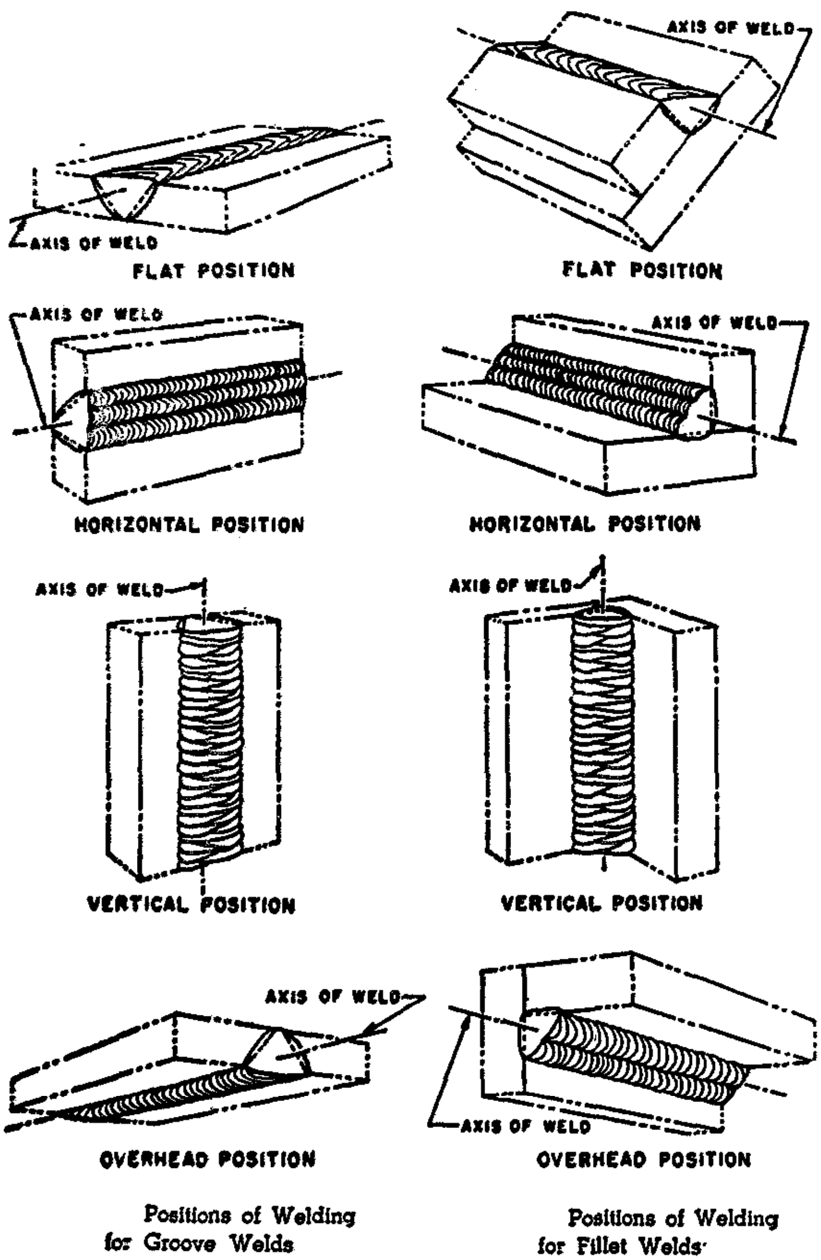
Common Kinds of Welds—Welds are often identified by the type of joint used, such as butt welds, corner welds, and lap welds. They also may be classified as (1) *groove welds* and (2) *fillet welds*. A groove weld consists of one or more beads deposited in a groove, such as in an open butt joint or in an outside corner joint. A fillet weld consists of one or more beads deposited in the angle between two surfaces, such as the angles provided by a corner lap or tee joint. See Fig. 13.15 for illustrations of these types of welds.

Single-Pass and Multiple-Pass Welds—In welding thin plate, one bead may be sufficient, but in welding heavier plate a number of beads are welded over one another. When only one bead is used in welding, it is called a *single-pass weld*, but when more than one bead is used, it is called a *multiple-pass weld*.

Making a Butt Weld—After persons have learned how to run beads on a flat surface, they should make butt welds. The following procedure is suggested for making such a weld:

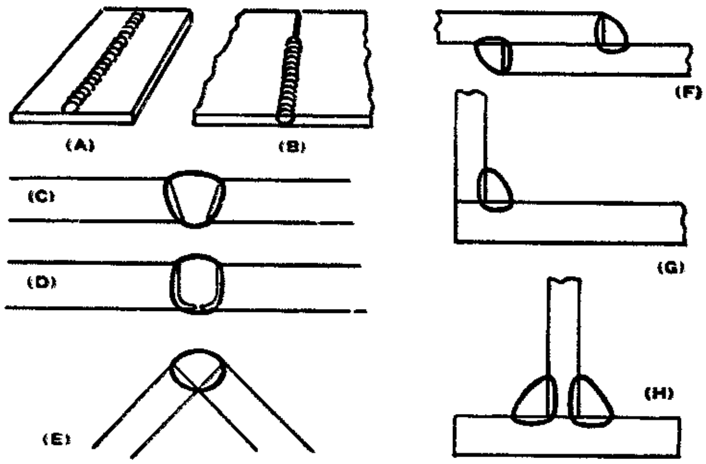
1. Prepare two pieces of steel plate approximately $^3/_{16}$ inch thick.
2. Place on the table the prepared pieces so that they will be parallel to each other, leaving a space between them slightly larger than the diameter of the electrode. This is to provide for the contraction and expansion of the metal.
3. Tack weld the pieces together at each end.

4. Weld the plates together, using a slight weave and a single pass of the electrode. Make sure that the metal penetrates the full depth of the pieces.
5. Clean the bead with a chipping hammer or a wire brush.
6. Apply a second bead, using a weaving motion, on top of the first, making this bead slightly wider than the first bead.



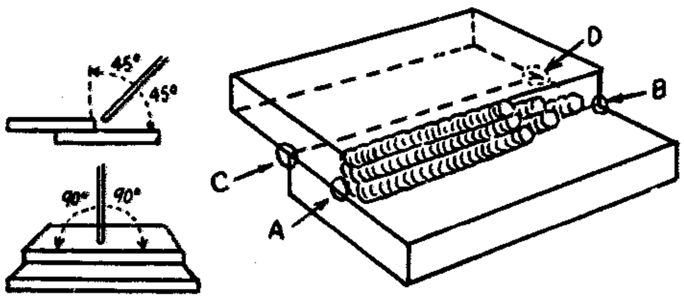
(Courtesy Hobart Brothers Company)

Fig. 13.14. Welding positions.



(Courtesy Hobart Brothers Company)

Fig. 13.15. Groove and fillet welds. A groove weld is illustrated in the open butt joint C. The Vee U joint groove weld is illustrated in D, and the outside corner joint groove weld is illustrated in E. Fillet welds are illustrated in F, G, and H—F being a lap joint, G an inside corner joint, and H a tee joint.

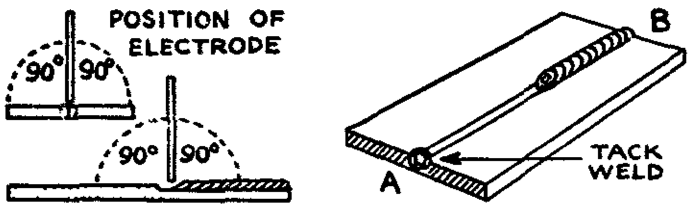


(Courtesy Hobart Brothers Company)

Fig. 13.16. A multiple-pass fillet weld in a flat lap joint.

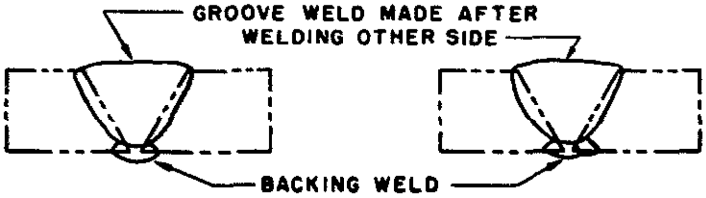
Making Fillet Welds—The fillet weld is one of the most common types of welds. The beginner should start making fillet welds by welding a flat lap joint. See Fig. 13.16 for an illustration of the flat lap joint. The following procedure for fillet welding practice is suggested:

1. Prepare two pieces of mild steel plate about ⅜ inch thick.
2. Place the pieces on the table, and lap one piece over the other piece.
3. Tack weld in four places, two tack welds on each end at the points where the pieces lap. See Fig. 13.17 for the locations of the tack welds.
4. Lay a straight bead in the groove of the joint, making sure to get good penetration of the metal. A relatively high amperage setting and a short arc give a well shaped bead.
5. Clean the first bead with a wire brush.
6. Lay a second bead along the side of the first bead, fusing half of it on top of the first bead.



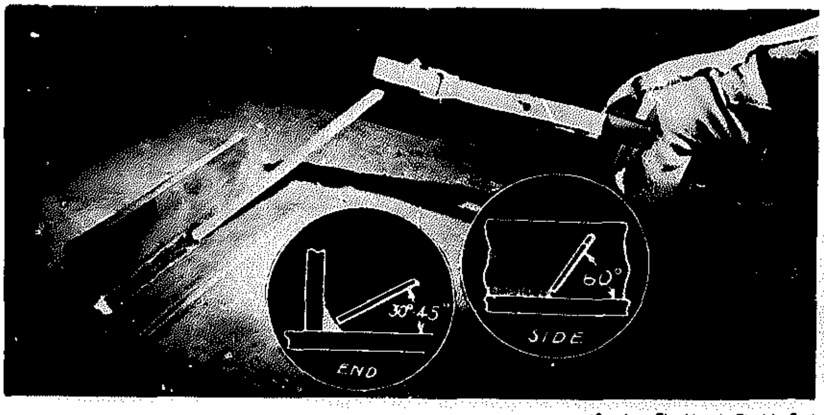
(Courtesy Hobart Brothers Company)

Fig. 13.17. A square butt weld in a flat position.



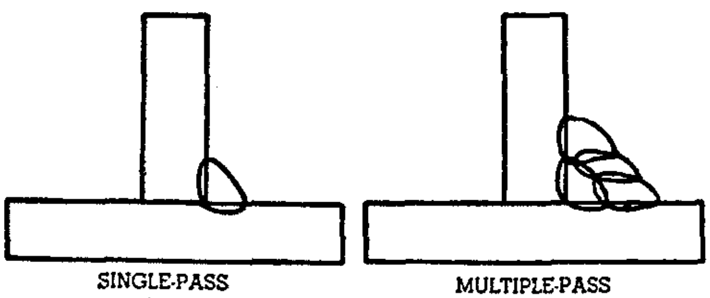
(Courtesy Hobart Brothers Company)

Fig. 13.18. Backing welds.



(Courtesy The Lincoln Electric Co.)

Fig. 13.19. The correct angle to hold an electrode for conventional fillet welding. The correct angle for an electrode will vary depending on the type of electrode used. Consult the electrode manufacturer's recommendations.



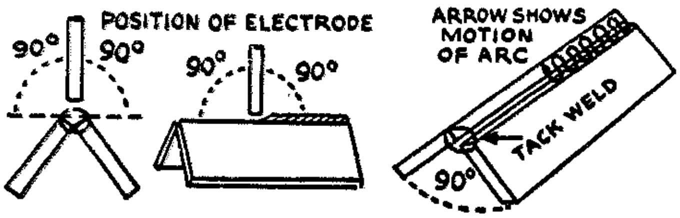
(Courtesy The Lincoln Electric Co.)

Fig. 13.20. Single-pass and multiple-pass welds.

7. Clean with a wire brush.
8. Lay a third bead, fusing it into the two previous beads.
9. Continue running beads until the two pieces are properly welded together. The number of beads will depend on the thickness of the pieces being welded.

Making Corner Welds—Practice welding outside corner joints as a means of learning how to make a groove or vee weld. See Fig. 13.21 for illustrations of outside corner joints. The following procedure for the practice welding of outside corner joints is suggested:

1. Prepare two pieces of 1/4-inch plate.
2. Place the two pieces in position illustrated in Fig. 13.21.
3. Tack the two pieces at the ends, leaving a 1/8-inch space between the edges at the bottom of the vee.
4. Weld with a light weaving motion, as indicated in Fig. 13.21.



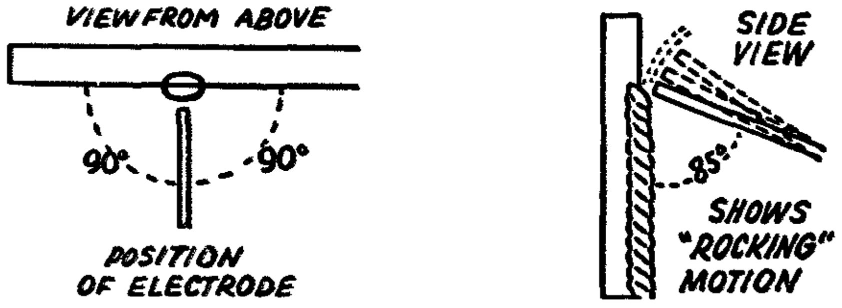
(Courtesy Hobart Brothers Company)

Fig. 13.21. An outside corner weld in a flat position.

Controlling Distortion—Metal expands when it is heated and contracts when it cools. Heating metal does not change its shape if the piece is equally free to expand and contract in all directions. In welding, metal is usually not equally free to expand and contract in all directions. For example, the cold metal surrounding a heated spot prevents equal expansion and contraction.

Several procedures are helpful in avoiding undesirable distortion. A few of these procedures follow:

1. Tack welding serves to clamp parts being welded so that undesirable warping cannot develop.
2. A welder can often position parts to be welded so that correct alignment results when the metal contracts after being welded.
3. A welder can control distortion by bending parts before they are welded, so that the contraction resulting from welding will draw the parts into their proper position.
4. The proper beveling of parts to be welded decreases the amount of welding rod necessary to fuse two pieces and thus decreases the amount of distortion.
5. Hammering (peening) a weld reduces the distortion produced.
6. A welding operator who is careful not to use an excess amount of welding rod for a joint is troubled less by distortion than a welding operator who tends to overweld.
7. Less distortion results when fewer passes are made. The number of passes necessary can be reduced by using a larger electrode.



(Courtesy Hobart Brothers Company)

Fig. 13.22. Vertical welding.

8. A welding operator can reduce the amount of distortion by using a high amperage and a higher speed of travel in making fillet welds.
9. The use of short beads deposited from right to left will produce less distortion than a continuous bead deposited from left to right.
10. Clamps and vises can often be used to hold parts being welded so that undesirable warping cannot take place.
11. Less distortion will result in sheet metal if the welding is done from the top toward the bottom of the sheet, when the sheet is placed in a vertical position.

Cutting Operations

An arc welding electrode may be used for cutting metal. An electrode is especially useful for cutting cast iron, for cutting in inaccessible places, and for cutting small jobs. The use of an arc is usually considered to be the best method of cutting cast iron, because cast iron does not oxidize with heat. To be cut, cast iron must be melted. An electric arc melts metal as a means of cutting it.

The melting temperature of steel is approximately 2,600 degrees. The heat of an electric arc is 6,500 degrees. Therefore, cutting metal with an electrode is fast, but the cut is not smooth. If a smooth cut is necessary, the edges may be ground after the cut is made.

Mild steel-coated electrodes are used for cutting. For metal up to $^1/_8$ inch thick, select a $^3/_{32}$-inch electrode and use a 75 to 100 amperage range. For metal from $^1/_8$ inch to $^1/_4$ inch thick, select a $^1/_8$-inch electrode and use a 125 to 140 amperage range. For metals over $^1/_4$ inch thick, select a $^5/_{32}$-inch electrode and use a 140 to 180 amperage range. A general rule for cutting is to use 30 per cent more amperage than would be used for welding.

Procedure—*In cutting flat metal* which is thicker than the electrode, place the metal to be cut in a flat or horizontal position. Strike the arc where the cut is to be made, and allow the heat of the arc to form a crater of molten metal. Then move the electrode back and forth to force the molten metal from the cut or kerf. A pushing downward motion coupled with a quick upward motion helps to force the molten metal from the cut. Since arc cutting is done by melting the metal, the motion of the electrode and the position of the work should assist the molten metal to fall out of the cut. Start cuts at the lower edge of the piece being cut so that gravity will help remove the molten metal. If it is not possible to start at the edge of the piece of metal to be cut, burn a hole and start cutting at the edge of the hole. (The techniques of cutting holes in metal will be described in later paragraphs.) In order to have room to manipulate the arc, the kerf must be kept larger than the electrode. This is done by weaving the electrode from side to side.

In cutting round stock, start at an outer edge of the stock so that the molten metal can escape. The same procedures are followed in cutting round stock as are followed in cutting flat stock. When a cut reaches the center of round stock, a new cut is made from the opposite side.

In cutting holes, burn a hole by pushing the electrode through the metal. Use a short arc and push the tip of the electrode into the crater of molten metal. If a larger hole is needed than the hole burned by the electrode, move the electrode around the edge of the hole in a widening circle until a hole of the desired size is obtained.

Carbon Arc—A carbon arc may be used for cutting. It is often used for scrapping metal, for cutting rivets, and for cutting scrap iron. The techniques used with an electrode to remove the molten metal from a cut also apply when using a carbon arc.

Safety—Cutting is dangerous because of the large amount of molten metal that falls from the cuts. Clothing that will not catch the molten metal that falls should be worn. A welding table with a cutting drawer is often used as a safety precaution. The drawer is so constructed that it may be pulled out to catch the molten metal that falls from cuts. The bottom of the drawer is covered with sand.

Cutting should not be done near a concrete floor, because the heat produced by the cutting operation may cause the concrete to "blow up." The particles of concrete may injure the operator of the welder and, of course, the "blow-up" ruins the concrete floor.

Characteristics of Various Metals

Characteristics of Metals—*Pig iron* is cured iron, a direct product from blast furnaces. *Cast iron* is a product of pig iron and contains a considerable amount of carbon, from 2.2 to about 4.3 per cent, and some impurities. It is very brittle and granular in structure and cannot be welded in a forge fire. Cast iron is often used in the manufacture of farm machinery, although there is a trend toward the use of steel and other tough materials instead of cast iron.

Wrought iron is also a product of pig iron but has had most of the carbon removed. Wrought iron is a two-component metal consisting of a high-purity iron and iron silicate. The latter is termed "slag" and is composed of several materials that decrease corrosion. The carbon content of high-quality wrought iron is usually around 0.02 or 0.03 per cent, while good wrought iron may contain 0.08 or 0.10 per cent carbon. The higher the carbon content, the lower the quality of the wrought iron. In wrought iron, the manganese content is usually below 0.06 per cent. Phosphorus may be partly alloyed with the base metal and partly associated with the slag, the content ranging from 0.10 to 0.15 per cent. The usual silicon content is between 0.10 and 0.20 per cent. Ferrous silicate fibers confer a high degree of machinability, especially for threading operations. Sulfur is not desirable in wrought iron.

Wrought iron is used frequently in agricultural shops for machinery and equipment repair and construction. It is easily bent when cold or hot, can be threaded and drilled, and is easy to weld. It has good tensile strength, will withstand shock, and is not brittle. Wire, nails, bolts, nuts, chains, pipes, rods and bars, strap iron, and other products are made of wrought iron.

Mild steel is often called soft steel. It is a product of pig iron and contains about 0.10 to 0.50 per cent carbon. This type of steel is often used in agricultural mechanics because it is strong and is cheaper than wrought iron. It is a good metal to use in making braces and trusses for machinery used in agriculture. Bolts are frequently made of mild steel.

Machinery steel is stronger and harder than mild steel and is used for plow beams, heavy braces, and other parts of farm machinery. Machinery steel is rolled into angle irons, channels, I-beams, and other shapes. It contains about 0.50 to 0.60 per cent carbon.

Tool steel is made with various carbon contents. A common carbon content is around 1.0 per cent. It can be tempered to various degrees of hardness and is used for making chisels, punches, drills, wrenches, and other tools.

Sheet metal is made of steel which is often galvanized. The approximate thickness of sheet steel used on farms and in nonfarm agricultural businesses varies from $^1/_{64}$ inch to $^1/_4$ inch.

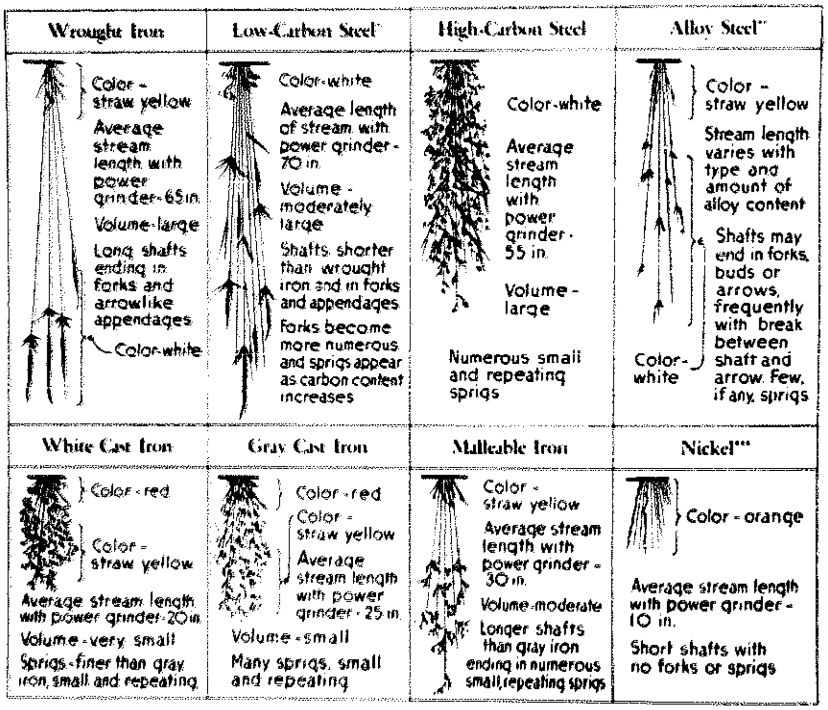
Identifying Metals by Spark Testing—"Spark tests should be made on a high speed grinder, and the specimen should be held so that the sparks will be given off horizontally. For most accurate results, the sparks should be examined against a dark background, preferably in a dark corner of the shop.

"The color, shape, average length, and activity of the sparks are details which are characteristics of the material tested. Spark testing can be a very accurate method of identifying metals, but it requires considerable practice and experience to become an expert." Several common sparks are given in Fig. 13.23. If operators learn the technique for identifying these metals readily, they will soon be able to expand their experience to include other metals by observation and comparison with the sparks from known samples.[2]

Welding Various Metals

Welding Sheet Metal—The welding of sheet metal is difficult because it is easy to burn or warp the metal. A special electrode for welding sheet metal should be used. Do not use an electrode larger in diameter than the thickness of the sheet metal to be welded. Use a low amperage. If the type of welder available does not

[2]Information on spark testing courtesy Linde Air Products Co. (adapted).



(Courtesy Linde Air Products Co.)

Fig. 13.23. The characteristics of sparks of metals placed on a high-speed grinder.

*In general the same as for cast steel.
**Spark shown is for stainless steel.
***Monel metal spark is very similar to nickel.

permit the use of low enough amperage, it may be possible to braze the sheet metal using a carbon arc torch. This process is described in a later section of this chapter.

Move the electrode as rapidly as possible, but not so rapidly that the weld does not penetrate. Rapid welding prevents the sheet metal from burning through, and it prevents excessive heating which may cause warping.

Use vise-grip pliers to clamp joints close together while they are being welded. A good fit of joints makes it possible to use a shorter arc. Tack weld to prevent excessive warping.

Welding Mild Steel—The techniques of welding mild steel have been described in a previous section of this chapter.

Welding Cast Iron—Cast iron is difficult to weld. It may be identified by the spark test, by its rough and pitted exterior appearance, and by its intricate interior design.

When cast iron is welded, it must not be allowed to cool rapidly, or it will crack. This tendency to crack is caused by the high carbon content of cast iron. The use of short beads, not over 2 inches long, will help prevent cracking, because the cast iron never becomes heated to a very high temperature. The short beads

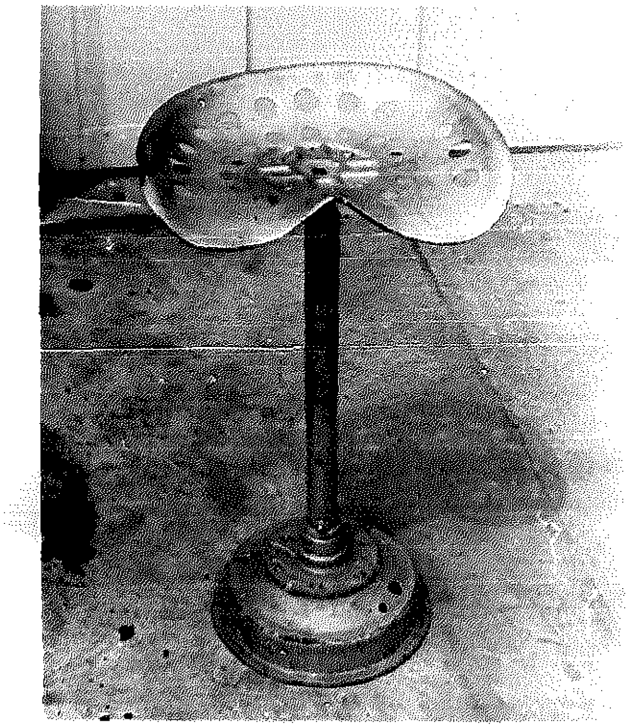


Fig. 13.24. A homemade seat for welding.

should be allowed to cool to the touch of the hand before the welding is continued. Welding cast iron is a slow process.

Preheating of cast iron will reduce its tendency to crack. In preheating, the whole section of cast being welded should be uniformly heated to a dull red color and kept at this temperature during the entire welding process. Cooling of a preheated section of cast should proceed slowly, and drafts should be avoided.

When a cast is welded, the crack should be "veed," but the vee should not separate the cast into two pieces. Casts are often difficult to fit together when they are broken or separated into pieces by the grinding of vees.

Use a short arc. The amperage setting should also be low, but high enough to fuse the metal. If too low, the arc will jump from one side of the vee to the other. If too high, the molten metal will bubble. Bubbles may also be caused by the gas, grease, and sand in the iron. If bubbles occur, however, an operator should check to see whether or not the amperage setting is correct. Failure to use a short arc and a low amperage will cause excessive heating which may cause cracking.

Cleaning of the pieces to be welded is very important in the welding of cast iron. It is porous and absorbs dirt easily. Cast iron may be cleaned by grinding or by preheating until it smokes.

If the weld is to be ground or filed, a machinable electrode is used. A nonmachinable electrode is also available. Its deposit is very hard, but it is cheaper than the machinable electrode. In recent years many new rods have been made available that make welding cast iron and high-carbon steel easier.

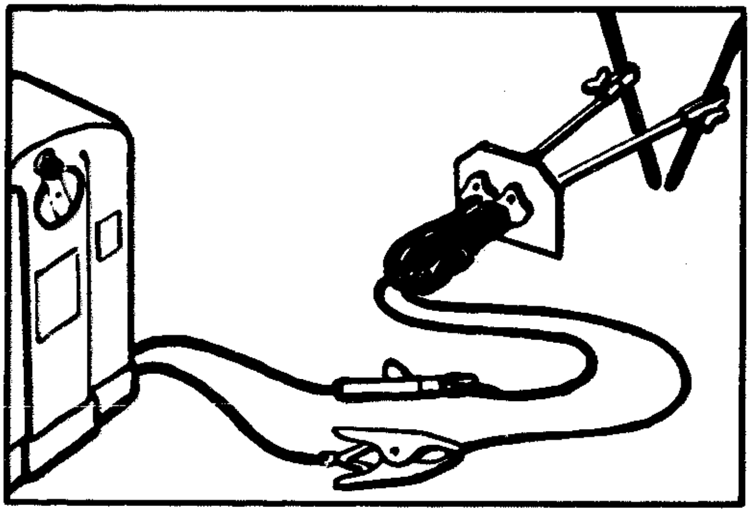
Welding High-Carbon Steel—High-carbon steel used in agricultural machinery for braces, beams, and other purposes is difficult to weld because it checks or cracks easily.

The process of welding high-carbon steel is the same as the process used for mild steel, but the joint to be welded should be preheated to a blue color. Welds on high-carbon steel should be allowed to cool slow'y and should be protected from drafts. Quick cooling produces a brittle weld. The preheating process decreases the rate of cooling. A mild steel electrode may be used if the steel is preheated.

Carbon Arc Torch

A carbon arc torch is used to provide heat for brazing, hard facing, and soldering. It is also used for heating metal to be bent or shaped. (Tig, mig, and oxyacetylene welders are also used for these purposes and are preferred, by some agricultural workers, over the carbon arc torch.) A carbon arc torch consists of two carbon rods. The flow of current between these carbon rods produces a flame with a heat intensity of 9,000 degrees.

Size of Carbon Rods—The size of carbon rods to use depends on the amount of heat required and the thickness and type of metal. For light metals up to $^1/_{40}$ inch thick, use $^1/_4$-inch carbons with an amperage range of 20 to 50. For metals from $^1/_{40}$ to $^1/_{20}$ inch thick, use $^5/_{16}$-inch carbons with an amperage range of 30 to 70. For metals from $^1/_{20}$ to $^1/_4$ inch thick, use $^3/_8$-inch carbons with an amperage range of 40 to 90. For metals over $^1/_4$ inch thick, use $^1/_2$-inch carbons with an amperage range of 75 to 140. These recommendations are for an A.C. welder. If a D.C. welder is used, the carbon attached to the positive terminal should be one



(Courtesy The Lincoln Electric Co.)

Fig. 13.25. A carbon arc torch heats by arcing the current between its two carbons.

size larger than the carbon attached to the negative terminal. If the carbon attached to the negative terminal is $^3/_8$ inch in diameter, the other carbon should be $^1/_2$ inch in diameter. The reason for the difference in size of carbon is that a D.C. welder produces two-thirds of its heat on the positive side.

Attaching and Adjusting a Torch—The two cables on a carbon arc torch are attached directly to the welder. Either of the two cables may be attached to the electrode post.

The carbon tips of the torch are adjusted to form a vee. When the torch is closed, the carbons should be about $^1/_{16}$ inch apart. The carbons should extend approximately 2 inches below their holders.

Adjusting the Welder—Adjust the amperage of the welder so that sufficient heat will be produced when the flame is $^1/_4$ inch from the metal. If the amperage is too low, the heating of the metal will be slow and the arc may be broken easily. If the amperage setting is too high, the coating of the carbons will be burned off. The amperage should not produce a cherry red color more than $1^1/_2$ inches from the tips of the carbons.

Safety Precautions—The ultraviolet rays of a carbon arc torch are more intense and cause burns more easily than the rays of a metallic arc. All parts of the body need to be protected adequately from the ultraviolet rays, and the hands need protection from the heat the torch produces.

Starting the Arc—Start the carbon arc by adjusting the carbons toward each other. After the flame is established, move the carbons until they are approximately $^3/_{16}$ inch apart.

Brazing

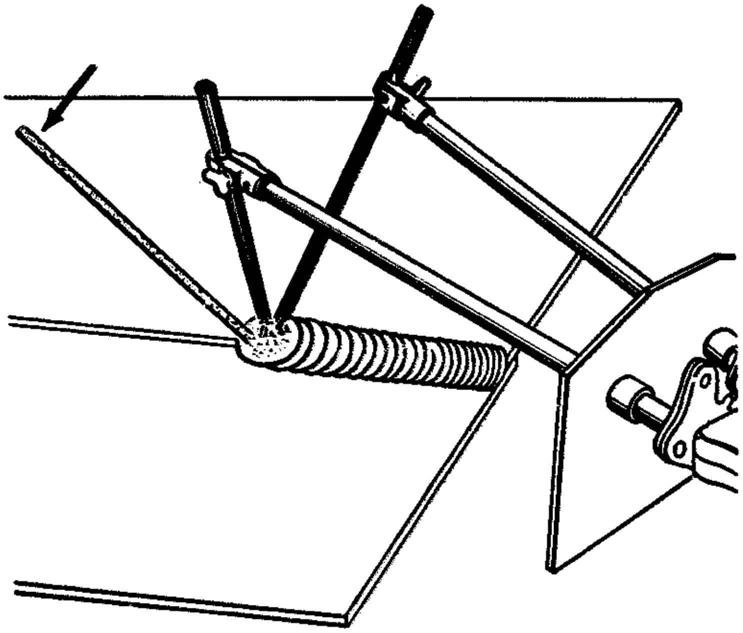
Brazing is the joining of pieces of sheet metal with the metal from a bronze filler rod, which has a lower melting point than the pieces of metal being joined. The process is often used in repairing the sheet metal parts of agricultural machinery.

Brazing with a Carbon Arc Torch—A carbon arc torch may be used to supply the heat for brazing.

Prepare the metal for brazing by cleaning it thoroughly. Dirty, greasy, painted, or rusted surfaces prevent the flowing of the binding metal into the pores of the pieces to be joined. Sandpaper, a wire brush, or a grinder may be used to clean the metal.

Heat the pieces of metal to be joined until the bronze rod will melt when rubbed across the metal. The bronze will run to the edges of the heated area if the metal is too hot, and balls of bronze will form if the metal is too cool. Preheating opens the pores of metals and allows the impurities to escape.

Place the flux-coated bronze rod against the heated metal. The metal and flux will melt together and cover the heated portion of the base metal with a bronze coating. This process is called *tinning*. Additional filler rod is applied by heating



(Courtesy The Lincoln Electric Co.)

Fig. 13.26. Brazing sheet metal with an arc torch and a brazing rod. The arrow points to the brazing rod.

the area until the bronze deposited before begins to melt. If not enough heat is applied, the bronze being added will not form a bond with the bronze added before, but will form into balls. If the area is overheated, the color will be orange and the bronze applied before will burn and become pitted.

Brazing with a Single Carbon Rod—Brazing may also be done by using a single carbon rod for heating instead of using a carbon arc torch. A flux-coated bronze rod is used as the filler rod when a single carbon rod is used for heating. The carbon rod used for this type of brazing is $^{5}/_{32}$ inch in diameter. This process of brazing has r any advantages:

1. It is easy to do.
2. It produces a good weld.
3. It is not necessary to heat a large area.
4. It is possible to braze in the horizontal, vertical, and overhead positions.

The procedure to follow in brazing with a single carbon rod and a flux-coated bronze rod is not difficult. Many of the principles of welding discussed previously apply, such as cleaning the surface of the base metal and tack welding the pieces of metal.

A short arc $^{1}/_{16}$ inch in length is used. Move the arc along the joint or crack being brazed, and feed the flux-coated bronze rod into the arc. Since the flux on the rod causes a stronger bond and stabilizes the arc, it helps to rotate the rod as it is fed into the arc. The arc should be on the filler rod at all times during the brazing process instead of on the base metal. Use only enough amperage to melt the filler rod.

Hard Facing

Hard facing is the process of applying an extremely hard metal to the surface of the parts of tools and machinery that wear away rapidly, or to the cutting edges of tools and machinery. Hard facing requires considerable skill.

Electrodes of several types are available for hard facing. A powder may also be used. The different types of electrodes are designed to prevent the different types of wear to which tools and machinery parts are subjected. The three types of electrodes used on farms and in nonfarm agricultural businesses for hard facing are electrodes which deposit metal:

1. To resist severe abrasive action.
2. To resist impact and moderate abrasion.
3. To resist severe impact and moderately severe abrasion.

Before hard facing, determine the type of wear, and then follow the electrode manufacturer's suggestions in selecting and applying the electrode. Use a carbon arc torch for hard facing thin metals, because a low heat is required. A powder instead of an electrode is usually used when a carbon arc torch is used for heating the metal.

Use a lower amperage setting for hard facing than for welding sheet metal, because deep penetration is not necessary. A current setting high enough to obtain a good-appearing bead is sufficient. Use a wide weave when a large area is to be covered. A short arc about 1/8 inch in length is used.

If a sharp edge is desired, hard face on only one side. Avoid an excessive deposit in spots, because it is difficult to machine away. If a gear or a part needs to be built up, use a mild steel electrode. Then hard face over the built-up part. Mild steel electrodes are much cheaper than hard face electrodes. Hammering a hard face weld with a ball-peen hammer will help to relieve stresses and thus prevent the weld from cracking.

Shaping, Forming, and Bending Metals

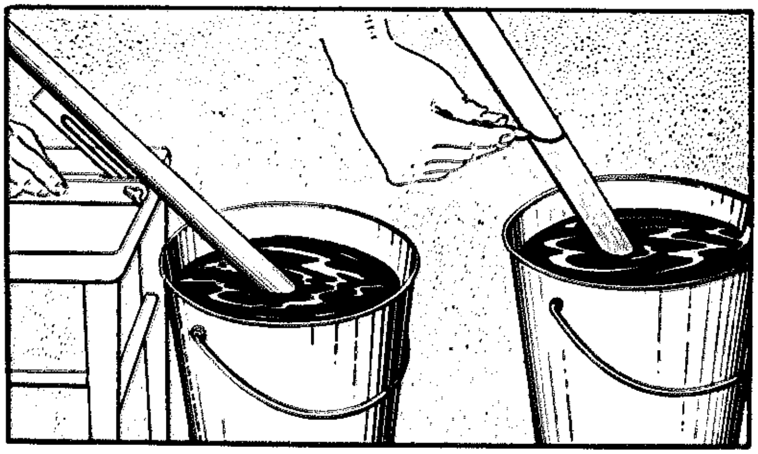
Heat for shaping, forming, and bending metals can be supplied with a carbon arc torch. For the techniques of shaping, forming, and bending hot metal see Chapter 15, "Working Hot Metal."

Welding Pipe

In agriculture, pipe is used for many purposes. It is used in the construction of many labor-saving devices. Welding of pipe does present the welder with some special problems because of the curved surfaces.

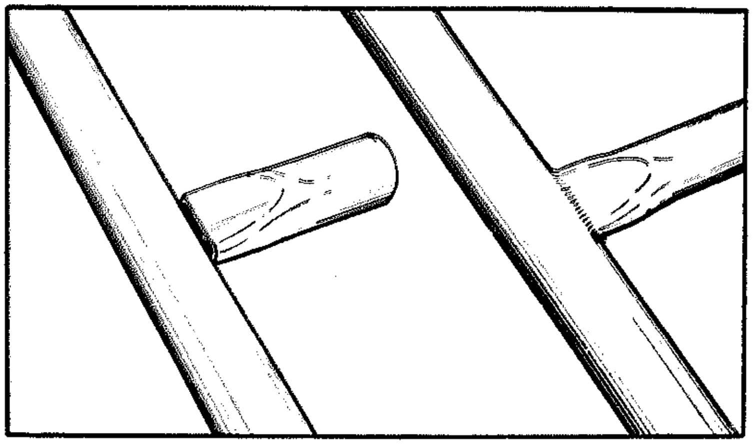
If possible, do all welding on pipe in a flat position. This may often be accomplished by rolling the pipe as it is welded.

The general principles of making butt and fillet welds apply to the welding of pipe. In making an ell, a 90-degree joint, with pipe, mark the pipe as shown in Fig. 13.27. Weld the joint from the outside point to the inside corner or heel. Figure 13.28 illustrates how the end of a pipe may be hammered for a simple welded assembly.



(Courtesy The Lincoln Electric Co.)

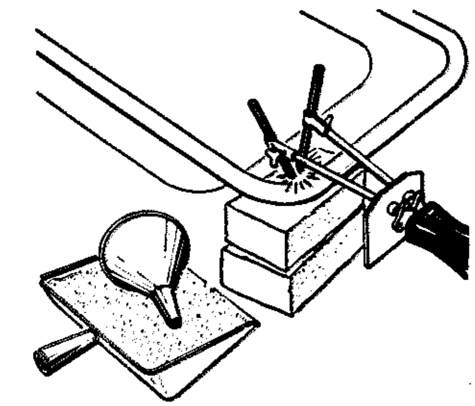
Fig. 13.27. Marking a pipe with water.



(Courtesy The Lincoln Electric Co.)

Fig. 13.28. Hammer the end of the pipe for simple welds.

If it is necessary to bend the pipe, a carbon arc torch may be used as the source of heat as shown in Fig. 13.29. A small-diameter pipe may be filled with sand and bent between two studs. With larger pipe, apply the torch on the inside of the pipe, in the direction of the bend. When the pipe becomes red, apply pressure and bend the pipe. The pipe will wrinkle as shown in Fig. 13.30. Continue to heat the inside of the pipe, in forward steps while bending, until the desired bend is obtained. The final product will look similar to the pipe shown in Fig. 13.30.



(Courtesy The Lincoln Electric Co.)

Fig. 13.29. A carbon arc torch may be used to heat pipe that is being bent.

(Courtesy The Lincoln Electric Co.)

Fig. 13.30. Wrinkle bending larger diameter pipe.

METAL INERT GAS (MIG) WELDING

Mig welding is another method of welding that may be used instead of the metal arc welding with stick electrodes, which was described in the preceding portion of this chapter. In metal arc welding with a stick electrode, the weld process is protected from the atmosphere by the gas shield produced from the coating on the electrode. In the mig process, the electrode is surrounded or shielded by an inert gas. The wire is fed through the tip of a welding gun, and the inert gas also flows through the tip of the welding gun, shielding the weld.

Why Use Mig Welding?—Mechanics in agriculture like to do mig welding because the welding process may be performed in all positions. The welding process usually produces no slag, or only a small amount of slag, which must be removed. It is often considered easier, with less learning time required to develop proficiency. The process produces a good-looking weld, and less smoke and fumes to annoy the welder. Faster travel speed is possible in mig welding. This faster travel speed produces a narrower heat area in the base metal, which results in less distortion.

The quality of the weld is high, and metal may be welded from 20-gauge metal to metal 1 inch thick.

The disadvantage of mig welding is the high cost of equipment. A mig welder often costs 10 times as much as a metal arc welder. The initial cost, therefore, is too high unless the quantity of welding to be done is considerable.

Procedures—For details regarding mig welding, consult the operating instructions provided by the manufacturer of the welder. Because of the high voltage involved, all safety precautions should be carefully observed.

TUNGSTEN INERT GAS (TIG) WELDING

In tig welding, a permanent non-consumable electrode, made of a metal which is primarily tungsten, is used, and inert gas is flowed around the weld puddle to avoid contamination of the molten metal from the atmosphere.

A tig welder may be used to weld aluminum, carbon steel, and stainless steel. A combination A.C./D.C. tig welding machine with a control to adjust current is available. Various types and sizes of tungsten electrodes are manufactured. The electrode size selected should correspond to the amount of heat used. As the amperage used is increased, the size of electrode used is increased.

Welding Aluminum—Switch the tig welding machine to D.C. straight polarity and strike an arc on carbon or copper. Melt the end of the electrode and stop. This will form a half-ball on the electrode. This half-ball will help keep the arc steady. The half-ball should be about the same diameter as the electrode.

Use the high-frequency setting on the tig welder for aluminum. Use argon as the shielding gas, with a 15 cubic feet per hour (cfh) flow, for aluminum up to 1/8 inch.

Before starting to weld, clean the aluminum. Alcohol or acetone may safely be used for cleaning aluminum. Practice is necessary to obtain a good bead. In tig welding the operator can control the heat, the torch, and the electrode. See a tig welding manual for details on making various types of welds when aluminum is the metal.

Welding Carbon Steels—Set the tig welder for straight polarity, direct current. Sharpen the end of the electrode to a point. This helps the operator control the arc and the size of the bead. Use the high-frequency setting to start the weld, but do not use a continuous high-frequency setting. The carbon steel being welded should be cleaned with a safe solvent to remove any grease film.

Considerable practice is required to obtain proficiency in obtaining good welds. Consult a tig welding manual for detailed instructions on making various tig welds when carbon steel is the metal.

Welding Stainless Steel—A tig welder permits the welding of stainless steel. Set the tig welder on direct-current straight polarity. Use a low-amperage setting on the machine. Use argon as the inert gas, with a flow of 10 cfh. Sharpen the point of the electrode. Use a rod for stainless steel. Use a slow travel speed. Watch the color of the stainless steel weld to tell whether or not too much heat is being

(Courtesy James F. Lincoln Arc Welding Foundation)

Fig. 13.31. A barrel stand, which makes the tilting of a barrel easy. (Constructed by Joe Rosenstiel, Illinois.)

used. A good weld will have a light red color or a mixture of light red and light purple. If the color is a dark purple, too much heat is being used.

Use the high-frequency setting to start the weld, but do not use a continuous high-frequency setting. See a tig welding manual for details on making various welds on stainless steel. Practice will be necessary to obtain the skill required for welding stainless steel.

SPOT WELDING

Spot welding is fusion welding. Fusion welding is the joining of two pieces of parent material, metal, without the addition of other metal from an electrode. Spot welding uses the same process as forge welding. In forge welding the two pieces of metal are heated to a plastic state and are joined together or fused by the pressure of hammer blows.

In spot welding, the heat is produced electrically and the pressure is applied by copper electrodes. No additional metal is added. The weld or weld spot produced is slightly larger than the size of the copper electrodes.

In agriculture, spot welds are frequently used to weld sheet metal parts on agricultural machines, such as sheet metal safety covers and shields.

Why Use It?—Spot welding is used because it is a fast method of welding light-gauge metals without objectionable distortion. It produces clean, uniform, and strong welds. It is an easy method of welding, a safe method of welding, and a reliable and accurate method of welding. It can be used for both repairing and constructing.

Procedures—For details regarding procedures of using a spot welder, consult the manufacturer's instructional manual.

CHAPTER 14

Welding by the Oxyacetylene Process[1]

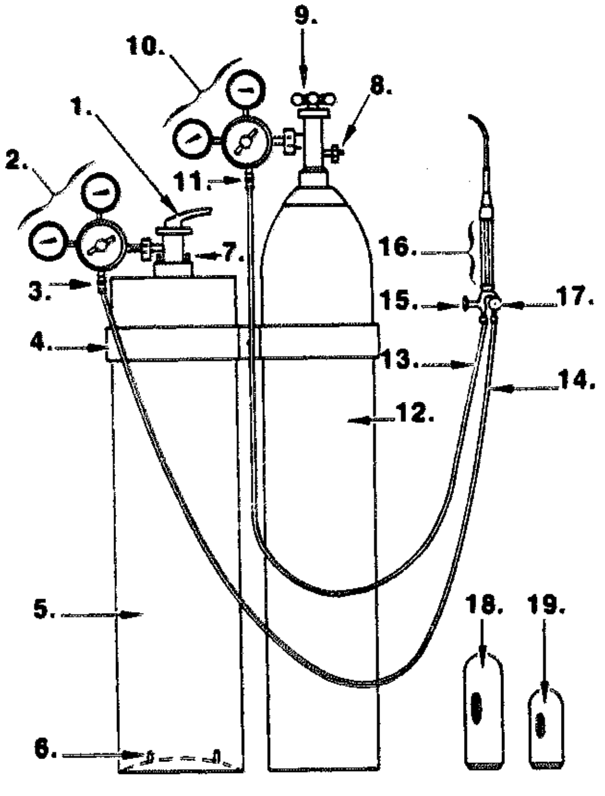
TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is meant by oxyacetylene welding?
2. Of what importance is oxyacetylene welding?
3. What gases are required in oxyacetylene welding, and what are their characteristics?
4. What are the names of the parts of an oxyacetylene welding outfit?
5. What precautions should be followed in oxyacetylene welding?
6. What procedure should be followed in preparing to weld?
7. What factors should be considered in selecting the welding tip to use?
8. What is meant by backfire? Flashback? How are they controlled?
9. What procedure should be followed in lighting and adjusting a welding blowpipe?
10. How should a blowpipe be turned off?
11. What welding materials are necessary?
12. How should the pieces to be welded be prepared?
13. What are the common types of welds? Welded joints? Welding positions?
14. How should the blowpipe be held?
15. What procedure should be followed in making melt strips?
16. What procedure should be followed in welding various metals?
17. What is meant by hard facing?
18. What cutting equipment is necessary?
19. What procedure should be followed in lighting and adjusting a cutting blowpipe?
20. How is the flame of a cutting blowpipe extinguished?
21. How is cutting done with an oxyacetylene flame?
22. How should oxyacetylene welding equipment be maintained?

[1]A considerable amount of information and most of the illustrations in this chapter have been supplied by the Linde Air Products Co.

INTRODUCTION

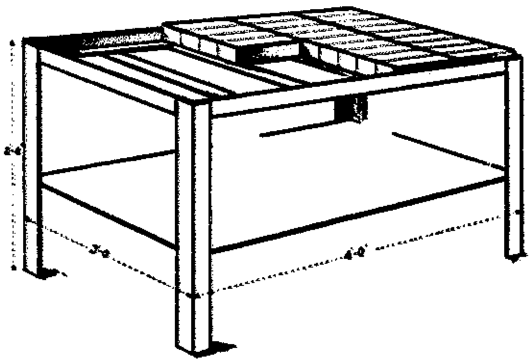
Oxyacetylene Welding—Oxyacetylene welding is a process by which two pieces of metal are joined together. An oxyacetylene flame is used to heat to their melting point the edges to be united, thus causing the edges to flow together. This is known as fusion welding. It may be accomplished with or without the addition of a filler metal. Metal from a welding rod, however, is usually added to the edges of the molten metal to produce a weld of the required strength and size. Fusion welding is also done with other pieces of welding equipment, such as spot welders and carbon arc torches.



(Courtesy Vocational Agriculture Service and Agriculture Education Division, University of Illinois)

Fig. 14.1. An oxyacetylene outfit: (1) acetylene cylinder valve wrench, (2) acetylene regulator, (3) acetylene safety check valve, (4) cylinder support, (5) acetylene cylinder, (6) plugs, (7) fusible plugs, (8) oxygen safety valve, (9) oxygen cylinder valve, (10) oxygen regulator, (11) oxygen safety check valve, (12) oxygen cylinder, (13) oxygen hose, green, (14) acetylene hose, red, (15) torch oxygen valve, (16) blowpipe handle, (17) torch acetylene valve, (18) acetylene cylinder cap, (19) oxygen cylinder cap.

Importance of Oxyacetylene Welding—Oxyacetylene welding has been used commercially for many years. It can be used in welding steel, malleable iron, cast iron, and many other metals. Only a relatively short time is required to train a farmer or a nonfarm agricultural worker to weld. Complex welding jobs, of course, should be done by an expert.



(Courtesy Modern Engineering Co., Inc.)

Fig. 14.2. An oxyacetylene welding table constructed with angle iron. The joints have been welded.

Gases Required in Oxyacetylene Welding—The two gases used in oxyacetylene welding are *oxygen* and *acetylene*.

Oxygen is a colorless and odorless gas which supports combustion and makes it possible for things to burn. It is stored and transported in steel cylinders. It should *not* be spoken of as *air*. *Acetylene* is a colorless gas with a characteristic odor. It is combustible, which means that it burns rapidly. It is stored in steel cylinders which are packed with a porous filler containing acetone, a liquid which acts like a sponge in absorbing acetylene gas. Consequently, the acetylene is dissolved in this liquid and remains in solution in the cylinder until the valve is opened and the free acetylene is removed.

Safety Precautions in Oxyacetylene Welding—There are a number of safety precautions which should be followed in oxyacetylene welding. Some of the more important of these precautions are as follows:

1. Avoid dropping tanks. Always wear goggles while you are welding.
2. Use a standard blowpipe, because mixtures of acetylene and oxygen, being explosive, should not be permitted except in approved apparatus having specially designed mixing chambers.
3. Avoid using acetylene or oxygen from a cylinder without first attaching a regulator to control and regulate the pressure.
4. Avoid the unnecessary release of free acetylene into the air, because acetylene is combustible.
5. Prevent oil or grease from coming in contact with oxygen under pressure or with any of the equipment through which the oxygen passes.
6. Wear gloves while you are welding.
7. Keep clothes, hands, and gloves free of grease and oil.
8. Weld in a well ventilated place, because clothing and other combustible material will readily ignite and burn in an oxygen-saturated atmosphere.
9. Avoid welding near combustible materials (flammable gases or liquids, waste, rags, paper, paint, wooden flooring, or partitions).
10. Avoid laying down a lighted blowpipe.
11. Do not substitute oxygen under pressure for compressed air.
12. Keep oxygen and acetylene cylinders in upright positions.
13. Keep the top of the acetylene cylinder free from tools and other articles

so that the acetylene can be quickly shut off in an emergency. Also, do not hang the blowpipe and hoses on the regulators.

14. Open cylinder valves slowly.
15. Keep the T-wrench in position on the valve of the acetylene cylinder while the cylinder is in use.

The importance of preventing oil or grease from coming in contact with oxygen under pressure cannot be overemphasized. According to the Linde Air Products Co., "When oxygen under pressure is imposed on readily combustible material such as oil or grease, particularly in a confined space, the heats of compression and friction may cause the material to burn. If such a fire starts in a confined space, as for example, inside a regulator, it may burn with sufficient speed to cause an explosion." The safety instructions supplied with a welding outfit should be carefully studied and followed.

PREPARING TO WELD

Oxyacetylene Welding Equipment—A typical welding outfit consists of the following:

1. A welding blowpipe
2. Several welding heads of various sizes
3. Acetylene regulator
4. Oxygen regulator
5. Oxygen hose (approximately 6 feet of lead hose for the oxygen and the acetylene)
6. Acetylene hose
7. Friction lighter
8. Gloves and goggles
9. Wrenches for the regulators and the blowpipe
10. Cylinder of acetylene and a valve T-wrench
11. Cylinder of oxygen
12. Section of chain (to fasten cylinders in place)

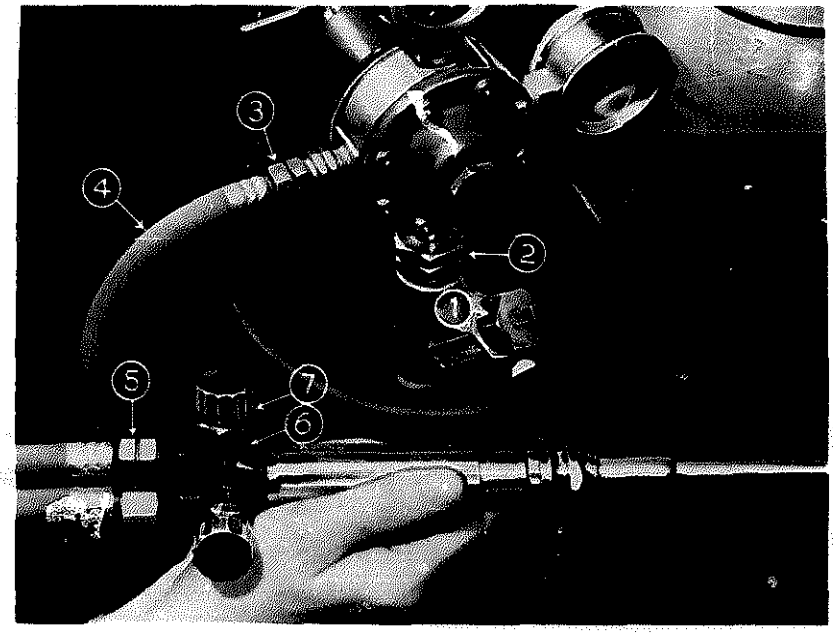
Using Oxyacetylene Equipment—The following method of handling oxyacetylene welding equipment is recommended by the Linde Air Products Co.

Connecting the Oxygen Regulator

1. Fasten cylinders together securely, in an upright position, to prevent their being accidentally knocked or pulled over. Use a chain, a rope, or another suitable device.
2. Unscrew and remove the iron cap that protects the oxygen cylinder valve.

   Note: This cap should be kept in place at all times when the cylinder is not in actual use. This will prevent damage to the valve if the cylinder should be overturned, and will help protect the valve from any oil or grease that might drip from overhead machinery or come from oily hands or gloves of workers.
3. Open the oxygen cylinder valve slightly and quickly close it. This is called "cracking" the valve.

   Note: When "cracking" the oxygen cylinder valve, stand behind and to the side of the valve opening so that oxygen does not blow over your clothing. Do not smoke! Cracking is done to blow out small particles of dust or dirt that tend to



(Courtesy Linde Air Products Co.)

Fig. 14.3. Test the acetylene system for leaks. The seven places numbered should be tested with soapy water.

collect in the opening of a cylinder valve. These particles, if blown into the regulator, may damage the mechanism or prevent efficient operation. Any mud or dirt found in the valve opening should be completely removed with a clean cloth before using the cylinder.

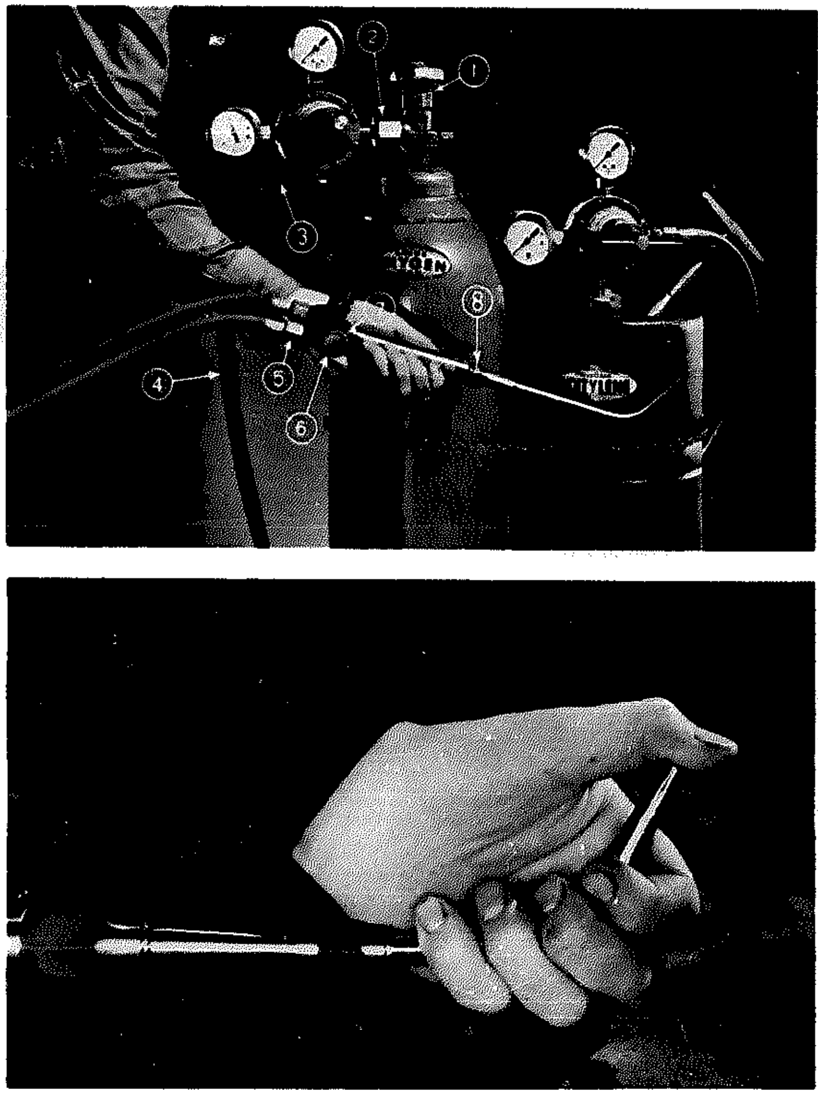
4. Remove the dust plug from the inlet connection of the regulator.
5. Make sure that the threads on the cylinder valve and on the regulator connection nut are clean and in good condition.
6. Connect the oxygen regulator to the cylinder. Use the regulator wrench—but never force a bad fit. Be sure the connection is tight.

Attaching the Hose Fittings

1. If the oxygen hose already has connection fittings attached, connect one end of the hose to the oxygen regulator. Use the regulator wrench to secure a tight connection.
2. If the fittings have not been attached, it is necessary to attach a set to each end of the hose. A set consists of a ferrule, a nipple, and a connection nut. To assemble them, first cut the end of the hose off squarely, then push the ferrule on the hose as far as it will go. Lubricating the outside surface of the end of the hose with spittle or soapy water (use Ivory soap or equivalent grease-free soap only) will make the ferrule go on more easily.
3. Next, put the nipple through the nut, and fasten both tightly to the regulator, using the regulator wrench.
4. Finally, twist the hose, with the ferrule attached, onto the nipple as far as it will go. A little spittle or soapy water on the nipple will make this operation easier. *Never use grease.*
5. Attach the green or black hose to the oxygen regulator and the red hose to the acetylene regulator. A V-fitting permits using two sets of hoses and blowpipes.

Opening the Oxygen Cylinder Valve

1. Before opening the oxygen cylinder valve, close the regulator by turning the screw counterclockwise until it feels loose.
2. Always stand to one side of and away from regulator gauges when opening the oxygen cylinder valve.
3. Suddenly releasing the high-pressure oxygen within the cylinder is likely to damage the regulator. Therefore, open the cylinder valve slightly, wait until the cylinder pressure gauge registers fully, and then open the cylinder valve all the way.
4. To remove dust or dirt from the inside of the oxygen hose, blow oxygen



(Courtesy Linde Air Products Co.)

Fig. 14.4. Test the oxygen system for leaks. Top—the eight places numbered should be tested with soapy water while the oxygen system is under pressure. Bottom—open the blowpipe oxygen valve and hold the thumb over the end of the tip to put the oxygen passages under pressure.

at a 5-pound pressure through the hose. Then close the oxygen regulator again.

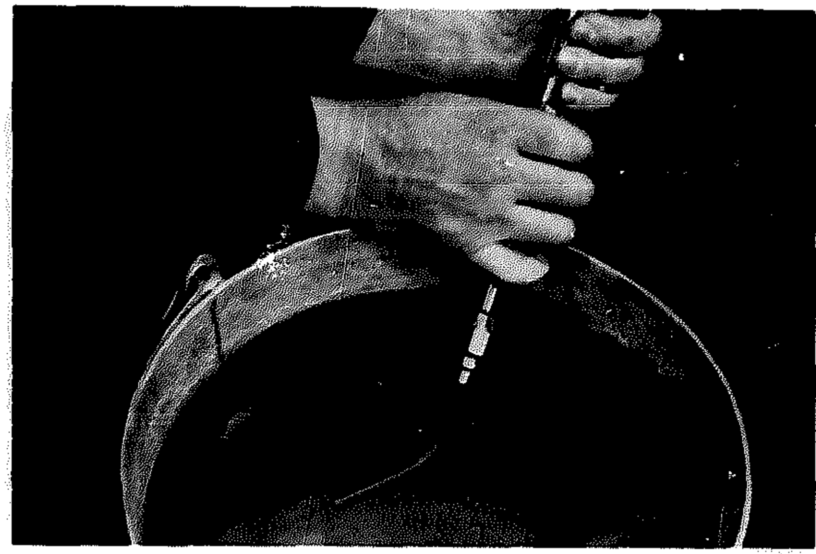
Note: The diaphragm in the regulator may be seriously damaged if oxygen under high pressure is released suddenly.

Connecting the Acetylene Regulator

1. To blow out any dust or dirt in the acetylene cylinder valve, "crack" the cylinder valve. Leave the cylinder T-wrench in the valve.

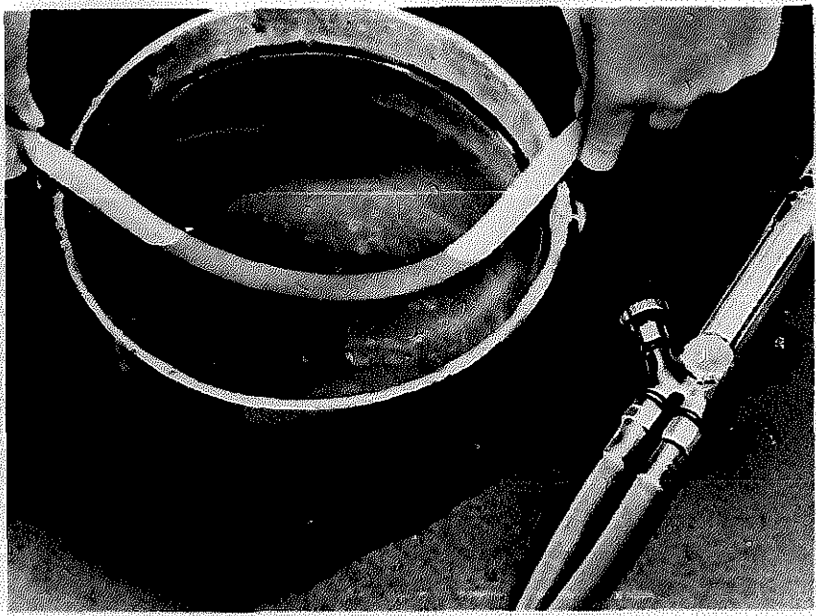
   Note: When cracking the acetylene cylinder, do not hold your face over or in front of the valve opening, because particles of dust or dirt (or even ice and snow, in winter) may be thrown out by the force of the escaping acetylene. And remember! Don't smoke when cracking an acetylene cylinder valve!
2. Position the regulator on the cylinder valve so that it will not be in the way of the T-wrench.
3. Tighten the union nut with the regulator wrench—but never force a bad fit. Threads are usually left-hand on acetylene equipment.
4. If the acetylene hose already has connection fittings attached, connect one end of the hose to the acetylene regulator. Use the regulator wrench and make a tight connection.
5. If hose fittings have not been attached, it is necessary to attach a set to each end of the hose. The procedure for attaching connection fittings to the acetylene hose is the same as the procedure for attaching fittings to the oxygen hose.

   Note: The fittings are also the same, except for the connection nuts. The acetylene nut has left-hand threads and a groove around it, and is marked "std. acet." The oxygen nut has right-hand threads and no groove, and is marked "std. oxy."
6. The acetylene hose should be blown free of dust or dirt, but this is done with *oxygen*—not *acetylene*. (This precaution is necessary to avoid releasing combustible acetylene into the air.) Therefore, disconnect the hose from the acetylene regulator.



(Courtesy Linde Air Products Co.)

Fig. 14.5. Test the blowpipe valve seat by holding the tip of the blowpipe in water with the pressure turned on the closed valves.



(Courtesy Linde Air Products Co.)

Fig. 14.6. Oxyacetylene equipment should be tested for leaks. To test a hose, place under water while it is under pressure. Bubbles will show the leaks.

7. Blow out the acetylene hose by holding one end against the end of the oxygen hose and blowing oxygen at a 5-pound pressure through both.
8. Now use your breath to blow the pure oxygen out of the acetylene hose. (This is a safety measure to prevent the possibility of an explosive mixture of acetylene and pure oxygen when acetylene is later passed through the hose.)
9. Reconnect the acetylene cylinder hose to the acetylene regulator.
10. Before opening the acetylene cylinder valve, be sure to close the regulator by turning the screw counterclockwise until it feels loose.
11. Open the acetylene cylinder valve slowly, one and one-half turns of the T-wrench—no more.

Connecting the Blowpipe

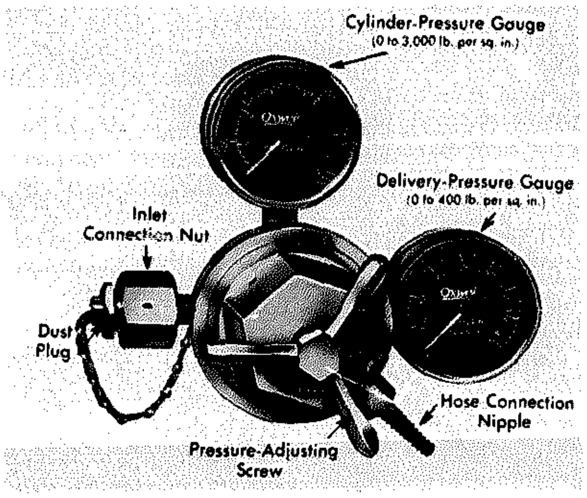
1. Attach oxygen and acetylene hose connections to the blowpipe. The oxygen connection has right-hand threads; the acetylene connection has left-hand threads.
2. If the blowpipe is new, tighten the packing nuts on the valve stems with the blowpipe wrench. (The manufacturer usually leaves these nuts loose to preserve the packing.)
3. Attach the welding head or tip to the welding blowpipe. Use the blowpipe wrench to make a tight connection.

Selecting the Correct Welding Tip—In selecting a suitable tip for the work to be done, study the instructions pertaining to tips supplied with the welding outfit. In general, a small tip should be selected for welding thin metal; a medium sized tip for welding metal of medium thickness, and a large tip for welding thick materials. The welding tips should be kept in a rack. They should not be thrown into a metal box, because this may damage the seat on the tips or batter the ends of the tips.

Controlling Backfire—Occasionally, especially after you first light the blowpipe, the oxyacetylene flame will suddenly go out with a loud snap or pop. This is called a *backfire*. It may be caused by any of the following:

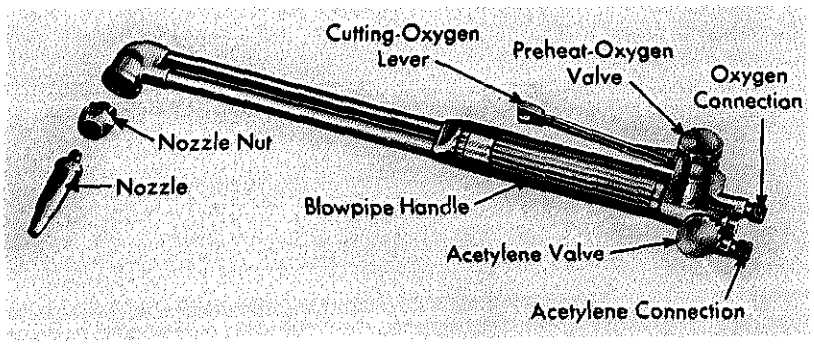
1. Insufficient acetylene or oxygen pressure.
2. A loose welding head.
3. Dirt on the seat of the head which fits into the blowpipe.
4. Touching the tip of the blowpipe against the work.
5. Overheating of the blowpipe tip. When the tip becomes overheated, which may be indicated by a popping noise, cool it by dipping it in water.

The above causes should be carefully checked to control backfires. Always make sure that the correct oxygen and acetylene pressures along with correct tip size are being used.



(Courtesy Linde Air Products Co.)

Fig. 14.7. One type of oxygen regulator.



(Courtesy Linde Air Products Co.)

Fig. 14.8. The various parts of a welding cutting head.

Controlling Flashback—A *flashback* is a fire inside the blowpipe. After the blowpipe has been lighted, the flame may disappear, followed almost immediately by any of the following:

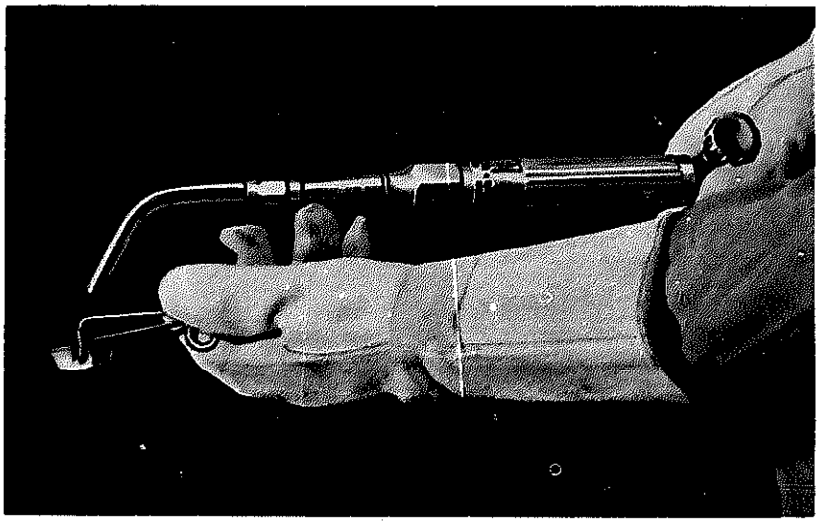
1. A squealing or hissing noise inside the blowpipe.
2. Sparks from the blowpipe.
3. Smoke coming from the blowpipe.

Checkvalves that prevent flashbacks from traveling into the hoses and the regulators are available for the ends of the hoses. In case of flashbacks the following should be done:

1. Close blowpipe oxygen and acetylene valves.
2. Close oxygen and acetylene regulators.
3. If the hose has not been damaged, wait a minute or two, then relight the blowpipe.

Lighting and Adjusting a Welding Blowpipe—Since blowpipes vary in internal construction, it is best to follow the manufacturer's instructions for lighting the blowpipe. The working pressures to use are supplied with the instructions. Some blowpipes are designed to have acetylene and oxygen pressures of approximately 1 pound per square inch for welding thin metal and pressures of approximately 5 pounds for thicker metals. The *safest procedure*, however, is to follow the pressures recommended by the manufacturer. The working pressure will be determined by the thickness of the metal to be welded and the size of the welding tip. If the manufacturer's instructions are not available, the beginner should use the following procedure for lighting a blowpipe:

1. Place goggles on your forehead.
2. Open the oxygen valve of the blowpipe.



(Courtesy Linde Air Products Co.)

Fig. 14.9. Always use a friction lighter to light a blowpipe.

3. Open the oxygen cylinder valve, and set the regulator at the correct welding pressure.
4. Close the oxygen valve of the blowpipe.
5. Check to see that the blowpipe acetylene valve is closed.
6. Open the valve of the acetylene cylinder, and set the regulator at the correct welding pressure.
7. Put on gloves.
8. Lower the goggles over your eyes.
9. Open the acetylene valve of the blowpipe one-fourth turn.
10. Open the oxygen valve of the blowpipe slightly.
11. Strike the friction lighter at the tip of the blowpipe.

If there is difficulty in getting the flame started, the pressure may be too high or there may be too much oxygen in the mixture. Both valves of the blowpipe should be closed and readjusted, and the blowpipe lighted again. If the flame burns some distance from the end of the blowpipe tip, there may be too much acetylene in the mixture. In this case the acetylene valve of the blowpipe should be closed slightly. In the case of *backfiring*, open the acetylene valve a little more and relight. In the case of a *flashback*, the blowpipe and pressure should be shut off at once.

Adjusting the Flame—There are three types of oxyacetylene welding flames: *neutral*, *oxidizing*, and *carburizing*. The neutral flame is the flame usually used for welding. The oxidizing flame is caused by an excessive amount of oxygen which produces a short white inner cone and a short envelope flame. A slightly oxidizing flame is used in the welding of bronze, in brazing operations, and in the welding of brass. The carburizing flame is caused by an excessive amount of acetylene. It has a long bluish outer flame. It is so named because it adds carbon to the welding surface. It is used in some types of welding and in hard facing.

The following procedure is suggested for adjusting the flame:

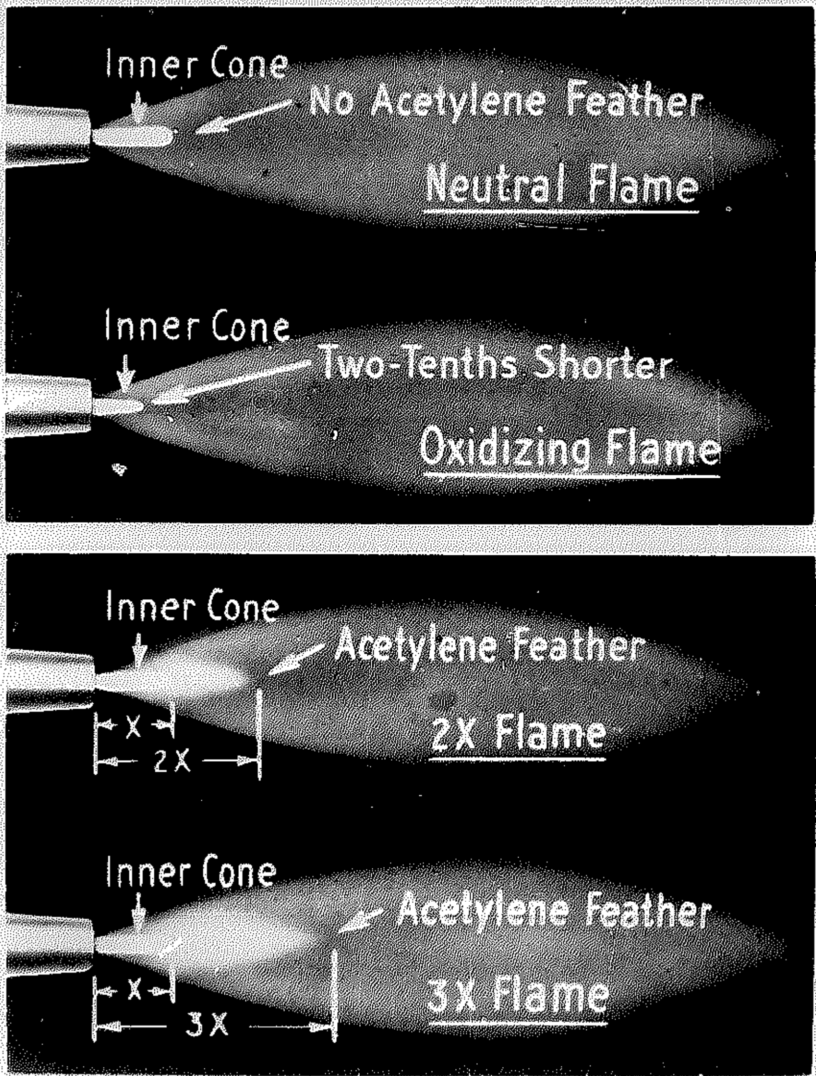
1. Light the blowpipe. There is usually a long yellow flame which must be adjusted to a neutral flame before welding.
2. Open the oxygen valve of the blowpipe gradually 1½ turns. As more oxygen is added, the flame will change from yellow to yellow and blue.
3. Close the acetylene valve of the blowpipe slowly, thus decreasing the flow of acetylene until the yellow zone becomes smaller, finally disappearing. The flame should then be neutral and have a brilliant white inner cone and a bluish outer envelope.

The flame may need to be adjusted from time to time while the blowpipe is being used.

Turning Off the Flame Temporarily—It is desirable to close the acetylene valve first in turning off a flame. When the oxygen is closed first, a backfire or flashback may occur, leaving a sooty deposit in the blowpipe which may cause trouble later.

The following procedure is suggested for turning off the blowpipe:

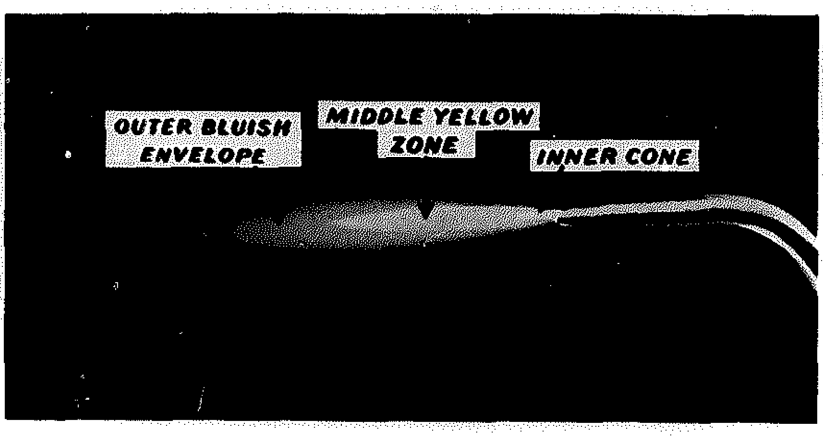
1. Close the acetylene valve of the blowpipe.
2. Close the oxygen valve of the blowpipe.
3. Close the acetylene regulator cylinder valve.
4. Close the oxygen regulator cylinder valve.



(Courtesy Linde Air Products Co.)

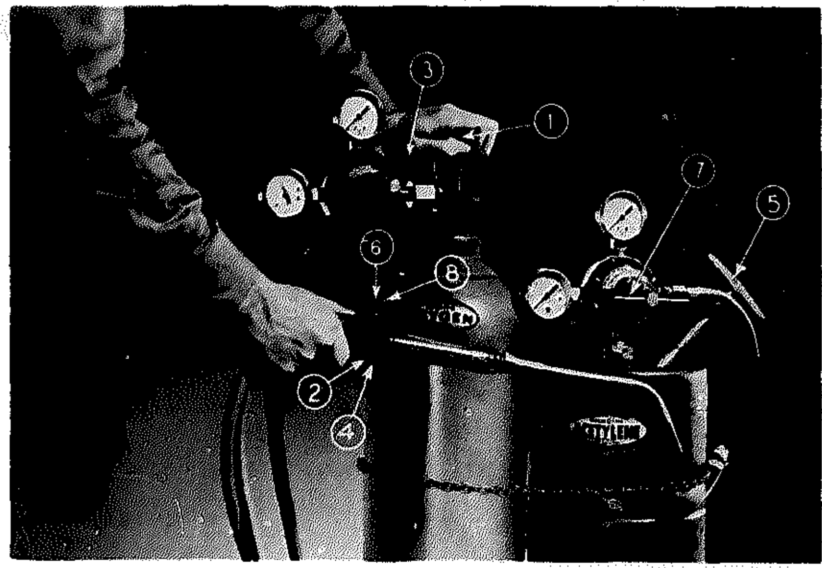
Fig. 14.10. Top—neutral and oxidizing flames. Bottom—excess, "carburizing" or "reducing," flames.

5. Open the acetylene valve on the blowpipe to drain the hose and release all pressure from the hose and the regulator.
6. Turn out the pressure-adjusting screw of the acetylene pressure regulator by turning it counterclockwise.
7. Close the blowpipe acetylene valve.
8. Open the blowpipe oxygen valve to drain the hose and release all pressure from the hose and the regulator.
9. Turn out the pressure-adjusting screw of the oxygen pressure regulator by turning it counterclockwise.
10. Close the blowpipe oxygen valve.
11. Close the shut-offs on both the acetylene and oxygen cylinders.



(Courtesy Linde Air Products Co.)

Fig. 14.11. During the adjustment of a blowpipe to a neutral flame, three distinct flame zones are visible.

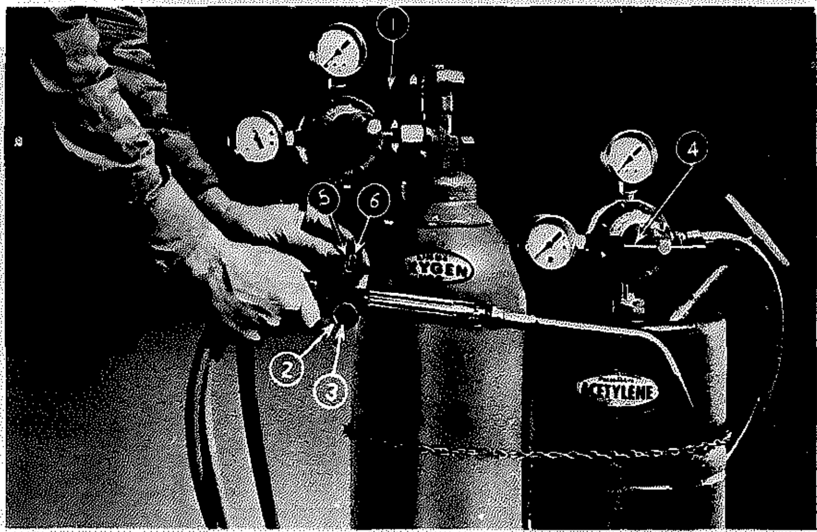


(Courtesy Linde Air Products Co.)

Fig. 14.12. The order of things that need attention when work is stopped for more than 10 minutes. (1) Close the oxygen cylinder valve. (2) Open the blowpipe oxygen valve until all pressure goes down to zero. (3) Turn the oxygen regulator handwheel out until it is loose. (4) Close the blowpipe oxygen valve. (5) Close the acetylene cylinder valve. (6) Open the blowpipe acetylene valve until all pressure goes to zero. (7) Turn the acetylene handwheel out until it is loose. (8) Close the blowpipe acetylene valve.

Selecting Welding Materials—The following is a partial list of welding materials and equipment needed to supplement the oxyacetylene welding outfit:

1. A welding table with a brick or clay top.
2. A supply of fire brick.
3. Fire clay, carbon putty, or cement.



(Courtesy Linde Air Products Co.)

Fig. 14.13. The order of turning things on and off when work is stopped for a few minutes. (1) Turn the oxygen regulator handwheel out until it is loose. (2) Open the blowpipe oxygen valve. (3) Close the blowpipe oxygen valve. (4) Turn the acetylene regulator handwheel out until it is loose. (5) Open the blowpipe acetylene cylinder valve. (6) Close the blowpipe acetylene valve.

4. A power grinder.
5. A machinist's bench vise.
6. Hammers, cold chisels, pliers, and files.
7. Welding rods.
8. Wedges, V-blocks, and clamps (optional).
9. Welding fluxes.
10. Metal for welding.

A flux is a chemical compound used to prevent the formation of an oxide coating on the metal being welded and to cause the welds to run together. The same flux cannot be used for welding all metals. When using a steel welding rod, it is possible to weld steel and wrought iron without a flux. When using a cast iron welding rod, a flux, however, is necessary. It is advisable to secure flux and other welding supplies from reputable manufacturers and to follow their suggestions in selecting the proper flux and welding rod to use for a specific job.

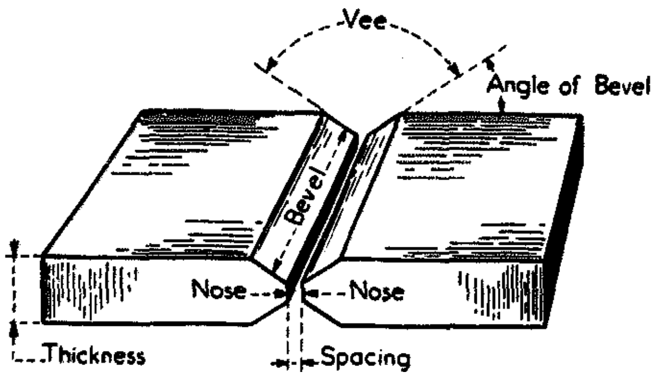
Welding rod is necessary in most welding to add metal to the weld; hence it is sometimes called filler rod. Filler rod is made of the same kind of metal as the base metal and usually contains other materials to help purify and strengthen the metal, resulting in a stronger weld. Welding rod may be purchased in sizes such as $^1/_{16}$ inch, $^3/_{32}$ inch, $^1/_8$ inch, $^3/_{16}$ inch, and $^1/_4$ inch. Small welding rod is usually used for light welding, and heavier rod is required for welding thicker metals. For example, $^1/_{16}$-inch welding rod may be used for welding sheet metal up to $^1/_{16}$ inch in thickness.

Preparing Pieces to Be Welded—When possible, it is desirable to provide by cutting, grinding, filing, or buffing a clean, bright surface for welding because clean, bright surfaces weld more easily than dirty or oxidized surfaces. All rust and scale should be carefully removed before welding, because such impurities have a tendency to weaken a weld. The edges of metals over $^1/_8$ inch should be cut to form a V, with approximately a 45-degree angle, to permit the complete fusion of the two pieces of metal. If the pieces are $^3/_8$ inch or more in thickness, it is usually desirable to cut a V on both the top and bottom sides of the two pieces of metal being welded. The pieces to be welded should be placed about $^1/_{16}$ inch apart to provide for the expansion and contraction of the metals and to permit the weld to penetrate deeply, if possible, through to the bottom edges of the pieces of metal.

Common Types of Welds—The two most common types of welds are the *butt weld* and the *fillet weld*.

Types of welded joints frequently used are the *butt joint, tee joint, corner joint, lap joint*, and *edge joint*.

The common welding positions are *downhand, horizontal, vertical, and overhead*. The downhand weld is used most frequently, and it is the easiest weld to make. See figures in Chapters 13 and 14 for illustrations of the welding positions, the types of welded joints, and the types of welds.



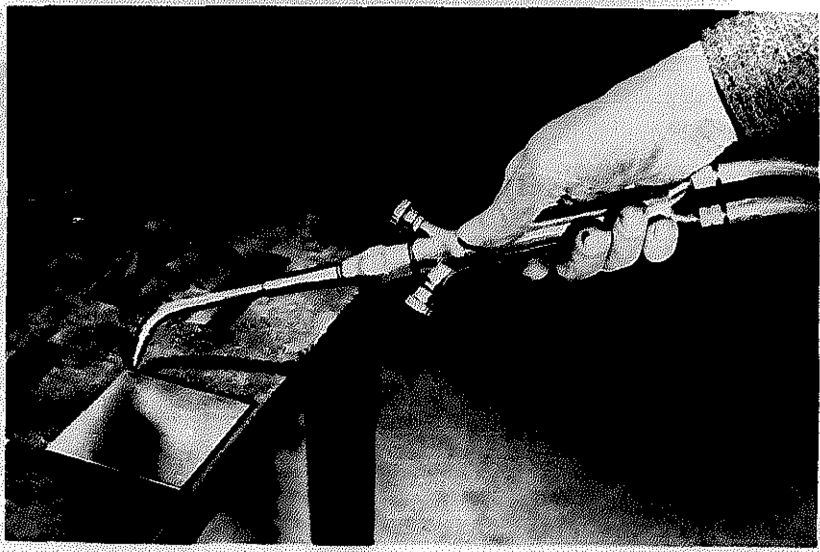
(Courtesy Linde Air Products Co.)

Fig. 14.14. Terms used in describing a joint to be welded.

Holding the Blowpipe—The blowpipe is usually held like a hammer or fishing pole when the operator is welding while standing. It is usually held like a pencil when the operator is welding while seated. See Figs. 14.15 and 14.16. However, it is desirable for the operator to hold the blowpipe in a comfortable way. If welding is done while the operator is sitting, the hose should pass over the back of the hand and rest on the floor in order to relieve the hand of much of the weight of the hose.

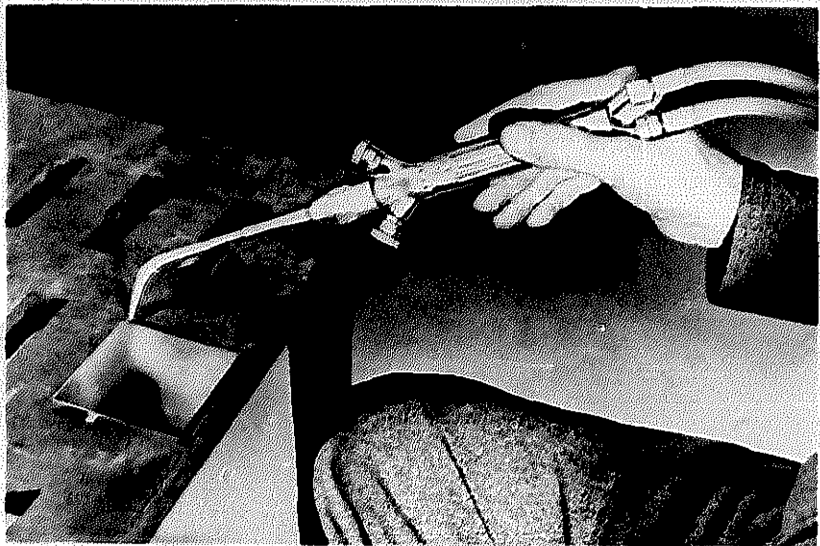
The blowpipe position should be as follows:

1. Hold the blowpipe so that the tip will be inclined at a 45-degree angle to the surface to be welded, as shown in Fig. 14.17.
2. Hold the blowpipe so that the tip will point directly along the line of the weld.



(Courtesy Linde Air Products Co.)

Fig. 14.15. When standing, hold a light-duty blowpipe like a hammer or fishing pole.



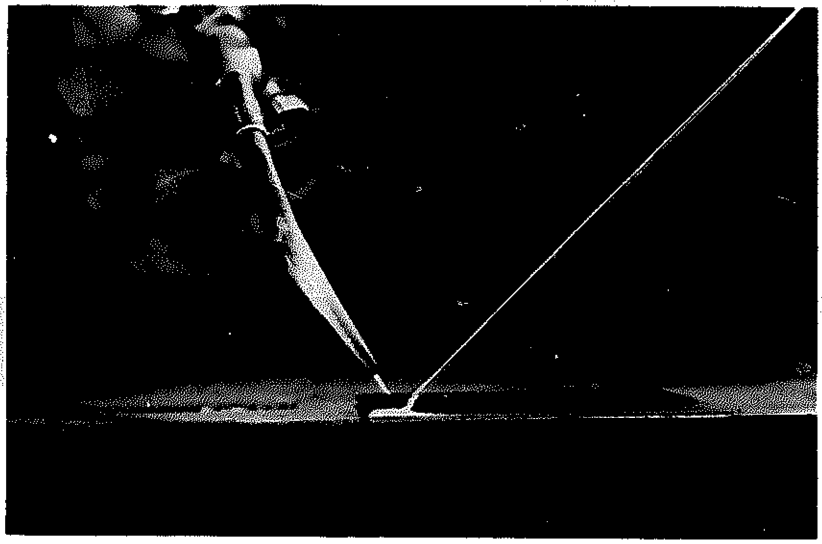
(Courtesy Linde Air Products Co.)

Fig. 14.16. When seated, hold a light-duty blowpipe like a pencil.

5. Hold the tip about 1/4 inch above the surface of the metal to be welded, thus permitting the inner cone of the flame to be about 1/8 to 1/16 inch from the metal.

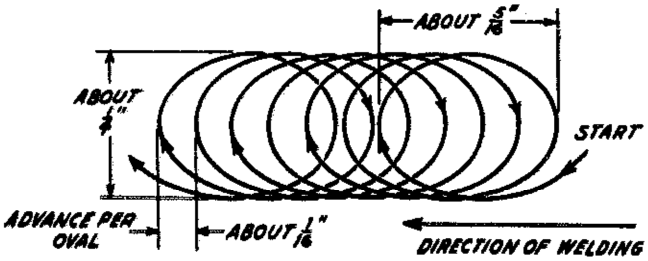
Using the Blowpipe—Before lighting the blowpipe, practice holding it. Also practice the motion used in welding. The blowpipe may be moved in a straight line, in a zigzag, or in a circular motion. The circular motion is used most frequently. The following blowpipe motion is suggested:

1. Move the blowpipe in a series of connected ovals in a left-to-right direction.
2. Move the blowpipe along the line of welding.
3. Advance each successive oval about $1/16$ inch.
4. Make the oval about $1/4$ inch wide and $5/16$ inch long.



(Courtesy Linde Air Products Co.)

Fig. 14.17. The correct position of a blowpipe and rod when the rod is lowered.



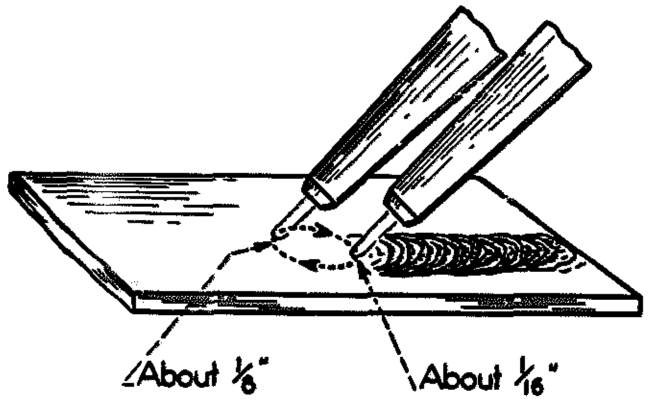
(Courtesy Linde Air Products Co.)

Fig. 14.18. The blowpipe motion frequently used.

Making Melt Strips[2]—The first step in learning to weld steel with an oxyacetylene welder is to learn how to melt the base metal and how to control the molten puddle. A piece of 16-gauge sheet steel may be used for this purpose. The piece of steel should be placed with the edge which is farthest from the operator over an opening in the welding table. If the table has a solid top, place the piece of metal on two other pieces of metal so an air space will be formed below it. This prevents the heavy metal top of the table from conducting the welding heat away

[2]Some operators prefer to call these "puddle strips."

from the steel. The blowpipe should be moved over the metal in a straight line, with a circular motion, melting the surface to form paths of a uniform width. These paths are designated as *puddle* or *melt strips*. A student should practice making melt strips before attempting to weld. (See Fig. 14.19.)



(Courtesy Linde Air Products Co.)

Fig. 14.19. This view of the blowpipe motion shows how the flame is lifted at the front edge of the circle.

The following procedure for making a melt strip is suggested:

1. Place a piece of prepared metal in the proper position.
2. Put on goggles.
3. Select the correct size tip, light the blowpipe, and adjust to a neutral flame.
4. Start the flame at the right-hand edge of the steel piece, and form a molten puddle about 1/4 inch in diameter and about 1/8 inch from the edge of the piece of steel.
5. Move the blowpipe slowly forward in a straight line, using a circular motion, and hold the blowpipe at a 45-degree angle to the metal so that the end of the inner cone of the flame is 1/16 inch above the steel. If necessary, support the right hand with the left hand
6. Maintain a puddle 1/4 inch to 3/8 inch in diameter, advancing the blowpipe about 1/16 inch with each oval completed.
7. Raise the blowpipe slightly as the flame passes along the front edge of the puddle.
8. Avoid burning a hole through the steel when approaching the opposite edge of the piece by flicking the flame away from the puddle.
9. Turn off the flame when the melt strip is completed, and examine the work before repeating the process.

Making a Bead—After a person has learned how to control the molten puddle by making melt strips, learning how to make a bead comes next. When molten metal from a welding rod is added to the puddle as it progresses across a piece of metal, it is called *making a bead*. This is not actually welding, because the bead of weld metal is deposited on the surface of the steel and does not join two pieces of metal together.

The following procedure is suggested for making beads:

1. Lay a piece of 16-gauge metal over a hole in the table top.
2. Select the correct size welding tip.
3. Select the proper welding rod.
4. Put on goggles.
5. Light the blowpipe and adjust to a neutral flame.
6. Start at the right-hand edge of the metal about 1/8 inch from the edge and melt the surface.
7. Hold the welding rod in the left hand (right-handed person) at a 45-degree angle so that the end of the rod will be within the outer envelope of the flame.
8. Move the blowpipe in a circular motion and move the welding rod in an up-and-down motion, thus synchronizing the motion of the flame and the rod as the puddle is formed. The beginner should practice this up-and-down motion of the rod before attempting to make a bead.
9. Maintain a molten puddle about 1/4 inch in diameter and move the rod and blowpipe slowly, straight forward about 1/16 inch with each oval motion of the blowpipe.
10. Raise the rod out of the way of the flame to permit the flame to heat the metal ahead of the bead.
11. Lower the rod so that the flame will melt it, causing the welding rod to flow into the molten puddle. The end of the welding rod should touch the puddle on the downward stroke. The rod should not drip into the puddle.
12. Repeat the synchronized motions of the blowpipe and the rod until a bead is completed across the piece of metal.
13. Turn off the flame and examine the bead.

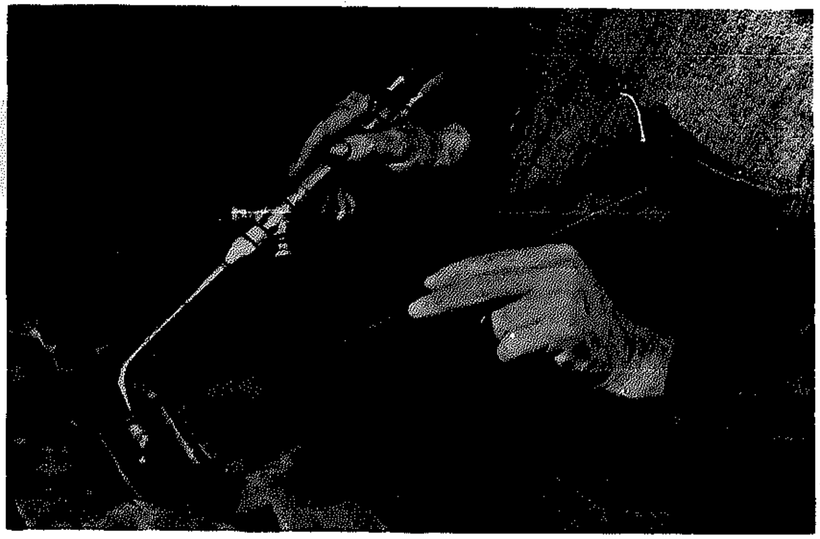
Correct timing of the circular motion of the blowpipe and the up-and-down motion of the welding rod is important. A hole may be melted through the metal sheet if the timing is too slow. If the timing is too fast, there will be insufficient melting of metal and rod. If the base metal is not hot enough, the end of the rod may stick to it.

WELDING TECHNIQUES

Welding Steel—After a person has learned how to make melt strips and beads, he or she is ready to make a fusion weld. Two pieces of 16-gauge sheet steel and 1/16-inch welding rod can be effectively used in learning how to weld steel. The following procedure for welding 16-gauge sheet steel is suggested:

1. Prepare two pieces of metal approximately 1½ by 3 inches in size, and place them on a welding table so that the 3-inch edges are adjoining.
2. Space the pieces so that the edges of the metal are 1/16 inch apart at one end and approximately 1/8 inch apart at the other end. These distances provide for the contraction of the cooling metal.
3. Select a welding rod, usually 1/16 inch mild steel; put on goggles and light the blowpipe.
4. Make a tack weld at each end of the pieces of metal to hold them together.
5. Place the tack-welded pieces on a welding table so that the space between the pieces will be over a hole in the table top. The narrow spacing between the pieces of metal should be to the right of the person doing the welding.

6. Pick up the welding rod and blowpipe and start welding at the right-hand side, using the motion followed in making a bead. To permit greater ease in using, the end of the welding rod may be heated and bent about 6 inches from the end to a 135-degree angle. The tip on the blowpipe should be directly over and in line with the bead being formed.
7. Place the end of the rod in the molten area to form a puddle as soon as the metal starts melting. The rod is used to fill the area between the pieces of metal and to give strength to the weld. *Be careful not to use more rod than is needed for a satisfactory job. Make sure parts are properly fused together.*

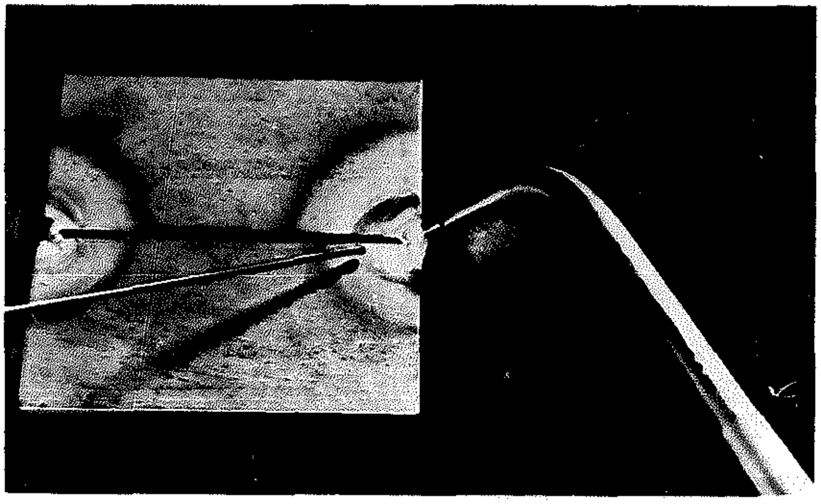


(Courtesy Linde Air Products Co.)

Fig. 14.20. Push the rod through your hand by pressing it with your body.

(Courtesy Linde Air Products Co.)

Fig. 14.21. An example of a good weld.



(Courtesy Linde Air Products Co.)

Fig. 14.22. Tack welds.

8. Dip the rod into the puddle as the flame starts upward, and remove the rod from the puddle as the flame moves near the rear of the puddle.
9. Continue straight across the metal until the second tack weld is reached. Remelt the tack weld into the advancing puddle.
10. Turn off the flame and examine the weld.

A beginner should practice such welds until satisfactory skill is developed.

Welding Cast Iron—Cast iron may be welded by either fusion welding or bronze-welding. Fusion welding is required when the color of the base metal and the weld metal must match. The vast majority of cast iron jobs, however, are bronze-welded. Many iron castings are made of malleable iron which require bronze-welding.

The welding of cast iron, using the fusion method, is very similar to welding steel except that a cast iron filler rod and a special welding flux are used. A beginner should start welding on thin pieces of cast iron. The following procedure is suggested:

1. Take two pieces of 1/8-inch cast iron; clean and bevel the edges to form a V.
2. Select the proper flux and a cast iron welding rod.
3. Put on goggles; light and adjust the blowpipe.
4. Tack the ends of the cast iron pieces together.
5. Begin to weld on the right-hand side.
6. Heat the cast iron to its melting temperature.
7. Heat the end of the welding rod to a red heat, dip in flux, and insert the end of the rod into the molten puddle of cast iron.
8. Continue to weld. Follow the procedure suggested in welding steel, moving the blowpipe in a circular motion and the rod in an up-and-down motion. Dip the rod in flux from time to time.

Because the base metal must be melted in fusion welding, large pieces of cast iron require preheating. Since bronze-welding does not require the melting of the base metal, it is generally preferred to fusion welding, especially in welding heavier pieces. Some machine parts can be repaired in place by bronze-welding but have to be dismantled for fusion welding.

Bronze-Welding—Bronze-welding has some advantages over fusion welding. Since bronze-welding does not require a melting heat, it can be done faster than fusion welding, thus saving time and gas. A "sweating temperature" is required for a bronze weld. Bronze-welding produces considerably less expansion and contraction of parts than fusion welding. The base metal should be heated to a bright salmon red color. The bronze rod should not remain in the inner cone of the flame, and the inner cone of the flame should not stay in one spot on the molten bronze because the intense heat will burn the bronze. The temperature of the base metal should be slightly higher than the melting point of the bronze.

A beginner should start bronze-welding with small pieces of cast iron or steel. The following procedure is suggested:

1. Bevel two cast iron parts to form a V groove.
2. Place the two pieces on a welding table so that they are spaced $^1/_{16}$ inch apart at the right end and $^1/_4$ inch apart at the left end. This spacing between the two pieces allows expansion and contraction of the metal.
3. Adjust the blowpipe to a slightly oxidizing flame.
4. Warm the pieces along the entire V, then heat to a red heat an area about 3 inches in diameter at the starting end.
5. Heat the bronze-welding rod and dip it into bronze-welding flux.
6. Melt a little bronze rod on the surface of the V. If it rolls off, the base metal is not sufficiently warm. If it tends to bubble or run around like drops of water on a hot stove, it is too hot. If the base metal is the proper temperature, the bronze metal will spread out evenly and adhere to it. It is important to cover the entire surface of the V with bronze. This is called *tinning*.
7. Apply more bronze rod, which has been dipped in flux, until the top of the V is reached.
8. Apply additional layers of bronze until a weld of the desired size is obtained. The top surface of the weld should be rippled.
9. Allow the metal to cool slowly at room temperature.

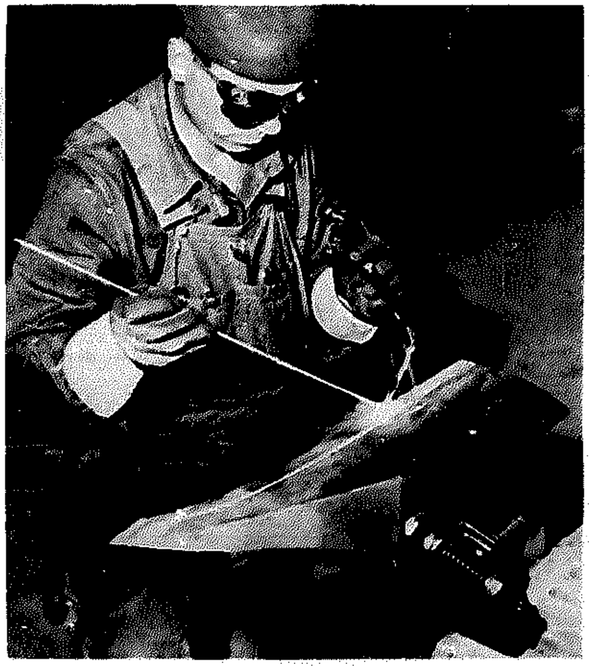
Welding Nonferrous Metals—The oxyacetylene process may be used to weld white metal (zinc die cast), aluminum, copper, and brass.

Many truck parts, such as carburetor parts and door handles, are white metal. In welding white metal, it is usually advisable to prepare a "timbers dam" because white metal is very weak when hot.

Much agricultural equipment, such as lawn mower castings, small engine parts, and power hand tools, is made of aluminum or has aluminum parts. Aluminum oxidizes rapidly in a molten condition, conducts heat readily, and expands considerably when heat is applied. It melts at approximately 1,200 degrees Fahrenheit. For aluminum, the tig welder is ordinarily used instead of the oxyacetylene outfit.

Brass is an alloy of copper and metals such as zinc and tin which have lower melting points than copper. In welding, these lower melting metals will be burnt out if too much heat is used. Brass being welded must be supported properly, or the heated area will collapse. The cone of the flame should be slightly above the metal as it is brought to fusion heat level. A manganese bronze-welding rod is often used.

Hard Facing—The process of applying a very hard coating to parts of machines that wear away rapidly is called hard facing. Parts such as plow shares or cultivator shovels may be hard-faced with a special material to make them last longer. The process can be used on either new or old parts. Some of the hard-facing materials are Stellite, Stoodite, and Haystellite. It is claimed that such materials will outlast steel from 2 to 25 times. Special braze torches are available for hard facing.



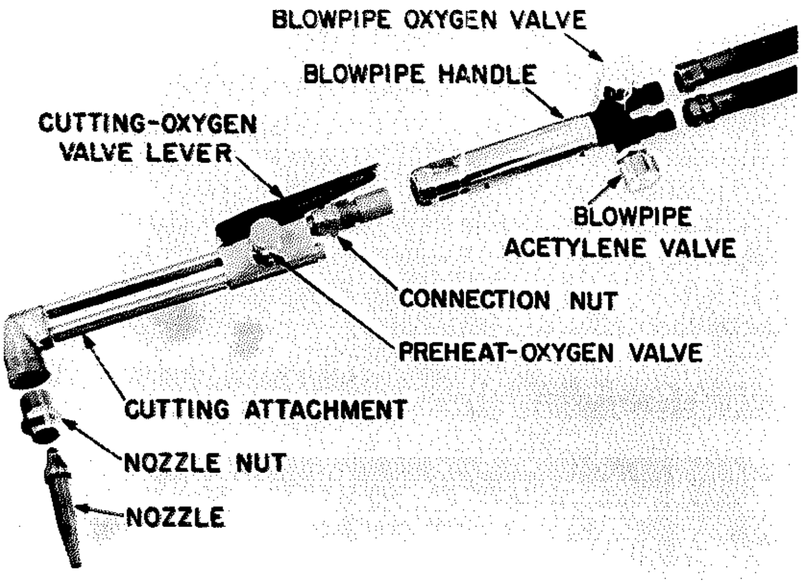
(Courtesy Linde Air Products Co.)

Fig. 14.23. Hard facing a plow share.

CUTTING

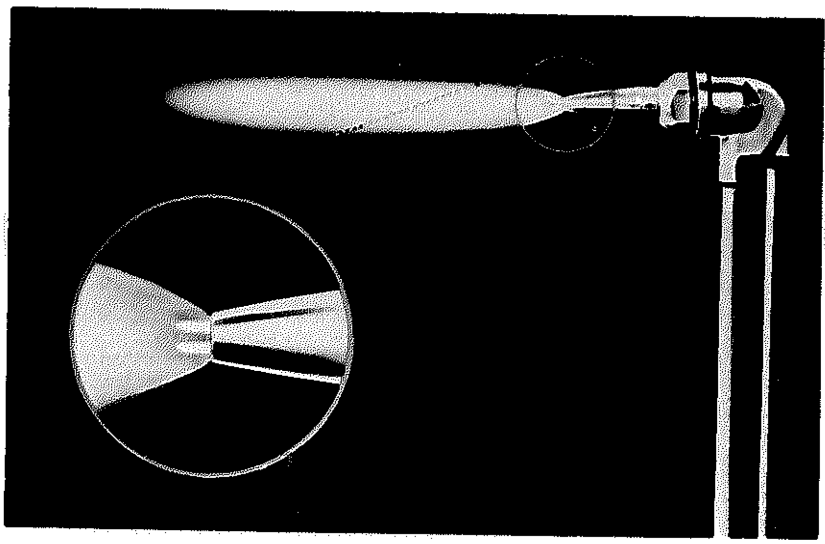
Cutting Equipment—For cutting metal, a cutting blowpipe is needed instead of a welding blowpipe. See Fig. 14.24. The tip of a cutting blowpipe has several small holes located around a larger hole in the center of the tip. The small holes permit an oxyacetylene mixture to pass through them, and they provide flames to preheat the metal before it is cut. The large hole in the middle of the tip supplies a jet of oxygen under high pressure that does the actual cutting after the metal is preheated to a red heat.

Lighting and Adjusting a Cutting Blowpipe—In lighting a cutting blowpipe, follow the procedures recommended by the manufacturer. This is important



(Courtesy Linde Air Products Co.)

Fig. 14.24. A cutting attachment with the principal parts named.



(Courtesy Linde Air Products Co.)

Fig. 14.25 A cutting torch's neutral flame.

because blowpipes vary in internal construction and, consequently, require different methods of lighting. If you are a beginner and the manufacturer's instructions are not available, the following procedure may be used in lighting a blowpipe:

1. Open the blowpipe preheat-oxygen valve.
2. Open the blowpipe cutting-oxygen valve by pressing down the lever.

3. Open the oxygen cylinder valve and set the oxygen regulator at the correct pressure for working. (This will depend on the metal to be cut and the size of the cutting nozzle used.)
4. Release the cutting-oxygen valve lever.
5. Close the blowpipe preheat-oxygen valve.
6. Check to see that the blowpipe acetylene valve is closed.
7. Open the acetylene cylinder valve and set the acetylene regulator at the correct pressure for welding.
8. Put on gloves and goggles.
9. Open the blowpipe preheat-oxygen valve slightly.
10. Open the blowpipe acetylene valve ½ turn.
11. Strike the friction lighter at the tip of the nozzle.
12. Adjust to a neutral flame by turning the preheat-oxygen valve to the required position.
13. Depress the cutting-oxygen valve lever and check to see that a neutral flame is present. If necessary, adjust the preheat-oxygen valve until a neutral flame is secured when the cutting-oxygen valve is open.

If in using the cutting blowpipe a *backfire* or *flashback* occurs, it should be controlled the same as in welding. See previous sections of this chapter on controlling flashbacks and backfires.

Extinguishing the Cutting Blowpipe Flame—The following procedure is suggested for extinguishing the flame of a cutting blowpipe if it will not be used for 20 minutes or more:

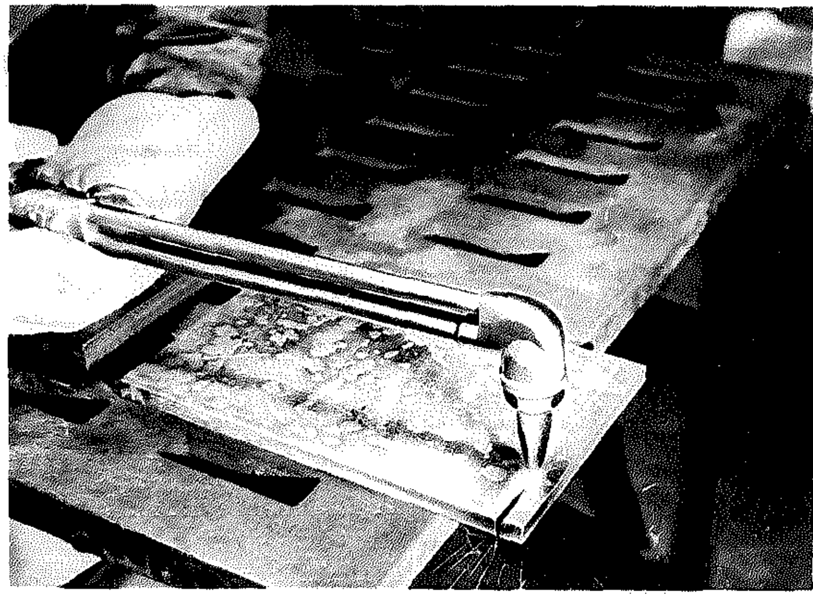
1. Close the blowpipe acetylene valve.
2. Close the blowpipe preheat-oxygen valve.
3. Close valves on the oxygen and acetylene cylinders.
4. Open blowpipe valves to drain all acetylene and oxygen from the equipment.
5. Close both regulators by turning the screws on them until they are loose.
6. Close the blowpipe valves. Do not close the valves too tightly.

Cutting with an Oxyacetylene Flame—The cutting is done by the oxygen. When it strikes a preheated metal surface, it causes the metal to burn or oxidize. The oxygen combines with the heated iron to form a molten metal and slag which flows or is blown away, exposing more metal to the oxygen jet.

A narrow *cut* or *kerf* is formed as the cutting blowpipe is moved across a piece of metal, cutting as it goes. A beginner should start by cutting a piece of ordinary steel about ½ inch thick, because ordinary steel is easy to cut with an oxyacetylene cutting blowpipe. The recommendations of the manufacturer relative to the oxygen pressure in the regulator should be followed. A higher oxygen pressure is required for cutting than for welding.

Cutting Steel—The following procedure is suggested for cutting ordinary steel:

1. Prepare a piece of steel approximately ½ inch thick and 12 inches wide. Clean it thoroughly.
2. Make a chalk line or mark a line with a center punch about 1 inch from the edge of the piece of steel.
3. Place the piece of steel on the welding table so that the mark clears the



(Courtesy Linde Air Products Co.)

Fig. 14.26. Cutting with an oxyacetylene flame.

edge of the table by at least 1 inch. A piece of metal clamped to the metal to be cut may be used as a guide.

4. Put on goggles and gloves.
5. Light the cutting blowpipe. The tip should be placed on the blowpipe so that the two outside holes and the center hole are on the line for the cut.
6. Hold the blowpipe with the nozzle perpendicular to the surface of the metal and with the inner cones of the preheating flames at the edge of the piece of steel and about 1/16 inch above the chalk line.
7. Hold the blowpipe steady at this spot until the steel becomes a bright red, then slowly press down the cutting-oxygen valve lever. A bright red color indicates that the steel is near the melting point.
8. Move the blowpipe slowly along the chalk line, cutting completely through the metal as the cutting proceeds.

The left hand (on a right-handed person) may be used to steady the blowpipe by permitting the tubes to rest on the closed fist.

Cutting Cast Iron—It is more difficult to cut cast iron than it is to cut steel, because more preheating is necessary. A carburizing flame, having an excess of acetylene, rather than a neutral flame is required. The following procedure for cutting cast iron is suggested:

1. Put on goggles and gloves.
2. Adjust for a carburizing flame when the cutting-oxygen valve is open. The excess acetylene feather should be 2 to 2 1/2 times the length of the inner cone.
3. Close the cutting-oxygen valve.
4. Start preheating the cast iron along the entire edge to be cut, heating as much of the area to be cut as possible.
5. Hold the nozzle at an angle of approximately 45 degrees, and about 1/8 to 1/4 inch above the surface to be cut

Table 14.1—Recommended Tip Sizes and Working Pressures for General Oxyacetylene Welding and Cutting[1]

WELDING				
		Pressure in Pounds		
Tip Size	Drill Size for Tip	Acetylene	Oxygen	Thickness of Metal
0	71	1	1	Up to 1/32"
1	63	1	1	Up to 1/16"
2	58	2	2	1/16" to 1/8"
3	54	3	3	1/8" to 3/16"
4	52	4	4	3/16" to 1/4"
5	48	5	5	1/4" to 3/8"
6	44	6	6	3/8" to 1/2"
7	40	7	7	1/2" to 5/8"
8	36	8	8	5/8" to 1"
9	32	9	9	1" and over

CUTTING			
	Pressure in Pounds		
Tip Size	Acetylene	Oxygen	Maximum Cutting Range
0–4	3	8–12	Up to 1/8"
1–4	3 1/2	10–15	Up to 1/4"
2–4	4	15–20	1/4" to 1/2"
3 & 4	5	20–25	1/2" to 3/4"
4 & 5	6	25–30	3/4" to 1"
5 & 6	7	30–40	1" to 2"

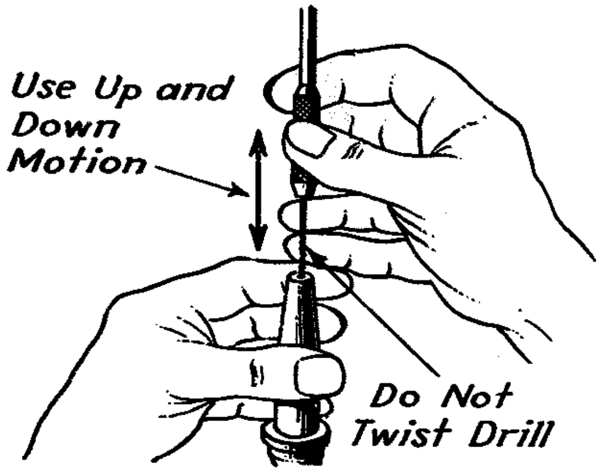
[1]S. M. Henderson and R. R. Harris, "That Versatile Shop Tool, Oxy-acetylene Welding," College of Agriculture, University of Georgia.

6. Heat a small area by moving the nozzle back and forth across the line to be cut until the metal begins to melt.
7. Open the cutting-oxygen valve wide, place the nozzle at a 45-degree angle to the surface to be cut, and start cutting. Keep the metal hot and use a swinging, side-to-side motion of the nozzle.
8. Straighten the cutting nozzle to a 75- to 90-degree angle as soon as the cut has been started. Keep the nozzle moving from side to side as the cutting progresses.
9. Continue cutting until the far edge is reached.

MAINTAINING THE EQUIPMENT

Efficient and long-lasting service can be obtained from welding and cutting equipment by keeping it in good condition. Following are a few suggestions for accomplishing this:

1. Keep equipment stored in a dry, well ventilated location.
2. Keep connections properly tightened to prevent leaks.
3. Remove leaking sections of hose and insert a special welding hose splice, unless new hose is necessary. A special welding hose splice is needed to prevent chemical reactions. *Do not use tape to repair hose.*
4. Use proper wrenches for adjusting nuts.



(Courtesy Linde Air Products Co.)

Fig. 14.27. Cleaning the preheat orifices of a blowpipe with a special drill.

5. Use packing recommended by the manufacturer for repacking blowpipe valves.
6. Use only standard parts when replacing parts.
7. Apply soapy water to connections when installing.
8. Be careful not to damage the threads when inserting tips.
9. Keep the orifice, or hole, in the end of the tip perfectly clean and round. Be sure to use the proper size drill when cleaning a tip. Never use a wire.
10. Use proper tip cleaners to clean orifices.
11. Fasten filled oxygen and acetylene cylinders securely in place to prevent them from falling over.
12. Keep the hose properly hung up when not in use.
13. Avoid using oil or grease, as oxyacetylene equipment does not require lubrication, and oil and grease may ignite in the presence of oxygen under pressure.
14. Prevent oil and grease from coming in contact with the equipment.
15. Keep the seats of valves clean so that the valves will shut completely.
16. Maintain gas-tight connections between the regulator and the cylinders.
17. Remove the regulator from the cylinders if the cylinders are not to be used for some time.
18. Relieve the pressure on the delivery-pressure valve seat by turning the pressure-adjusting screw in a few turns.

HOT AND COLD METAL WORK

Student Abilities to Be Developed

1. Ability to measure and cut stock properly.
2. Ability to hold the stock while it is being heated.
3. Ability to do the following jobs: squaring, drawing, upsetting, twisting, bending, tempering, and welding.
4. Ability to bend, cut, drill, punch, and rivet cold metal.
5. Ability to cut threads on bolts and nuts.

CHAPTER 15

Working Hot Metal

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What are the types of hot metal equipment needed in a shop?
2. What is the best kind of anvil and anvil base?
3. How should the equipment be arranged?
4. What supplies are necessary for metal work?
5. How should stock be held, and what kinds of tongs are best?
6. How is stock measured, heated, annealed, tempered, bent, twisted, cut, squared, drawn out, shortened, and punched?

HOT METAL EQUIPMENT[1]

The average worker should be able to do simple hot metal jobs such as the following:

1. Measuring and cutting
2. Upsetting and drawing
3. Bending and twisting
4. Tempering and welding
5. Punching and drilling
6. Threading and riveting

If a farmer or nonfarm agricultural worker does a great amount of the above types of metal work, a forge will provide the most economical way of heating the iron or steel.

Types of Forges—A portable forge is the cheapest type of forge that can be obtained for a home shop. It can be easily moved. Many forges of this type, however, are light in weight and are not well adapted for heavy iron work. Gas-fired forges are popular and are preferred by many workers.

Chimneys—In order for a forge to work properly, it must have a good draft

[1]See Chapters 13 and 14 for a description of oxyacetylene and electric welding equipment and its use.

through the chimney. If possible, each forge should have a separate outlet for the smoke, unless an electrical blower is provided.

Anvils and Bases—A 150-pound cast iron body, steel-faced anvil is satisfactory for a home shop. The anvil should be of good quality; otherwise, the steel face will crack and chip.

Various types of anvil bases are used. Some agricultural mechanics use heavy chunks of wood; others use concrete bases. The latter is preferred by most farmers and nonfarm agricultural workers because they are firmer, easier to keep in place, and neater in appearance. A 2-inch block of wood should be placed on top of a

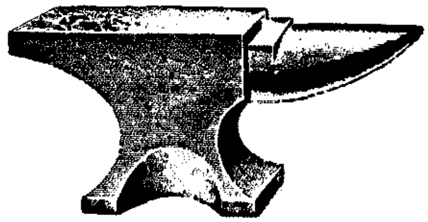
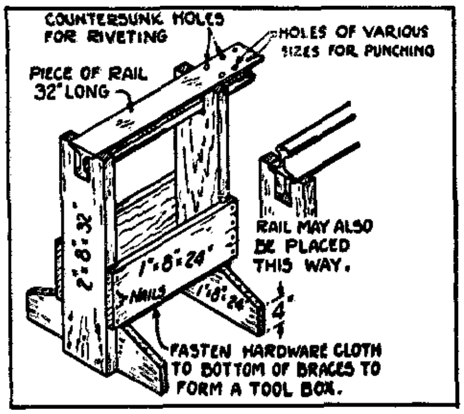


Fig. 15.1. An anvil.



(Courtesy E. C. Atkins and Co.)

Fig. 15.2. A homemade anvil for light blacksmith work.

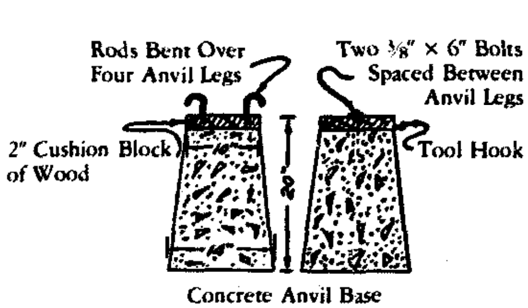
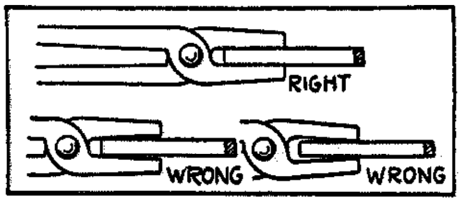


Fig. 15.3. Plans for an anvil base.

concrete base as a cushion for the anvil. There should be hooks for a square, a hardie, and tongs on the side of the base.

Other Equipment—In addition to a good way of heating metal, an anvil, and an anvil base, the following equipment is necessary:

1. Blacksmith's ball-peen hand hammer, 1 lb., 10 oz.
2. Machinist's hammer, 1 lb., 8 oz.
3. Blacksmith's cross-peen sledge, 10 lb.
4. Machinist's vise
5. Hardie to fit anvil
6. Steel square, 12" × 8"
7. Hacksaw with blades
8. Power drill with bits 1/8" to 1", by 16ths
9. Set of taps and dies
10. Power grinder
11. Hot cut chisels
12. Straight lipped, 1/4" opening, 18" length, blacksmith's tongs
13. Bolt tongs, 3/8" to 1/2", 18" long
14. Fluted jaw tongs for 1/4" to 1/16" iron, 18" long
15. Assorted wrenches
16. Steel marking punch
17. Workbench
18. Water bucket
19. Files
20. Oil can



(Courtesy E. C. Atkins and Co.)

Fig. 15.4. Correct and incorrect shapes of tongs.

Arranging Equipment—The equipment should be arranged for its convenient use. Sufficient light is also essential. If a forge is used for heating metal, it should be accessible from all sides and placed near one side of the shop.

The anvil should be securely fastened to its base and placed about 3 feet from the forge. It should be placed in front of and near one corner of the forge, and set on a 45-degree angle to the forge with the horn of the anvil facing the side of the shop where the forge is located. This position of an anvil is convenient when you are turning with a hot piece of metal from the forge to the anvil.

A power drill should be placed along a wall near the forge. A machinist's vise should be placed on a workbench located along a wall near the forge. The metalworking tools may be kept in a cabinet located above the metalworking bench or near the forge.

Supplies for Metal Work—There are some supplies which every shop should have. The following are recommended:

1. Assorted machine, carriage, and stove bolts.
2. Flux materials for welding.
3. Assorted sizes of octagon-shaped tool steel.
4. Assorted sizes of wrought iron (flat, round, and square).
5. Assorted sizes of mild steel.
6. Sandpaper and emery cloth.
7. Metal paint.
8. Hacksaw blades.

HOT METAL WORK

Holding the Stock—To work metal satisfactorily, hold the stock securely and properly. This may be accomplished as follows:

1. Select tongs which fit the work. The jaws should be parallel when clamped on the stock. If necessary, heat the jaws to a cherry red and bend them to fit and hold the stock firmly.
2. Keep the tongs cool by dipping them frequently in water.
3. Be careful not to bend the jaws or handles of the tongs.

There are several different kinds of tongs, but only a few are frequently used in agricultural mechanics. They are as follows:

1. Flat-jawed tongs with a lengthwise groove in the middle of each jaw to help hold materials securely.
2. Link tongs with a crosswise groove in the jaws which helps in holding links, rings, and similar materials.
3. Bolt tongs with a curved opening in the jaws to permit the holding of round or square materials.

The type of tongs to use depends upon the kind of work that is to be done.

Measuring Stock—Measuring stock is very important. It may be done as follows:

1. Measure the required length and mark with chalk. If the piece is to be heated, the mark must be made with a center punch or a file because a chalk mark will burn off.
2. If a bent piece of metal is to be duplicated, take a lightweight piece of wire and follow the bends with the wire. Then remove the wire, straighten it, and measure its total length. The wire should be placed near the center of the piece being measured.
3. The amount of material required for making a ring is $3\frac{1}{7}$ times the diameter of the ring plus $\frac{1}{2}$ the diameter of the stock.
4. In measuring a piece to be welded, add the length needed for upsetting to the total length needed.

In construction work it is best to secure a plan or a blueprint, if possible, which will indicate exact dimensions.

Heating the Stock—Heating of stock may be done with oxyacetylene and carbon arc torches, or with a forge. A forge is the most economical way to heat large areas of metal. When the metal to be heated cannot be removed from a machine, or when the area to be heated is small, an oxyacetylene torch or a carbon arc torch has many advantages. One advantage is that a carbon arc and an oxyacetylene flame are readily available.

Care must be exercised in heating metal with a carbon arc or an oxyacetylene flame, because the heat is very intense. If too much heat is used, the metal may oxidize (burn), and checking of the metal may occur. The carbon arc torch or oxyacetylene flame should be moved over the entire area to be worked to prevent overheating in spots and to provide sufficient heat to last until the shaping operation is completed.

In a forge the following heating procedure is recommended:

1. Place the stock in the fire in a horizontal position so that the surface of the metal in the fire will be heated uniformly. If a piece of metal is inserted downward in a fire, the end of the piece will heat before the surface next to it does.
2. Look at the piece occasionally to determine whether or not it is heating properly.

When heating two pieces of material at the same time, as in welding, keep them placed in the fire so that both will heat to the same temperature. If one becomes hotter than the other, move it to the outer portion of the fire until both pieces are the same temperature.

Annealing—Annealing is the heating and very slow cooling of metal. It softens metal and removes stresses. Previous treatment of iron or steel may have left it brittle, making annealing necessary. The reaction of iron and steel to different degrees of heat is as follows:

1. A coarse grain structure results from heating iron or steel to a yellow or white color.
2. A finer grain results when steel is reheated to a cherry red color and allowed to cool slowly. Through this process, known as annealing, steel develops toughness, strength, and a uniform structure.

To anneal iron and steel, (1) heat the stock slowly to a uniform red color and (2) bury the heated stock in air-slaked lime, pulverized charcoal, or wood ashes. Since the air is shut out, the stock cools very slowly. Do not remove the metal until it is cold.

Tempering—For satisfactory use, tool steel must be of the proper hardness and brittleness. If it is too hard, it will chip; if it is not hard enough, it will bend. Worn and broken tools such as axes, wood chisels, and shears often need to be hardened or tempered after they are repaired. Tempering may be done as follows:

1. Heat the piece of metal to a cherry red color.
2. Hold the piece vertically and dip the end to be tempered into cold water. At the same time move the piece up and down in the water in order to bring its surface in contact with as much cold water as possible, thereby cooling it rapidly. The end will thus be cold and hardened, while the piece will be hot at some distance back from the end being tempered.
3. Brighten immediately the surface of the part dipped into water with an emery cloth or a piece of sandstone.
4. Watch the bright surface very closely. Colors will gradually move down

> from the heated portion. First will be seen a light straw color, then a dark straw color, then a light brown color, followed by a dark brown color. When the dark color has reached the end of the piece, quickly plunge the part to be tempered into cold water, and the required temper will be secured. Keep the tempered portion cool until the entire piece has cooled to a black color. Then the entire piece may be cooled further by being dipped in water.

In tempering such items as lathe cutting tools and hammers, follow the preceding procedure, but plunge the part to be tempered in cold water when the light straw color has moved down from the heated portion. For punches, dies, hacksaw blades, drills, taps, knives, and reamers, wait to plunge the part to be tempered into cold water until a dark straw color has moved down from the heated portion. For cold chisels, center punches, and rivet sets, wait until a purple color has moved down from the heated portion. For such items as screwdrivers, springs, gears, picks, and saws, wait until a blue color has moved down from the heated portion. Because of the variance in quality of steel in the items mentioned, the desired temper may not be obtained by following the preceding directions. If this occurs, the process may be repeated, allowing the portion to be tempered to cool more or less as previous experience indicates.

Bending Stock—One of the important phases of metal work on a farm or in a nonfarm agricultural business is the bending of materials. Small pieces often may be bent cold, but some pieces should be heated before they are bent. Eyes and rings are made in the following manner:

1. The stock should be heated until a dull cherry red color is obtained.
2. Bend the stock to a right angle on an anvil.
3. When eyes are to be made, reheat and bend the end of the stock over the point of the anvil horn. Strike the metal with glancing blows.
4. When a ring is to be formed, reheat and continue to bend the stock over the anvil horn until the end reaches the point where the right angle began. Reheat whenever necessary.
5. In forming right angles, first upset the portion of the metal to be bent. The right-angle bends should have sharp corners.
6. If flat stock bends edgewise or buckles on the curve, the stock should be hammered flat on the anvil.

Twisting Stock—It is often necessary to twist certain portions of a piece of stock. This may be done as follows:

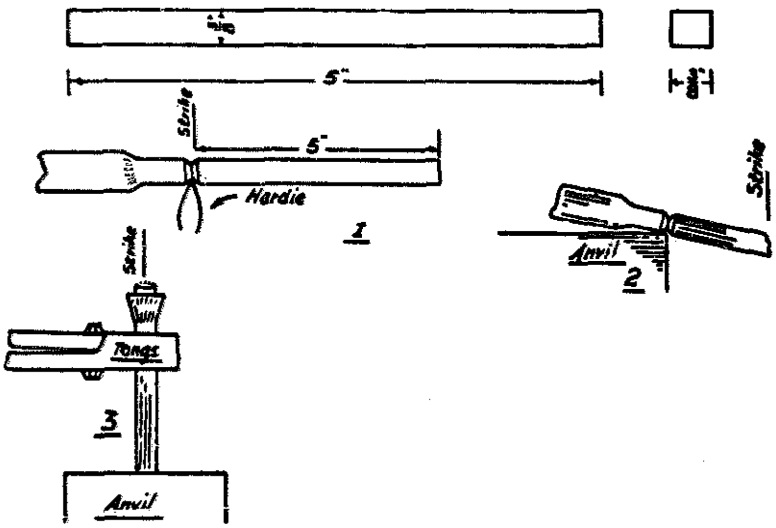
1. Mark the section of the stock to be twisted with a center punch.
2. Heat the section to be twisted to a uniform bright red color.
3. Place one end of the stock in a vise and clamp it securely.
4. Clamp the other end of the stock with a vise-grip wrench and twist. If some portion of the stock twists too rapidly, cool it with a little water.
5. Straighten the stock with a wooden mallet when the twist is completed.

Cutting Metal—Hot metal may be cut with a hot chisel, a hardie and a cutter, an oxyacetylene cutting torch, or an electric arc.

Hot chisels and cutters are used for cutting hot pieces, which are generally large and heavy, as follows:

1. Heat the stock to a cherry red color.
2. Lay it across the hardie with the mark exactly above the cutting edge of the hardie.
3. Place the cutter on the stock directly above the hardie.
4. Deliver heavy blows to the cutter with a hammer.
5. Finish the cut by placing the stock over the edge of the anvil and breaking it off.

When cutting a light piece of material, often it is not necessary to use the cutter. Merely place the stock over the hardie and deliver hammer blows directly to the stock.



(Courtesy College of Agriculture, University of Nebraska)

Fig. 15.5. Cutting a piece of steel with an anvil and a hardie.

Squaring—Squaring may be done as follows:

1. Mark the piece to be squared with a file, using a steel square.
2. Heat the piece to a cherry red color. Only a small portion should be heated; otherwise the piece may enlarge when it is struck on its end.
3. Place the piece over an anvil, and hammer it. Be sure that the face of the hammer falls parallel with the face of the anvil.
4. Continue to hammer, turning the piece, if necessary, until it is square.
5. Reheat to a cherry red color if the piece becomes cool before it is squared.

Drawing-Out—When a piece of iron or steel is pounded so that it is longer and smaller in diameter, it is said to be drawn out. This is accomplished as follows:

1. Heat the stock to a white heat.
2. Place the stock over the anvil horn and hammer with slight, glancing blows.
3. Turn the stock while hammering so it will be hammered evenly on all sides.

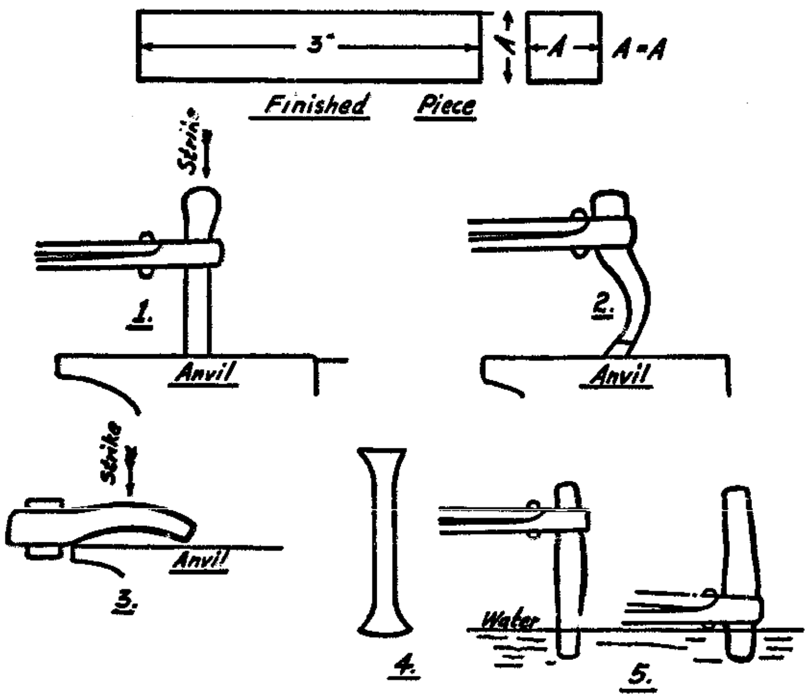
4. Hammer the stock square, then gradually make it round by first changing it to an octagon shape. Then round the corners of the octagon.
5. Finish the stock on the flat face of the anvil.
6. Reheat the stock as necessary.

If the stock is to be drawn out to a point, the end should first be made blunt and slightly enlarged. Otherwise the drawing-out may cause the stock to become too small just back of the point. To blunt and enlarge the end to be drawn to a point, apply heat to this end of the piece of stock and place it against the edge of the anvil. Then hammer on the opposite end. The stock is now ready to be reheated and hammered to a point.

If the stock is to be drawn out hurriedly, place the heated stock over the horn of the anvil, strike a heavy blow, move slightly, then strike again. Continue this process as many times as necessary. The notches are then hammered out.

Upsetting—When a piece of iron is too long or too small, it may be made shorter or thicker by upsetting, as follows:

1. Heat the portion of the stock to be enlarged to a white heat.
2. Place the stock on the anvil in a perpendicular position, forming right angles to the face of the anvil to prevent the stock from bending. See sketch 1, Fig. 15.6.
3. Strike the cold end of the stock with hard blows. If the stock bends, place it over the anvil and straighten it. See sketches 2 and 3, Fig. 15.6.



(Courtesy College of Agriculture, University of Nebraska)

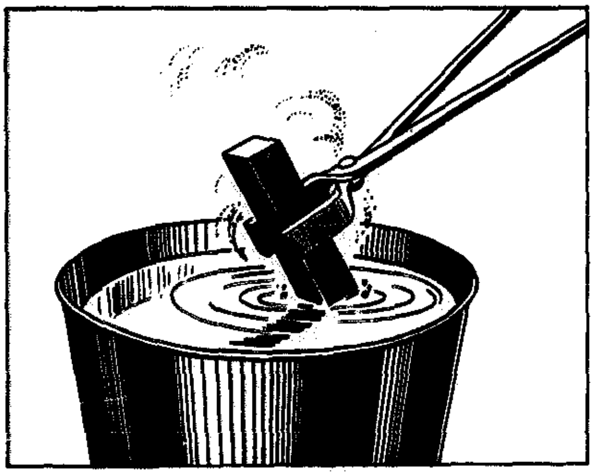
Fig. 15.6. Upsetting.

If the stock becomes too large on the end, cool the end in water. Then place the piece vertically on the anvil and strike the unheated end; this will cause the piece to enlarge just back of the end which has been heated. See sketches 4 and 5, Fig. 15.6.

If the stock is to be enlarged several inches from one end, heat the stock and cool all of it but the portion to be enlarged.

Punching Holes—Holes may be made in metal by punching, drilling, or cutting with oxyacetylene or electric arc welders. Drilling is usually the most satisfactory procedure to use in agricultural mechanics, but there may be times when it is necessary to make a hole with a punch. The procedure used to punch holes is as follows:

1. Mark the piece carefully with a file or scratch awl and with a square by crossing two fine lines at the point where the hole is to be made.
2. Heat the stock to a bright red color and lay it over the pritchel hole in the face of the anvil.
3. Drive a hole about one-third to three-fourths of the way through the stock with a pointed punch.
4. Turn the stock over and drive the punch through from the other side. This will produce a smooth edge on both sides of the stock. If necessary, the punch should be withdrawn and cooled occasionally to prevent the drawing of the hole.



(Courtesy Linde Air Products Co.)

Fig. 15.7. Quenching.

CHAPTER 16

Working Cold Metal

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What operations can be performed in working cold metal?
2. How is stock marked, bent, cut, drilled, and punched in cold metal work?
3. How are threads cut on bolts and nuts?
4. What methods are used in riveting?

It is possible to work metal cold if the metal is of the right kind and size. If a metal stock permits, it is often more economical and convenient to work it cold. See Chapter 13 for a discussion of different kinds of metals, their uses, their characteristics, and their identification.

Marking Metal—Metal often needs to be marked for cutting, welding, bending, and drilling. Marks for holes to be drilled are made with a center punch. Lines on metal are made with a scriber, which is a sharp-pointed tool. A sharp prick punch may also be used for marking metal.

Bending—Light pieces of metal can often be bent cold. A vise is used in bending metal rods and bars. If a heavy piece of strap iron is to be bent cold, clamp it in a machinist's or blacksmith's vise of adequate size. Slip a piece of pipe over the strap iron to provide leverage. The bend can also be made by hammering after the piece of strap iron has been clamped in the vise.

A sharp bend in a piece of strap iron can be made by clamping it in a vise against a piece of round stock. Then hammer or pull the piece of strap iron around the piece of round stock. A large bend can be made in a piece of strap iron by placing it between the jaws of a vise, but do not clamp the jaws against the piece of strap iron. Slip the piece down between the jaws of the vise as it is bent. This process will produce a large gradual bend.

Cutting—Cold metal may be cut with a hacksaw, a bolt cutter, or a cold chisel.

A *hacksaw* is used as follows:

1. Fasten the blade into the hacksaw frame with the teeth pointing away from the handle of the saw. Make sure that the blade is fastened securely so that it will not twist and break.

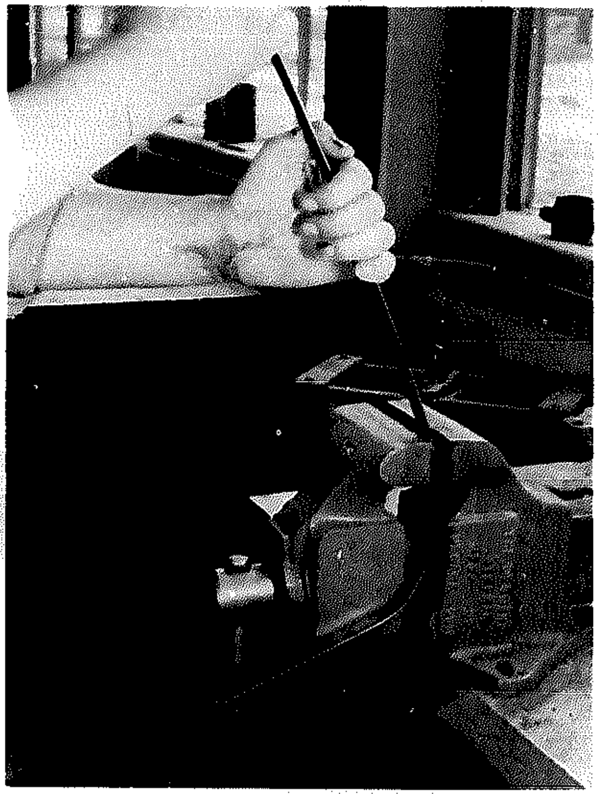


Fig. 16.1. To make a large bend, slip the material down between the jaws of the vise as you bend it.

2. Use a blade with 16 to 18 teeth to the inch unless thin metal is being sawed. Thin metal requires a blade with more teeth to the inch.
3. Mark the stock at the point at which it is to be cut.
4. Place the stock in the vise, with the mark close to the jaws, and clamp it securely. Sawing close to the jaws of a vise makes the sawing easier, because the piece is held firmly and does not spring back and forth.
5. Cut a notch at the mark with a file. This will help in getting the saw started in the proper place.
6. Apply slight pressure on the forward strokes of the hacksaw, and release the pressure on the return strokes to insure proper cutting and to lessen the danger of breaking the blade of the saw.
7. Run the saw evenly, using long strokes, with all the teeth cutting to prevent wear on a small portion of the blade, thus shortening the life of the blade.

See also Chapter 4, "Selecting and Using Hand and Power Tools," for a discussion of the correct use of hacksaws.

A *bolt cutter* can be used to cut small pieces of iron quickly and easily.

A *cold chisel* is frequently used to cut cold metal. In cutting cold metal with a cold chisel, use the following procedure:

1. Place the stock on an anvil.
2. Cut a groove entirely around the stock.

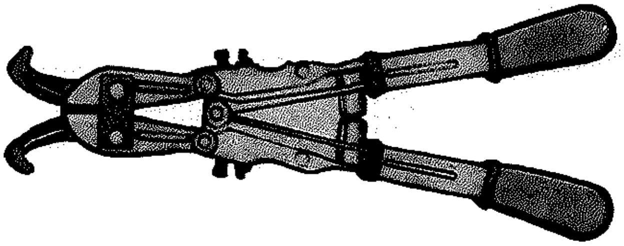


Fig. 16.2. Bolt cutter.

3. Place the cut portion of the stock over the edge of the anvil and break it off.

See also Chapter 4 for a discussion of how to use cold chisels.

Filing—Small amounts of metal may be removed where needed with a file. See Chapter 4 for a discussion of the correct use of a file and a discussion of filing techniques.

Center Punching—Holes to be drilled may be marked with a center punch. Accurate drilling is not possible when holes to be drilled are not marked adequately with a center punch.

Before using a center punch, mark the location of a hole with a scriber. Use two crossed lines to mark the location for the point of the center punch. Place the point at the intersection of the crossed lines and give the punch a light blow with a hammer. Inspect the mark made to determine whether or not it is located in the right place. If it is, give the punch two or three heavy blows to deepen the mark. If the center punch mark is not in the right place, hammer out the mark with a ball-peen hammer and start over.

Drilling—Holes may be made in metal with a drill bit. Drilling may be done with a hand drill, a portable power drill, or a drill press.

The procedure for using a drill press is as follows:

1. Mark the location of the hole with a center punch.
2. Place the stock on a wooden block on the drill stand.
3. Feed the drill bit down to the center of the mark and start drilling.
4. Raise the bit to determine whether or not the hole is started in the proper place.
5. Re-mark the location of the hole if the hole is not started in the correct location.
6. Start the drill, using the automatic feed. Put a small amount of oil on the drill bit, about 2 to 3 inches above the work.
7. Clamp the stock securely to prevent it from spinning as the bit cuts through the metal and into the wood.

See also Chapter 4 for a discussion of the use of hand drills, portable power drills, and drill presses.

Punching Holes—For a discussion of the use of punches for punching holes in sheet metal, see Chapter 4.

Tapping and Threading—A common metalworking job in agricultural mechanics is the cutting of threads on bolts and nuts. Taps and dies are used for thread cutting. A tap is used for cutting the threads in nuts, and a die is used for cutting the threads on bolts. Care must be used in selecting the proper size of taps and dies for the job to be done. There are three classifications of threads—National coarse, National fine, and National special. Taps and dies have their sizes and classifications stamped on them. Bolts and rods should have the same diameter as the die size used to cut threads on them. Tap drills are usually stamped with their size or number on the shank. Sometimes smaller drills are too small to stamp, and their sizes can be determined with a steel stand or a gauge plate. Table 16.1 lists the tap drill sizes for bolt threads.

Table 16.1—Threads per Inch and Tap Drill Sizes for Bolt Threads

	National Coarse		National Fine	
Size of Thread	Threads per Inch	Tap Drill Size	Threads per Inch	Tap Drill Size
0	—	—	80	3/64
1	64	53	72	53
2	56	50	64	50
3	48	47	56	45
4	40	43	48	42 (3/32)*
5	40	38	44	37 (7/64)*
6	32	36	40	33
8	32	29	36	29
10	24	25	32	21 (5/32)*
12	24	16	28	14 (3/16)*
1/4	20	7 (13/64)*	28	3 (7/32)*
5/16	18	F (1/4)*	24	I (17/64)*
3/8	16	5/16	24	Q (21/64)*
7/16	14	U (23/64)*	20	25/64
1/2	13	27/64	20	29/64
9/16	12	31/64	18	33/64
5/8	11	17/32	18	37/64
3/4	10	21/32	16	11/16
7/8	9	49/64	14	13/16
1	8	7/8	14	15/16

*Approximate size—in most cases a trifle oversize.

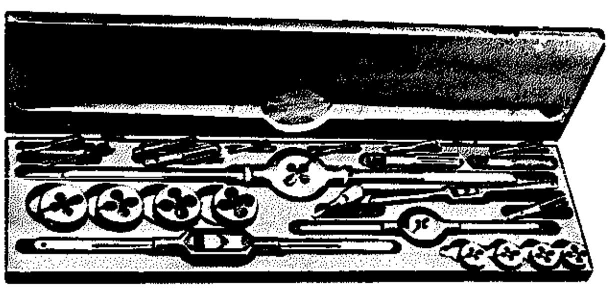


Fig. 16.3. Bolt and screw threading diestocks, adjustable split dies, taps, and tap wrenches.

Threading Bolts

1. Place the rod in a perpendicular position in a vise and clamp securely.
2. File off any projections on the end of the rod or bolt, slightly tapering it.
3. Select the proper size of die.
4. Place the die squarely on the rod or bolt and apply pressure evenly as the die is turned.

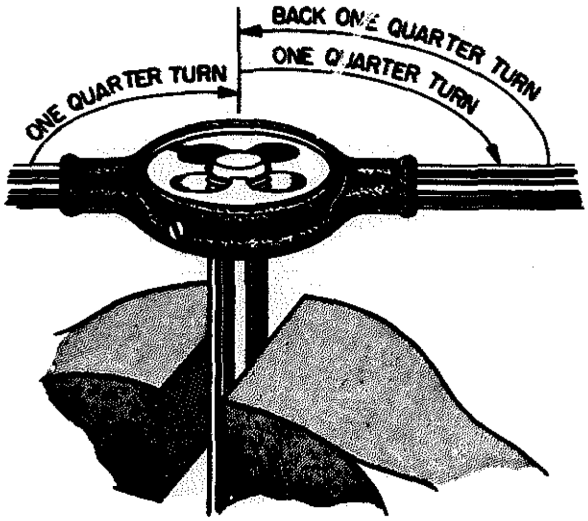


Fig. 16.4. Using a die to cut outside threads on round stock.

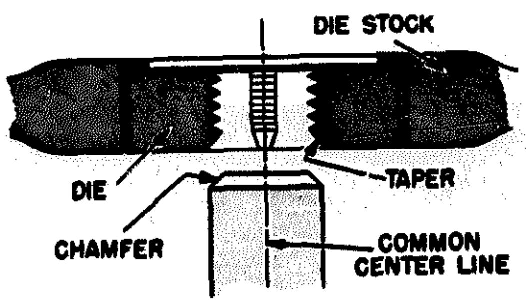


Fig. 16.5. The correct position of the diestock in relation to the chamfered end of the work when external threads are cut.

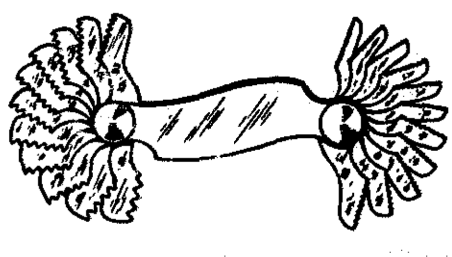


Fig. 16.6. A screw pitch gauge to measure external or internal threads per inch.

5. Apply oil so that the die will run in oil while cutting.
6. Move the die back and forth so the chips of metal will fall out.
7. Remove the die by turning it counterclockwise after the required number of threads are made.

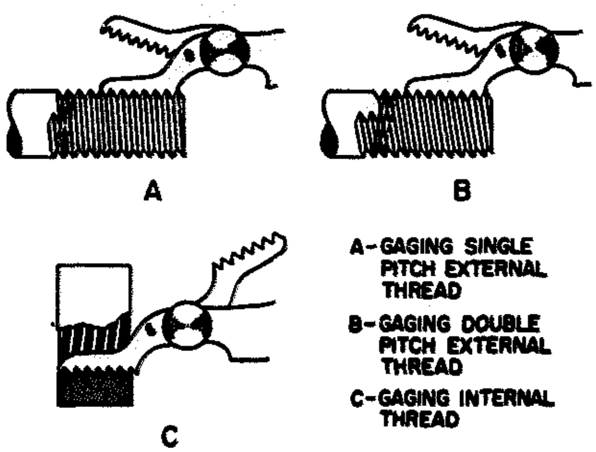


Fig. 16.7. Using a screw pitch gauge to determine the number of threads per inch.

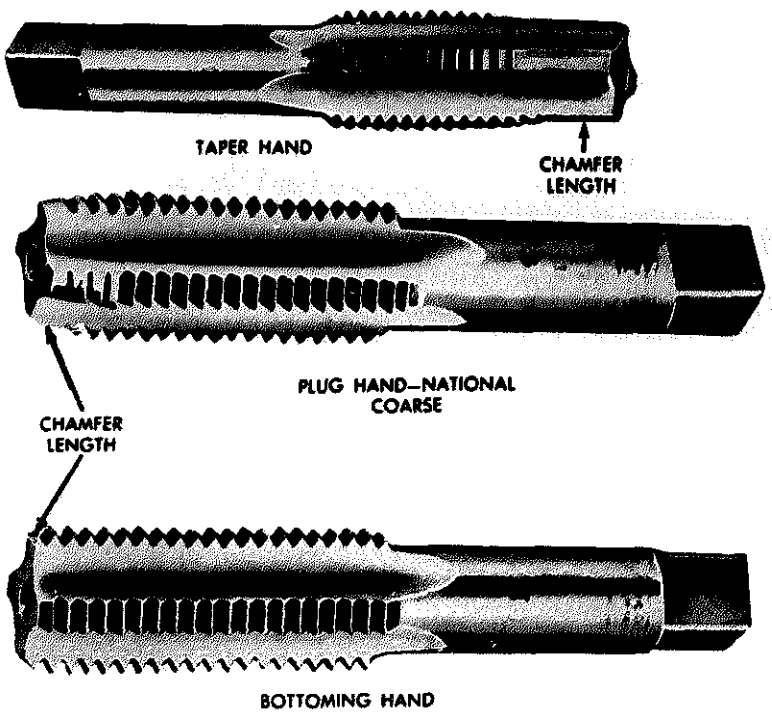


Fig. 16.8. Taps. The taper tap is used for starting the threading of holes. The plug tap is designed for use after the taper tap is used. The bottoming tap is used to thread the bottom of a blind hole.

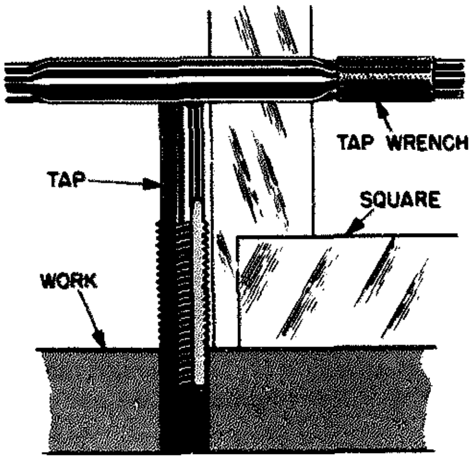


Fig. 16.9. Use a square to determine whether or not the tap is square with the work.

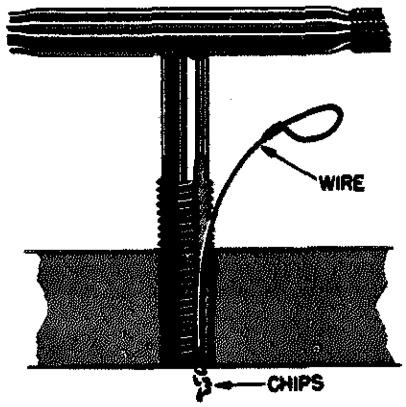


Fig. 16.10. Use a wire to clear chips from the flute of a tap.

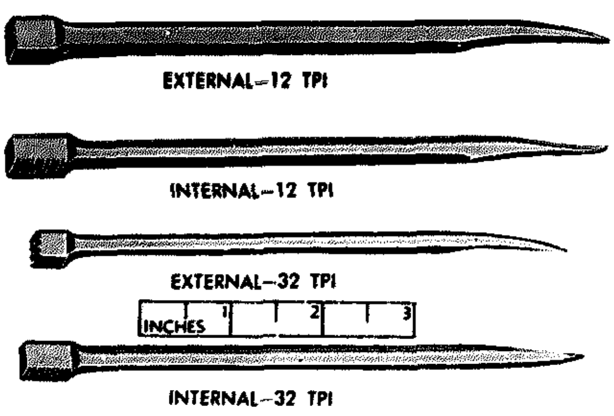


Fig. 16.11. Thread chasers are used on damaged threads. They have several teeth, and the process of rethreading damaged threads is termed chasing.

Threading Nuts

1. Select the proper size of tap, and place it in the tap wrench.
2. Place the nut in a vise and clamp securely.
3. Place the tap straight up and down in the nut and turn slowly, using a slight pressure.
4. Apply oil if cutting hard metal such as steel. Other materials do not ordinarily require oil.
5. Turn the tap forward two quarter turns. Then back it up one quarter turn to break up the chips.
6. Remove the tap by turning it counterclockwise when the threads are cut.

Riveting—When two pieces of metal cannot be welded satisfactorily, they are often riveted together. Rivets are used for many agricultural jobs. Riveting may be done with either cold or hot rivets. Hot rivets make a stronger union because they contract when they cool, which draws the joint together. Consequently, where possible, it is best to use hot rivets. The following procedure may be used for riveting with either hot or cold rivets:

1. Make holes of the size desired.
2. Select rivets which are slightly larger than the holes so that they will fit snugly. The rivets should extend 1/8 to 1/4 inch beyond the pieces being riveted.

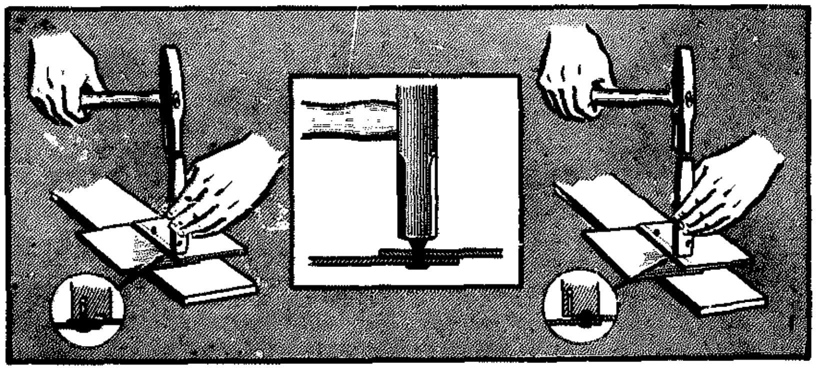


Fig. 16.12. Drawing, upsetting, and heading a rivet.

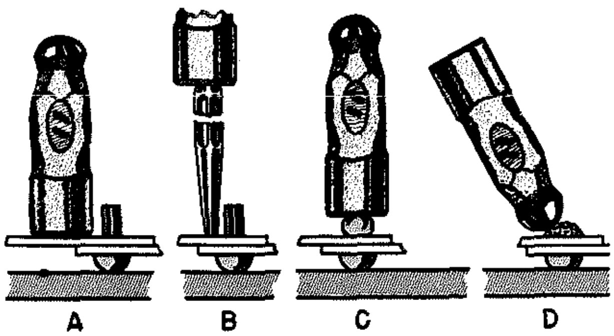


Fig. 16.13. The riveting technique to use with large rivets.

3. Insert the rivets and place the heads on the face of the anvil. If hot rivets are used, they should be heated to a bright red color.
4. Place the washers on the rivets if washers are used.
5. Deliver several blows to the center of the rivet, first with the peen of the hammer, then with the face of the hammer, until the pieces are closely united. In using hot rivets the blows must be fairly rapid.
6. Round the edges of the head and finish to an oval shape.
7. Use a rivet set to obtain a smooth finish.

SHEET METAL WORK

Student Abilities to Be Developed

1. Ability to appreciate the importance of sheet metal work on the farm and in nonfarm agricultural businesses.
2. Ability to cut, bend, and fasten sheet metal.
3. Ability to operate an LP gas torch and to tin coppers.
4. Ability to solder.
5. Ability to construct or repair sheet metal projects.

CHAPTER 17

Cutting, Bending, and Fastening Sheet Metal

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. How and where is sheet metal used on farms and in nonfarm agricultural businesses?
2. How and with what equipment is sheet metal cut?
3. How is sheet metal bent and shaped?
4. How are pieces of sheet metal fastened together?

USES AND IMPORTANCE OF SHEET METAL

Sheet metal is used in agriculture in many ways, such as for:

1. Roofing
2. Parts of farm machinery
3. Trailer and truck beds
4. Utensils, pails, pots, and pans
5. Grain elevators
6. Safety guards
7. Car, truck, and tractor bodies
8. Grain bins
9. Water tanks
10. Metal furniture
11. Guttering and flashing

The use of sheet metal increases the speed of manufacture of many machines used in agriculture.

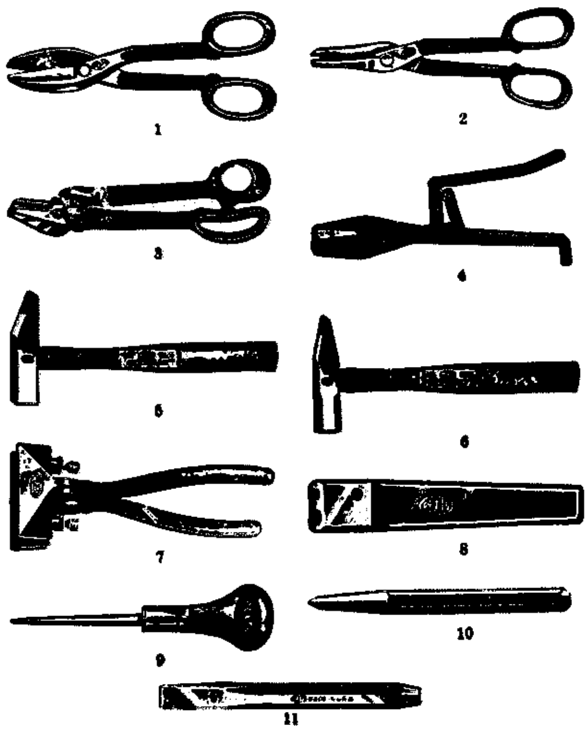
Ability to cut, bend, and fasten sheet metal is important because a farmer or a nonfarm agricultural worker frequently needs to replace or repair a guard or another part of a machine made of sheet metal.

CUTTING AND PUNCHING

Before sheet metal is cut, it should be marked. Marking may be done with any sharp-pointed tool such as an awl.

Sheet metal is cut with a (1) hacksaw, (2) cold chisel, (3) metal snip, (4) double cutting shear, or (5) bench shear. It may also be cut with welding equipment, oxyacetylene or electric.

The metal snip is probably the tool most frequently used in cutting sheet metal. A metal snip works like a pair of scissors. It is used to cut thin and soft metal of 20 gauge or less. Metal snips are of two types, straight snip and scroll snip. The scroll snip is used to cut curves. Aviation snips have compound leverage action, thus delivering more cutting power.



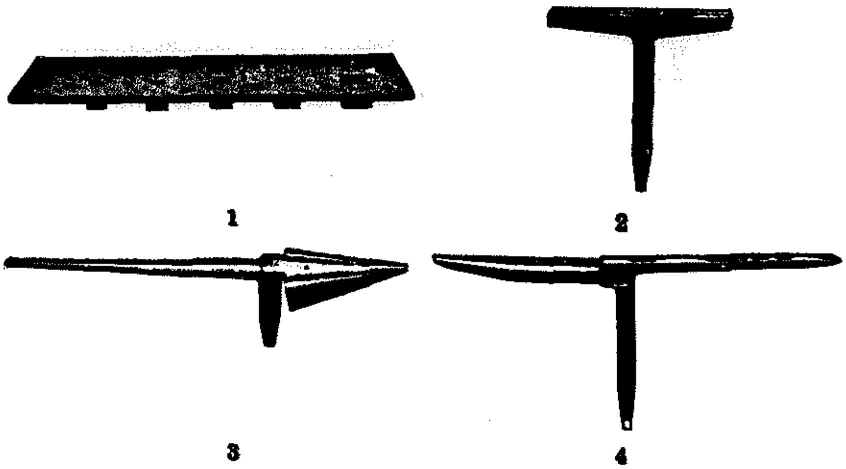
(Courtesy Peck, Stow and Wilcox Co., Southington, Conn.)

Fig. 17.1. Tools used in cutting, bending, and fastening sheet metal: (1) metal snip, (2) scroll snip, (3) double cutting shear, (4) bench shear, (5) setting hammer, (6) riveting hammer, (7) hand seamer, (8) rivet set, (9) scratch awl, (10) solid punch, and (11) cold chisel.

A double cutting shear has three blades. It is used for jobs such as cutting sheet metal pipes (for example, furnace pipes and guttering pipes).

A bench shear is a large shear, 2 to 4 feet long. It is designed to cut heavier-gauge sheet metal, 22 to 16 gauge. When it is used, one handle is fastened in a vise. The other is moved up and down to cut the metal as it is moved forward into the shear.

In using metal snips, place the metal as far back as possible in the snip. Cut almost to the tip of the snips and then move the snips forward. Not taking a full cut each time avoids nicks. To stay on a marked line in cutting, place the upper



(Courtesy Peck, Stow and Wilcox Co., Southington, Conn.)

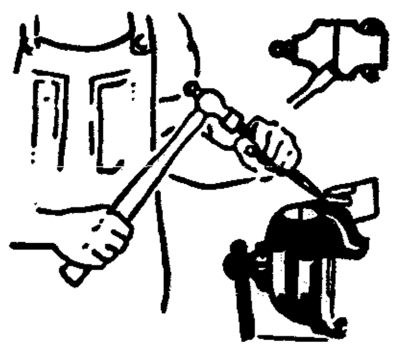
Fig. 17.2. A tinner's bench plate and stakes: (1) bench plate, (2) hatchet stake, (3) blow horn stake, and (4) beakhorn stake.

blade over the line. Bend the two pieces of sheet metal apart slightly during the cutting process to prevent the snips from binding.

Cold chisels are often used to cut heavy sheet metal. The metal is clamped in a vise and is sheared with a cold chisel. The chisel is held so that the vise jaw and the chisel act as a pair of shears. In cutting a hole in sheet metal, use a narrow chisel so that the cut will follow the line closely.

For a discussion of the procedures to follow in using a hacksaw to cut sheet metal, consult Chapter 4, "Selecting and Using Hand and Power Tools." For a discussion of cutting metal with an oxyacetylene welder or an electric arc welder, consult Chapters 13 and 14.

A *punch* is often used to punch holes in sheet metal. Either a solid or hollow punch may be used. The metal should be placed on a solid block of wood for punching.



(Courtesy Stanley Tools)

Fig. 17.3. A desirable method of shearing sheet metal.

(Courtesy Stanley Tools)

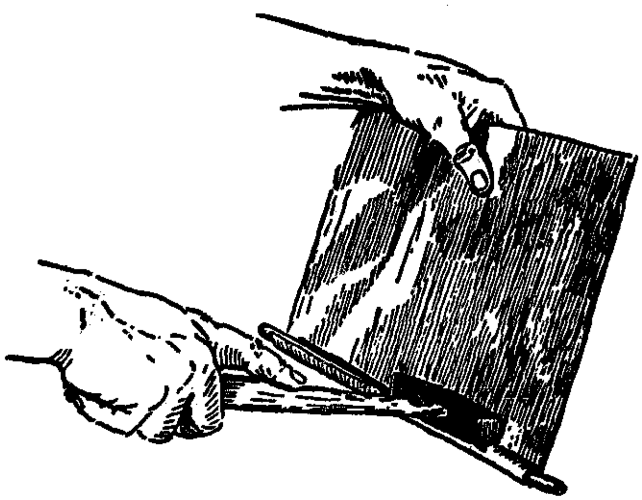
Fig. 17.4. Cutting a hole in sheet metal with a cold chisel. Be sure to wear safety glasses.

BENDING SHEET METAL

Sheet metal is bent in constructing new sheet metal parts for machines, in constructing sheet metal equipment, and in patching or repairing the sheet metal parts of machines. Often in these operations it is necessary to bend sheet metal to:

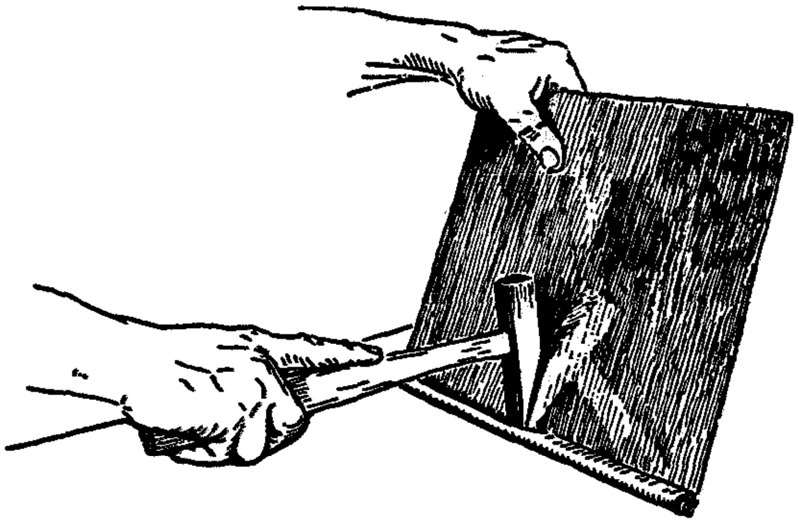
1. make a *hem* to stiffen the edge of the metal and to remove the sharp edges, or
2. form a *seam* to join two pieces of metal and to make square corners.

A simple *hem* is made by folding over an edge of a piece of sheet metal. If a stronger hem is desired, the edge may be folded over twice. This is called a *double hem*. Several types of anvils are used in bending metal. They are called stakes. The



(Courtesy Stanley Tools)

Fig. 17.5. Dressing metal around a wire to make a reinforced wire edge.



(Courtesy Stanley Tools)

Fig. 17.6. Peening the edge around a wire to finish a reinforced wire edge.

hatchet stake is used for making simple and double hems. A bench plate is needed for holding the stakes when they are used. The folds may also be made over the edge of a bench, an anvil, an iron bar, or a piece of hard wood if a hatchet stake is not available.

A wire hem may be made by folding the metal over a wire. In making this type of hem, first make a round bend or fold on a round tinner's stake. Place a wire in the fold and tap the metal around the wire with a setting hammer. A tinner would use a bar folding machine to make the round bend, but it is not practical to have the larger pieces of tinners' equipment on farms and in most nonfarm agricultural businesses.

A simple *seam* is made by hooking two simple hems together and locking them with a hand seamer. This type of seam is often called a lock joint. If a hand seamer is not available, the hems may be hammered together with a wooden mallet.

FASTENING SHEET METAL

Sheet metal is fastened with hook joints, special screws, and rivets, and by welding and soldering. Soldering processes are described in the following chapter. Welding of sheet metal is described in Chapters 13 and 14.

Self-tapping screws may be used to fasten sheet metal together. A lap joint is used, and a small hole is made with a punch or sharp-pointed tool. The hole should be smaller than the screws to be used. The screws cut threads in the sheet metal as they are screwed into the metal with a screwdriver. Screws are used to fasten light-gauge metals. They are often used for fastening sheet metal when the pieces may need to be taken apart later. If a very tight joint is desired, some other method of fastening should be used, such as riveting or welding.

Rivets are often used to fasten sheet metal, because riveting is easy to do and few tools are necessary. A rivet can be used to punch its own hole if it is placed on a solid object such as an anvil. The metal is driven onto the rivet. A rivet set is often used in riveting heavy sheet metal. A rivet set may be homemade by taking a bar of steel and drilling a hole in it. An oval should also be drilled into the bar for use in forming round heads on the rivets. If a rivet set is not available, the holes may be punched or drilled.

In hammering a rivet, use a medium-weight hammer. Do not hammer too hard or too long. If straight blows are not used, the rivet may be bent. If this happens, it is necessary to use a new rivet.

Holes in utensils and agateware can often be filled with rivets when the surrounding metal is of a quality to warrant the procedure. When copper rivets are used for the *patching of holes*, the following procedure is recommended:

1. Round out the hole to be riveted with the tang of a file.
2. Clean the surface around the hole in preparation for soldering. Grease may be removed with a cleaning solvent.
3. Insert a soft copper rivet that fits very snugly in the hole, and clip it to the correct length.
4. Drive the rivet in solidly and, with a burr (washer) placed on the point side, hammer the rivet firmly in place.
5. Solder over the rivet to smooth and finish the job.

CHAPTER 18

Soldering

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is soldering?
2. What is flux, and how is it used?
3. How should heat be provided?
4. How should soldering irons be tinned?
5. What other equipment is necessary for soldering?
6. How should solder be applied?
7. How should a small hole be soldered? A large hole?
8. What is meant by sweating a patch, and how is it accomplished?
9. What materials other than sheet metal may need soldering?
10. How may each of these materials be soldered?

INTRODUCTION

Soldering is the process of uniting two pieces of metal by means of a metal alloy having a lower melting point than the metals to be joined. Solder is usually termed "half and half" or "50-50," meaning half tin and half lead. Solder may be secured in a base or wire form. The latter may be solid, acid core, or rosin core.

SELECTING AND USING SOLDERING EQUIPMENT

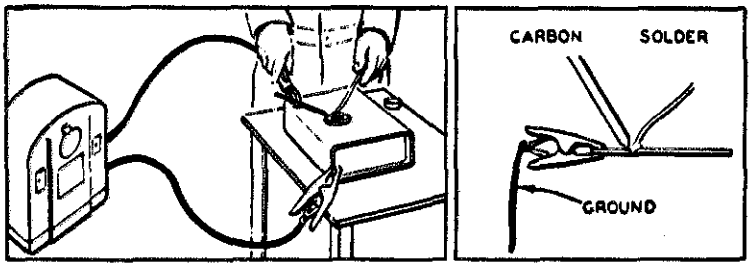
Flux and Its Use—Flux is a substance used to destroy the oxide (the compound of oxygen and the basic elements in the metal) in the piece to be soldered and to clean the surface to be tinned. Flux helps solder to stick to the metal. There are many soldering fluxes which may be used, but zinc chloride is the best flux for most soldering jobs on farms and in nonfarm agricultural businesses. Zinc chloride will work on most metals. The following shows the common fluxes, listed after the metals for which they are recommended:

Tin (new) .... Rosin
Galvanized iron .... Hydrochloric (muriatic) acid, zinc chloride

Black iron	Powdered sal ammoniac
Copper and brass	Clean mechanically, sal ammoniac
Lead	Tallow, zinc chloride
Electric wiring	Special fluxes
Sheet metal roofs	Hydrochloric (muriatic) acid, zinc chloride
Zinc	Dilute muriatic acid or commercial paste
Copper tubing	Commercial paste

Heat for Soldering—Heat for soldering can be secured in various ways:

1. A propane torch is a very convenient heat for soldering.
2. Electrically heated soldering irons are satisfactory.
3. A gas furnace may be used.
4. An electric welder may be used.
5. An oxyacetylene welding outfit may be used.



(Courtesy The Lincoln Electric Co.)

Fig. 18.1. Use of a welder for soldering. Short carbon against the work to heat the local area for soldering.

Propane Torch—The propane torch is a convenient source of heat for soldering (Fig. 18.2). It provides sufficient heat for most soft soldering jobs. The propane torch is convenient to move because of its small size and light weight. The heat is immediately available without a prolonged warm-up. There are no objectionable odors from the flame. A propane torch is easy to operate and may be used outdoors or indoors. No carbon, soot, and smoke are produced, and a propane torch will operate in the wind.

In lighting a propane torch, light a match and let it burn until a full flame is produced. Then fully open the valve on the torch. Hold the match to the burner as shown in Fig. 18.3. After the torch is lit, adjust the valve until the desired flame is obtained. Allow the torch to warm up before operating it in an inverted position.

Nonelectric Soldering Irons—Soldering irons are made of copper, and consequently are called soldering coppers. They are used for melting and applying the solder. Coppers are usually sold in pairs, because it is often necessary to have one heating while the other one is being used. A 2- or 3-pound pair of coppers is the best size for most soldering jobs. Smaller sizes are more convenient, however, for some jobs. The small-size coppers do not hold heat for a very long time.

Electric Soldering Irons—Electric soldering irons are available in 100-, 200-, and 350-watt sizes. The 100-watt electric soldering iron is recommended for elec-

Fig. 18.2. A propane torch.

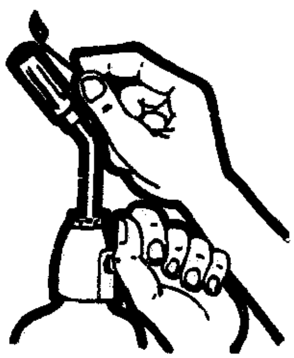


Fig. 18.3. Lighting a propane torch.

trical work and for most home soldering. The 200-watt iron is recommended for heavy work. The 350-watt iron is recommended for very heavy, rugged work. Various size tips are available for electric soldering irons. An electric soldering iron should be equipped with a thermostatic control. An iron with a thermostatic control may be left on without becoming too hot for soldering.

Electric Soldering Gun—The gun produces an intense heat at the point of application to the metal being soldered. The soldering gun is well adapted to the soldering of small parts or to the confinement of heat application to a small area. It may be used when there is a flame hazard. Frequently it may be used when the part to be soldered is inaccessible for a soldering iron.

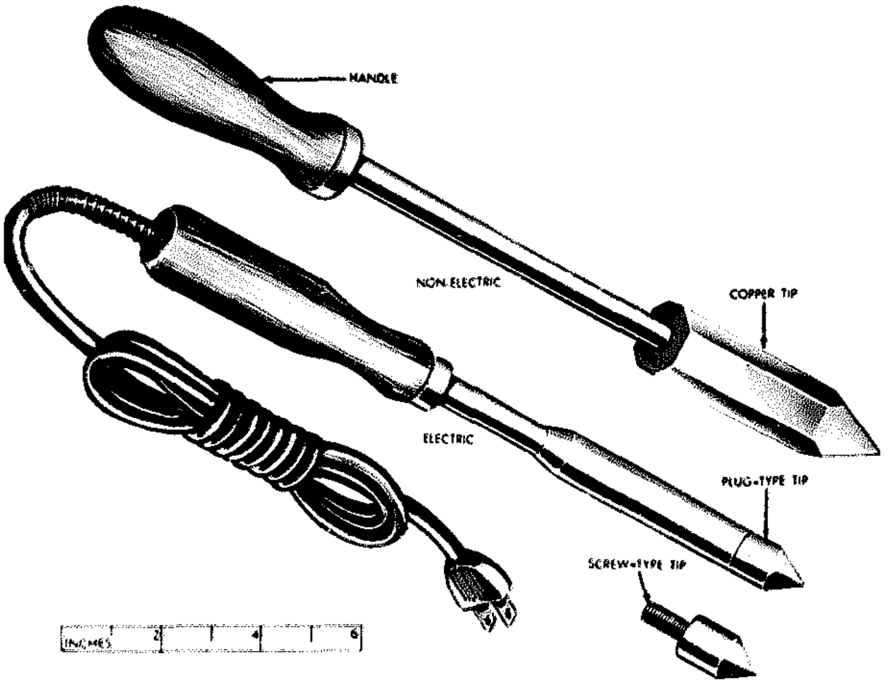


Fig. 18.4. Soldering irons.

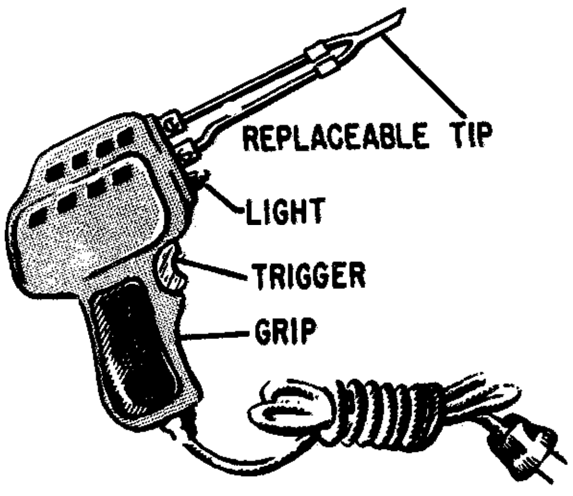


Fig. 18.5. An electric soldering gun.

Tinning—A soldering iron must be tinned before it will pick up and run solder properly. Tinning is the coating of the four faces of a soldering iron with solder. It is done as follows:

1. Heat to a cherry red color, then file each face until it is smooth and bright. If a face is pitted, carefully hammer it until it is smooth.

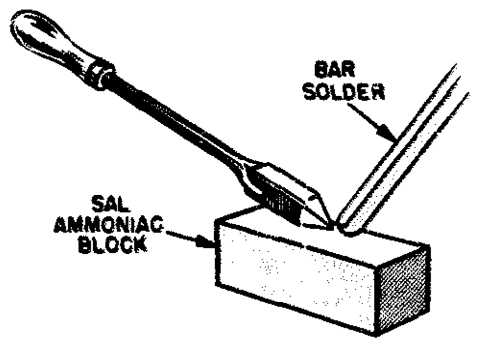


Fig. 18.6. Tinning a nonelectric soldering iron.

2. Rub with or dip into sal ammoniac or resin flux to make the solder adhere to it.
3. Dip into zinc chloride flux.
4. Melt solder into a brick which has a depression chiseled into it.
5. Rub the heated soldering iron back and forth through the molten solder.
6. Wipe off excess solder with a damp cloth.

Retinning—After a soldering iron has been tinned, it is not necessary to file the surface of the faces every time retinning is necessary. Retinning is done as follows:

1. Melt some solder into a groove or hollow place chiseled into a brick.
2. Heat the soldering iron, and dip it into a zinc chloride flux solution or rub the four faces on a sal ammoniac block.
3. Rub the tip of the soldering iron back and forth through the solder in the brick. The brick helps to polish the iron.

Each time before beginning to solder, examine the soldering irons to see whether or not they are clean and properly tinned.

Essential Soldering Equipment—The most frequently used soldering equipment is as follows: knife for scraping, emery cloth for smoothing and finishing, sal ammoniac for keeping the soldering iron in good condition, cotton waste, pliers, file, rivet set, tin snips, tinner's hammers, soldering iron, solder, flux, hollowed brick, brush for applying flux, and propane torch.

SOLDERING

Importance of Proper Preparation of Pieces for Soldering—Much of the success of soldering depends upon the preparation of the pieces to be soldered. Dirty or rusty pieces cannot be soldered successfully; neither can pieces which do not fit together. All pieces should be fitted together closely and cleaned well before soldering is attempted. The proper flux must be selected and applied.

Essentials for Good Results in Soldering—To obtain good results, provide the following:

1. A clean, hot source of heat
2. A hot, well tinned soldering iron
3. Thoroughly cleaned metals to be soldered
4. A proper, good-quality flux
5. Metal heated enough to prevent the solder from "setting" too quickly
6. Solder well "sweated" into the joint

Cleaning Metal for Soldering—The surface of any metal to be soldered should be cleaned until bright. This may be done by scraping, filing, grinding, or sandpapering. New metal may be cleaned by using emery cloth or sandpaper. Old metal may be cleaned as follows:

1. Remove grease (if any) with a safe liquid solvent.
2. File or grind until clean.
3. Apply muriatic acid.
4. Rub with sandpaper.
5. Wash with water to remove the acid.
6. Apply the proper flux.

Muriatic Acid as a Cleaner of Metal—Muriatic acid is often used in cleaning metal that is rusty, but it should be removed with water before the solder is applied, to stop its action on the metal. Removal of the acid should precede the application of the flux, or the metal may rust under the solder. After the muriatic acid is applied, the rust should be removed with a wire brush or with sandpaper.

Applying Flux—Flux should be applied after the metal is cleaned and just before soldering to help the solder stick. It may be applied with a small swab. A bottle containing an acid flux should be kept corked with a glass stopper when not in use.

Correct Heat Essential—Ability to determine when a soldering copper or a soldering iron is heated sufficiently can be acquired only through experience. A beginner can tell best by applying the soldering iron to solder. If the solder melts readily and sticks, the correct heat has probably been reached. Soldering irons must be hot; otherwise, it is impossible to run and apply the solder properly. Insufficient heat often reduces the durability of a soldered joint. However, too much heat should be avoided, or the solder will be burned.

Applying Solder—The first essential in applying solder is to heat the metal to the melting point of the solder with a clean, hot, well tinned soldering iron. Students often use an excessive amount of solder, which produces an unattractive piece of work. Solder should be applied as follows:

1. Heat the soldering iron and dip it in flux.
2. Place it against the solder, causing a little solder to stick to it.
3. Apply the point to the parts to be soldered. The point only should be used; otherwise, too much solder will be applied.
4. Allow sufficient time for heating the metal as the solder is applied. In some cases, the bar of solder may be held against the soldering iron, which causes it to melt and run down to the metal being soldered. (Care must be taken not to use an excessive amount of solder.)

Sweating on a Patch—Sometimes holes in metal are repaired by sweating on a patch. The procedure is as follows:

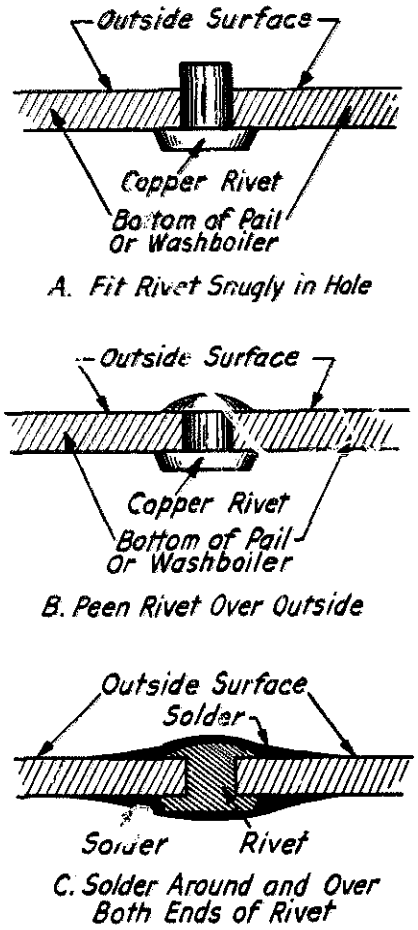
1. Cut a patch slightly larger than the hole to be soldered.
2. Clean the patch on one side.
3. Trim all ragged edges from the hole.
4. Apply suitable flux to the surface around the hole and to the clean side of the patch.
5. Pick up a small amount of solder on the end of the soldering iron and apply a thin coat of solder around the hole and to the clean side of the patch.
6. Place the tinned side of the patch over the hole.
7. Hold the patch firmly in place and apply heat to the patch. Heat it until the solder under the patch has melted.
8. Move the soldering iron around the patch until heat has been applied to the entire patch.
9. Hold the patch in position until the solder is cool.
10. Apply solder around the edges of the patch.

Soldering Holes—Soldering holes in metal is more difficult than merely soldering two surfaces together, but with a little experience satisfactory results can be obtained. Use the following procedure in soldering small holes:

1. Clean the surface around the hole thoroughly with sandpaper.
2. Apply the proper flux.
3. Pick up a small amount of solder on the end of the soldering iron.
4. Apply a coat of solder around the hole.
5. Be sure to bring the temperature of the metal to the temperature of the melted solder.
6. Move the soldering iron around the hole, thus filling the hole with solder.
7. Polish off the excess solder after it has cooled.

(Courtesy Linde Air Products Co.)

Fig. 18.7. Utensils with small holes may be repaired by soldering.



(Courtesy Linde Air Products Co.)

Fig. 16.8. A medium-size hole may be plugged with a copper rivet and soldered as shown.

Soldering Various Metals

There are several metals which farmers or workers in nonfarm agricultural businesses may need to solder. These metals are as follows:

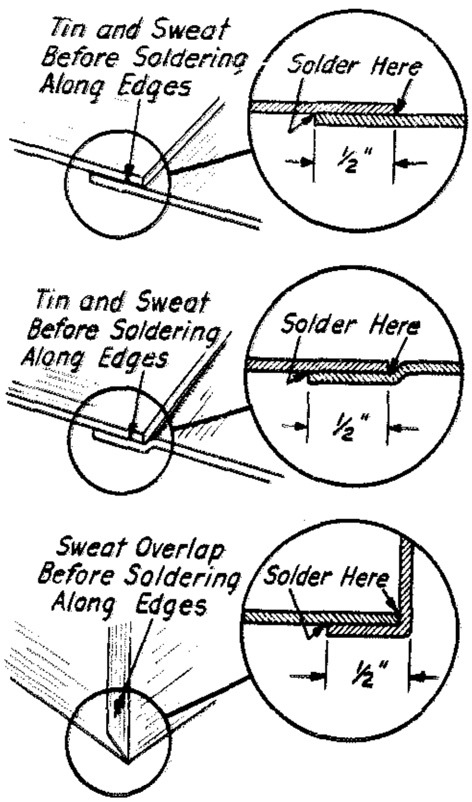
1. Tin
2. Galvanized iron
3. Copper
4. Cast iron
5. Enamelware
6. Zinc
7. Lead pipe

Soldering Tin—Follow the techniques in preceding paragraphs relating to soldering all metals. The following generalized steps are recommended:

1. Clean the surface thoroughly.
2. Use rosin as a flux.
3. Apply solder.

Soldering Galvanized Iron—The general procedure for soldering galvanized iron is as follows:

1. Clean the surface to be soldered by sanding or scraping.
2. Apply muriatic acid (flux) to the surface.
3. Apply solder.
4. Repeat until well soldered.



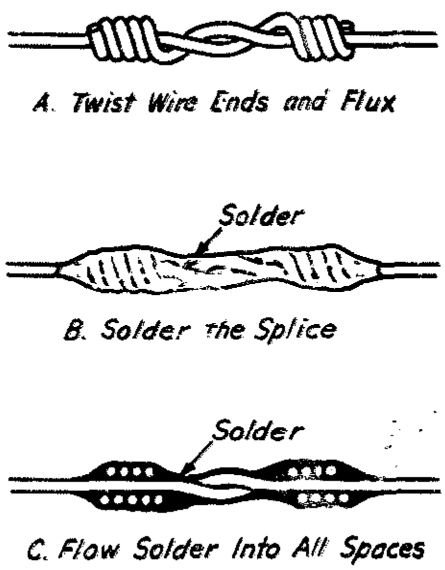
(Courtesy Linde Air Products Co.)

Fig. 18.9. The three lap joints frequently soldered when you work with light sheet metal.

Soldering Copper—The following procedure is recommended:

1. Clean the surface thoroughly.
2. Apply powdered sal ammoniac or commercial paste.
3. Apply solder, covering the surface first with a thin layer of solder.

Soldering Cast Iron—Use the same procedure as given for enamelware.



(Courtesy Linde Air Products Co.)

Fig. 18.10. Soldering an electrical splice.

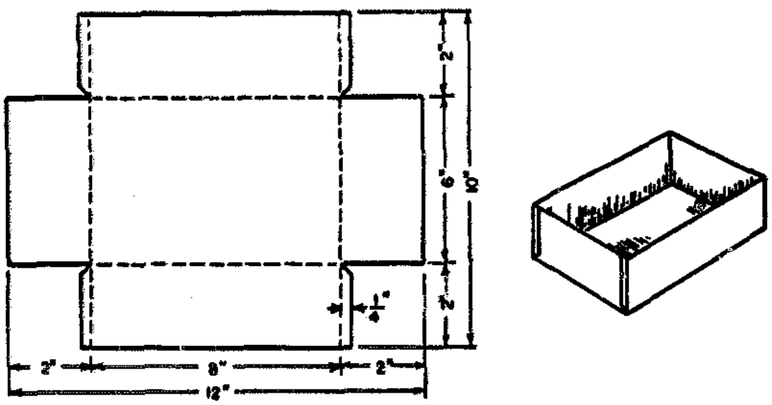


Fig. 18.11. A pan that may be used for small hardware supplies. The seams are soldered.

Soldering Enamelware—Proceed as follows:

1. Remove enamel around the hole.
2. Clean the surface thoroughly.
3. Apply zinc chloride flux.
4. Apply solder.

Soldering Zinc—Use the following procedure:

1. Clean thoroughly.
2. Apply diluted muriatic acid.
3. Apply solder, covering the surface with a thin layer first.

Soldering Lead Pipe—Proceed as follows:

1. Clean thoroughly.
2. Apply tallow flux immediately.
3. Apply solder.

ROPE AND LEATHER WORK

Student Abilities to Be Developed

1. Ability to select the kinds and sizes of ropes suitable for the particular needs of farms, nonfarm agricultural businesses, and other businesses associated with the care and utilization of plants and animals.
2. Ability to handle and care for rope so as to get the maximum service from it.
3. Ability to finish the end of a rope.
4. Ability to make and to use the knots, hitches, and slings that are most helpful in working with plants and animals and their products.
5. Ability to splice a rope.
6. Ability to make a rope halter.
7. Ability to use a block and tackle.
8. Ability to splice and repair leather.
9. Ability to clean and oil leather.

CHAPTER 19

Selecting and Using Rope

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What are the materials used in making rope?
2. How is rope made?
3. How is rope sold, and what are the more common sizes?
4. How do you determine the proper size of rope to use?
5. What are the precautions to observe in the care of rope?
6. What is the advantage of using pulleys, blocks, and tackle?
7. Why is a knowledge of the proper methods of whipping and tying ropes important?
8. What are the principal parts of a knot? What is a hitch?
9. What are some of the essentials of a good knot or hitch?
10. What knots and hitches are used in working with plants and animals and their products?
11. How are they made?
12. What are the essentials of a good splice?
13. What are the steps involved in making rope splices?
14. What are the common splices? How are they made and used?
15. How may broken strands in ropes be repaired?
16. What types of rope halters are frequently used, and how are they made?
17. How are slings made?

SELECTING AND CARING FOR ROPE

The Use of Rope in Agriculture—Rope is an essential part of the equipment of most farms and nonfarm agricultural businesses. Many kinds and sizes of rope are in constant use in agricultural activities. Like any other piece of equipment, the efficiency and economy of rope depend upon suitability as to size and quality for the purpose for which it is to be used. Knowledge of the important factors involved in the selection, care, and use of rope, and skill in using and repairing rope are important in many jobs relating to plants and animals and their products.

Rope Materials—Many kinds of fibers may be used for ropes. Cotton makes a soft, pliable rope, often used for small ropes such as clotheslines and window cords. Other materials used are hemp, flax, jute, and similar fibers, plus synthetic fibers such as nylon. Steel cables are in common use on heavy hoisting machinery. The two most important and most frequently used materials for the ropes used in agriculture have been manila and sisal.

In recent years synthetic fiber ropes have been used with increasing frequency, especially for certain purposes. Synthetic fiber ropes are usually stronger than natural fiber ropes. Nylon or dacron rope is especially useful in wet conditions. It will not rot or mildew, and it does not absorb water. It is often used for lariats, towlines, and starter ropes. Oils, solvents, and alkalies do not damage nylon rope. Dacron rope resists damage from heat, insects, and acids. Glass fiber rope resists damage from high temperatures, and polyethylene rope floats in water.

Rope is also made from steel wires wound on a core made of fiber or small wire. Wire rope exceeds all other types of rope in strength. It is often used as a part of agricultural machinery.

Manila rope is made from the fibers of the abacá plant, which is a native plant of the Philippine Islands. The plant grows from 15 to 20 feet tall with stems and leaves resembling a banana plant. The stalks have many thread-like fibers like the strings in celery. After the pulpy part of the stalk has been scraped away, these long fibers are given a special treatment and then twisted into yarns and made into rope. Manila rope is usually considered to be better than sisal rope, being softer, more pliable, and stronger. However, it is usually more expensive.

Sisal rope is made of the fibers from the long, pointed leaves of a cactus-like plant which is extensively grown for this purpose in Mexico, especially in the Yucatan. Most "binder twine" is made of sisal.

There are many grades and qualities of rope manufactured from both manila and sisal fibers which sell at varying prices and which may be expected to give varying degrees of service.

Construction of Rope—By unraveling the end of a rope, it is possible to see how it is constructed. The fibers, after being oiled and specially prepared, have been twisted together loosely with a clockwise twist to form *yarns* similar to binder twine. A number of yarns are then twisted together with a counterclockwise twist to form *strands*. Three or four of these strands are then twisted together in a clockwise direction to form a rope. This twisting holds the fibers together and gives the rope strength. Since each twist is in an opposite direction, the rope does not untwist or unravel when it is used. A very hard-twisted rope is heavy and stiff. It may have a tendency to kink, and it is difficult to splice and handle. Most of the rope used in agriculture is composed of three strands put together with a clockwise twist. It is called "hauser-laid" rope. A "shroud-laid" rope contains four strands. A core or strand runs through the middle of it.

Weight and Strength of Rope—Rope is sold by weight. Tables 19.1 and 19.2 have been prepared to show facts regarding rope weights and strengths.

Table 19.1—Facts About Three-Strand Manila Rope[1]

Diameter (Inches)	Weight of 100 Feet of Rope (Pounds)	Length of Each Pound of Rope (Ft.-In.)	Safe Load (Pounds)	Breaking Load (Pounds)	Least Diameter of Pulley (Inches)
¼	3	33-4	55	400	2
⅜	5	20-0	130	900	3
½	7⅔	13-0	230	1,620	4
⅝	13⅓	7-6	410	2,880	5
¾	16⅓	6-1	520	3,640	6
⅞	23⅔	4-3	775	5,440	7
1	28⅓	3-6	925	6,480	8
1¼	45	2-2	1,445	10,120	10
1½	65	1-6	2,085	14,600	12
2	113	0-10	3,600	25,200	16

[1]Taken from "The Use of Rope on the Farm," Extension Circular 700, University of Nebraska, Agricultural College Extension Service, Lincoln.

Table 19.2—Safe Working Strength of New Fiber Rope[1]

Rope Diameter (Inches)	Working Strength (Pounds)[2]					
	Natural Fiber		Synthetic Fiber			
	Manila	Sisal	Nylon	Dacron	Polyethylene	Saran
⅜	200	150	400	390	300	150
½	440	350	780	745	600	300
⅝	880	700	1,710	1,355	1,100	620
¾	1,080	865	2,000	1,870	1,600	800
⅞	1,540	1,230	2,700	2,520	2,120	1,140
1	1,800	1,440	3,600	3,220	2,800	1,600

[1]Taken from *Rope on the Farm*, Farmers' Bulletin No. 2130, United States Department of Agriculture.
[2]Actual breaking strengths are at least 5 times the figures given.

A general rule for computing the approximate breaking strength of manila rope is as follows:

Square the diameter in inches.
Multiply the product by 7,200.

For example, the breaking strength in pounds of a ¼-inch rope could be estimated in this way: ¼ × ¼ × 7,200 = 450 lbs. breaking strength. The safe load may be found by dividing the breaking strength by 7, thus: 450 ÷ 7 = 64 lbs.

Selecting Rope—In selecting rope which will be under heavy strain, such as lifting hay, use a large safety factor. That is, if the load to be lifted is 500 pounds, a rope should have a breaking strength of at least 7 times that weight, or 3,500 pounds. For hard, continued use, the best grades of rope are the most economical. For a halter rope a loosely laid soft rope is desirable because it is flexible, pliable, and easy to handle.

Care of Fiber Rope—Natural fiber rope such as manila rope should be kept in a reasonably dry place. If it becomes wet in use, it should be dried in the sun before it is coiled and put away. The fibers will weaken and loosen if stored wet in a damp place or if subjected to a great deal of wetting and drying.

Rope should be coiled to the right, the direction in which the strands are laid. When a long rope or bale is uncoiled, it should be uncoiled in a counterclockwise direction from the inside of the coil, starting with the end that was laid down first. Uncoiling rope in a counterclockwise direction from the inside of the coil prevents kinking and snarling. Binder twine will also twist and snarl if uncoiled from the outside of the ball.

If a rope has a tendency to twist and kink, it can be straightened out by fastening it to the back of a tractor and dragging it over a grassy field.

An exceptionally hard and stiff natural fiber rope can be made more pliable and easier to handle by boiling it in water for 15 to 30 minutes, then stretching it out to dry thoroughly. This process decreases the strength of the rope considerably, however.

Inside wear on a rope may be detected by twisting it open with the hand and noting the "rope dust" and finely broken pieces of fiber that can be shaken out of it. Note the condition of the yarns and strands, even though the outside of the rope may seem to be in good condition.

USING AND HANDLING ROPE

The knots and hitches now generally recommended for use in agriculture are the result of generations of experience in the handling of ropes. Many knots and hitches were developed by the seafarers on the old sailing ships where ropes were such an important part of a ship's gear, and necessity required that ropes be handled with the greatest possible speed, efficiency, and safety. To develop skill in the use of ropes and in making the particular type of knot or hitch which is most suitable for a particular use requires close observation and a great deal of practice.

Elements of a Knot—The names of the basic parts or elements of knots, hitches, and bends are (1) the round turn, (2) the loop or open bight, and (3) the closed loop or true bight. (See Fig. 19.1.)[1] These terms are used in describing knots and should be learned.

A hitch is a temporary knot used to fasten a rope around a timber, pipe, or post in such a manner that it will hold securely and can be easily unfastened.

Essentials of a Good Knot or Hitch—Three requirements of a good knot or hitch are as follows:

1. Rapidity with which it can be tied.
2. Ability to hold fast when pulled tight.
3. Readiness with which it can be untied.

[1]Most of the illustrations used in this chapter are furnished through the courtesy of Iowa State University, Ames.

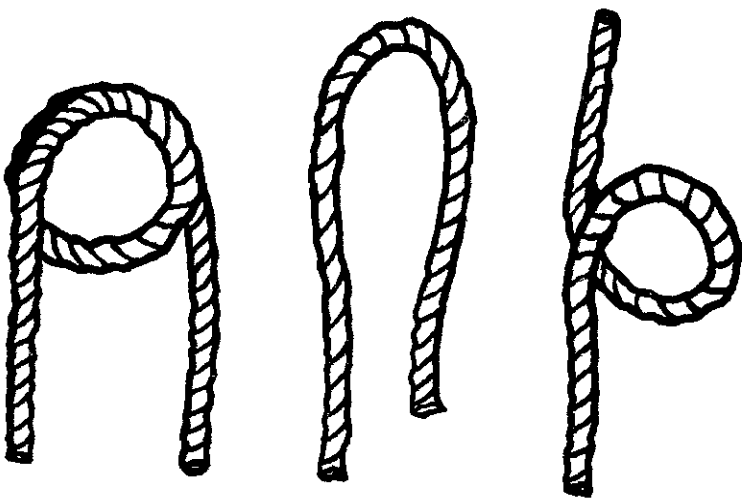


Fig. 19.1. Elements of knots: left—round turn, middle—bight, and right—loop.

Two fundamental principles which must be kept in mind by a student have been given as follows:

"The principle of a knot is that no two parts which move in the same direction, if the rope were to slip, should lie along side of and touch each other.

"A knot or hitch must be so devised that the tight part of the rope must bear on the free end in such a manner as to pinch and hold it, in a knot against another tight part of the rope, or in a hitch against the object to which the rope is attached."[2]

The equipment needed for rope work is a knife for cutting the rope and a large nail or a marlinspike for separating the strands. A marlinspike approximately 4 inches long and ¾ inch in diameter, tapering to a blunt point at one end, may be whittled from a piece of wood. (See Fig. 19.2.)

Knots and Other Means of Finishing the End of a Rope

Unless the end of a rope is properly secured, it will soon unravel and become frayed. An ordinary knot in the end of a rope may be used to prevent unraveling and fraying, but a knot is inconvenient when the rope is to be passed through a pulley or ring. An ordinary wrap of the end of a rope with a cord soon loosens and wears out. A wrap with wire or metal, especially on a halter tie, may result in a bad cut or tear if the rope is accidentally jerked through the hand. A small amount of time spent in securing rope ends by one of the methods explained in the following paragraphs is well worthwhile.

Relaying Loose Ends—If the rope has become untwisted and raveled, the

[2]Fred D. Crawshaw and E. W. Lehmann, *Farm Mechanics*. Peoria, Illinois: The Manual Arts Press, p. 382.

strands should be retwisted and carefully laid into their proper place again. Hold the rope with the left hand just below the point where the unraveling begins. (See Fig. 19.3.) Take one of the loose strands in the right hand, twist it tightly together again with a right-hand twist, and lay it across the other strands from left to right, holding it in place with the left thumb. Do the same with each of the other strands in succession, twisting them tightly and placing them in their original positions. Move the left hand along the rope, holding the strands securely in place to prevent their untwisting. Continue twisting each strand in order, laying each in position a little at a time until the end of the rope has been relaid. Fasten the end securely by whipping or some other suitable method.

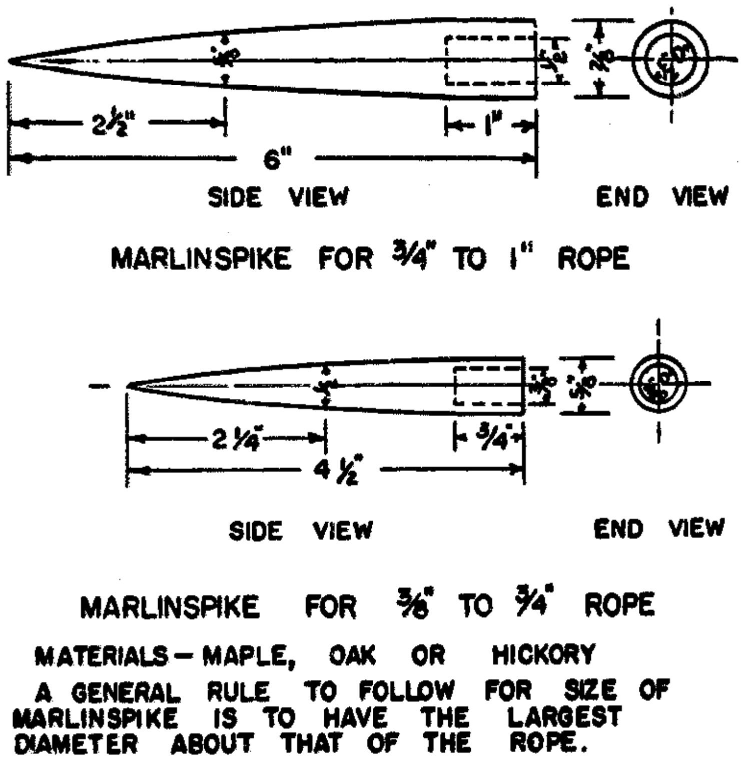


Fig. 19.2. Sketches of a marlinspike.

Fig. 19.3. Relaying strands.

Whipping—Whipping a rope end with a cord is the most satisfactory method for securing the ends of ropes to be passed through pulleys and for securing the ends of halter ropes. If properly made, the whipping will last the life of the rope, will hold the end securely, and will not increase the diameter of the rope. The following procedure should be followed in whipping the end of a rope (see Figs. 19.4 and 19.5 for illustrations of the process):

1. Select a strong medium-weight cord about 3 feet long.
2. Lay one end of the cord along the rope in such a manner that the cord extends about 3 inches beyond the end of the rope *(a)*.
3. Place the other end of the cord along the first, but pointing in the opposite direction *(b)*, the main part of the cord forming a large loop *(y)*.
4. Hold with the left hand, as indicated in Fig. 19.4.
5. Take the loop in the right hand and begin to wrap the rope over both cords. Wrap tightly and neatly for 1 to 2 inches.
6. Draw ends *a* and *b* tight, pulling the remainder of the loop under the wrap.
7. Cut off the ends close to the wrap. The finished end should appear as shown in Fig. 19.5.

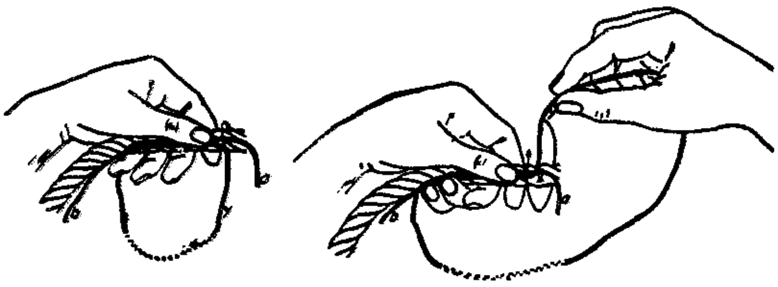


Fig. 19.4. The beginning of "whipping."

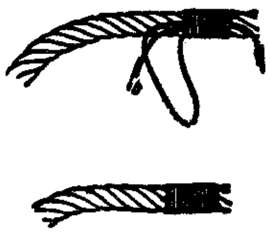


Fig. 19.5. Whipping finished.

Overhand Knot—Used frequently, the overhand knot is simple to make. It may be used temporarily to keep a rope from unraveling. The overhand knot also is the basis for many other types of knots. (See Fig. 19.6.)

Figure-Eight Knot—This knot is used to form a knot on the end of a rope. It may be used temporarily to prevent unraveling, but its chief use is to serve as a convenient knob handhold or to prevent ropes from pulling through pulleys or holes. Form the figure-eight knot as follows (see Fig. 19.7):

1. Throw a loop near the end of the rope.
2. Give the short end *(a)* a complete turn around the standing part of the rope *(b)*, and pass it through the loop at *x*.
3. Pull tight.

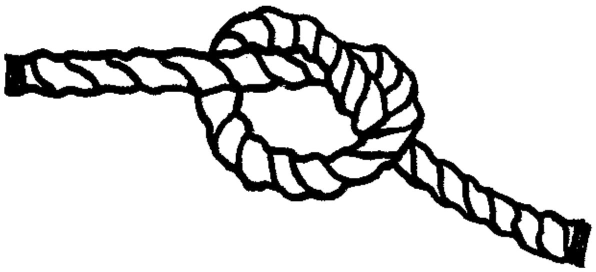


Fig. 19.6. An overhand knot.

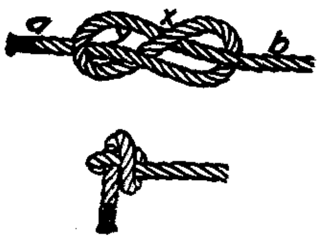


Fig. 19.7. A figure-eight knot.

Wall Knot with Crown—This is a combination wall knot and crown knot which forms a neat and fairly large knot. It is used to prevent a rope end from pulling through a small opening.

Make the wall knot as follows (Fig. 19.8):

1. Unlay the end of the rope about five turns.
2. Hold the rope in the left hand, loose strands upward.
3. Make a loop in the right-hand strand *(1)*, laying it across the front of the rope with the end hanging free as shown in Fig. 19.8. Hold it in place with the left thumb.
4. Bring the middle strand *(2)* down around the free end of strand *1* as indicated by the arrow. Hold it in place with the thumb.

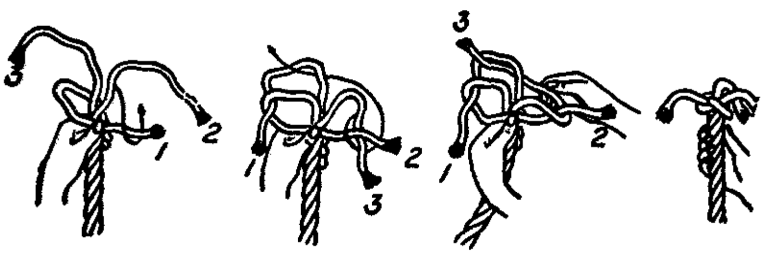


Fig. 19.8. A wall knot.

5. Pass the remaining strand (3) under and around strand 2 from front to back, and then pass the end through the loop in strand 1.
6. Hold securely with the left hand and draw each strand gradually until the knot is tight. Pull strands at right angles to the rope. Work the knot down against the twisted part of the rope.

Make a crown knot on top of the wall knot as follows:

1. Bend the left-hand strand (1) down between strands 2 and 3, forming a loop on the left-hand side of the rope. (See Fig. 19.9.)
2. Pass the right-hand strand across to the left of the rope, laying it between the loop and strand 3.
3. Pass strand 3 through the loop in strand 1.
4. Tighten the crown by pulling each strand. Cut off loose strands. The finished knot should have the appearance of the knot in Fig. 19.10.

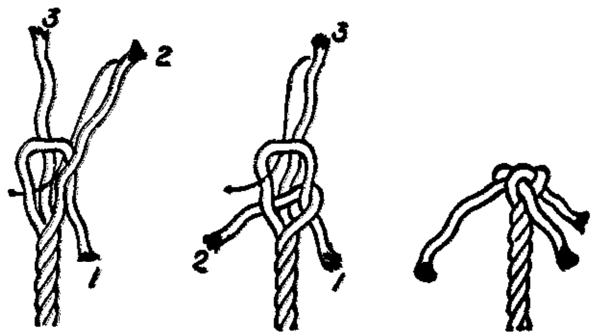


Fig. 19.9. A crown knot.

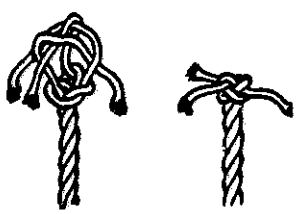


Fig. 19.10. A wall and crown knot.

End of Crown Splice—The spliced crown is one of the best ways to finish a rope end when a slight enlargement is not objectionable. It takes a little longer to finish than the more simple knots, but when carefully made it is neat, smooth, and permanent. It is especially good for finishing a halter rope. It consists of a crown knot with the ends spliced into the rope. (See Fig. 19.11.)

Make a tightly drawn *crown knot* as shown in Fig. 19.9. Then weave the loose ends as follows:

1. Pass strand 1 to the right over the strand nearest to it on the main rope and under the next strand, pulling it through tightly in a diagonal direction, almost at right angles to the twist of the strands.

2. Handle strands *2* and *3* in the same manner, passing over the main strands next to them and under the following strands.
3. Continue with each strand in turn until all have been spliced in, over one strand and under the next for three or four times. A marlinspike may be used to raise the strands.
4. Smooth the crown by rolling it under the foot and by removing the loose ends. The finished end should have the appearance of the splice in Fig. 19.11.

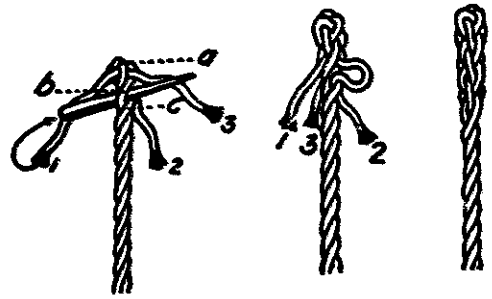


Fig. 19.11. An end or crown splice.

Knots Used for Tying Two Ropes Together

It is often necessary to tie the ends of two ropes or cords together to obtain a rope or cord of a greater length. Such a knot should (1) be easy to tie, (2) hold securely without slipping, and (3) untie readily.

Square Knot—One of the most frequently used and best knots for tying ropes together is the *square knot*, which is sometimes called the *reef knot*. (See Fig. 19.12.)

1. First tie the ends together with a simple right-hand form of the overhand knot.
2. Then cross strand *a* in front of *b*, and tie a left-hand overhand knot. Draw tight.

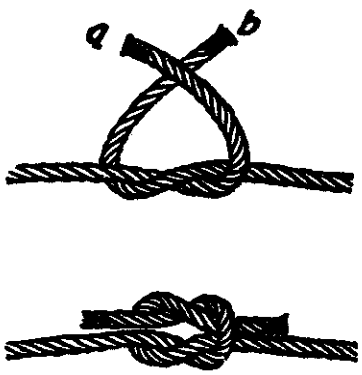


Fig. 19.12. A square knot.

Notice that in the square knot both parts of the same end lie together in leaving the loops. This is the chief distinction between it and the *granny knot,* which, although often used, is a very inferior knot and has little value because it slips easily and is hard to untie. The granny knot is illustrated (Fig. 19.13) to show the difference between it and the square knot for which it is often mistaken.

Fig. 19.13. A granny knot.

Surgeon's Knot—This is a modified form of the square knot. The difference lies in giving the first overhand knot two turns instead of one as in tying the overhand knot. (See Fig. 19.14.) This extra twist keeps the knot from slipping while the second overhand knot is being tied. Note that the ends come out of the loops doubled back on themselves as in the square knot. The knot is especially good for tying cords and twine when they are to be drawn tightly about something. It is used in surgical operations.

Fig. 19.14. A surgeon's knot.

Carrick Bend—This knot is well suited for tying heavy ropes together. It will withstand heavy strain and will untie easily. It is also used as a fancy knot in braids.

1. Throw a loop in the end of one rope with the end *y* under the standing part of the rope *a*. Hold with the left hand. (See Fig. 19.15.)
2. Pass the end of the rope *b* under the loop *x*, over the standing part at *a*, and under the end *y*.

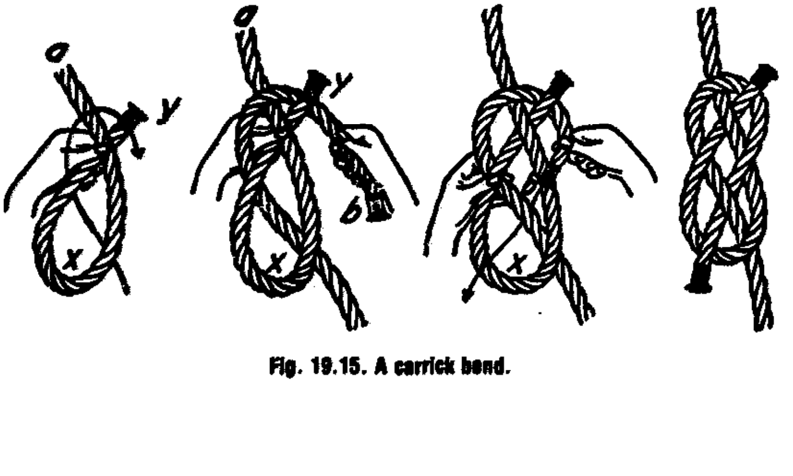


Fig. 19.15. A carrick bend.

3. Hold the knot together with the left hand and continue with end *b*, passing it over the right side of the loop *x*, under the standing part of *b*, then over the left side of loop *x* as indicated by the arrow in Fig. 19.15.
4. Hold parts in position and draw tight.

Knots and Hitches for Fastening Animals, Forming Loops, and Tying a Rope to Rings, Hooks, and Poles

Slip Knot—The slip knot is frequently used. It forms a loop that will slip tight around an object. However, it often does not hold securely and is hard to untie.

Manger Knot—This knot is familiar to all persons who have tied animals to mangers. It is similar to a slip knot, but may be untied easily; hence, it is more satisfactory for tying halter ropes.

Bowline Knot—This is a knot that has a great many practical uses. It forms a loop that will not slip or draw tight. It is easily untied. It may be made by several different methods.

Beginner's Method—Bowline (Fig. 19.16):

1. Place the end of the rope through a ring or around the object to which it is to be tied.
2. With the left hand, throw a bight or a loop in the standing part of the rope as shown in Fig. 19.16.
3. Bring end *a* through loop *b* from the upper side, passing it around the standing part of the rope at *c*, and then up through loop *b* again as shown in Fig. 19.16.
4. Draw the knot tight.

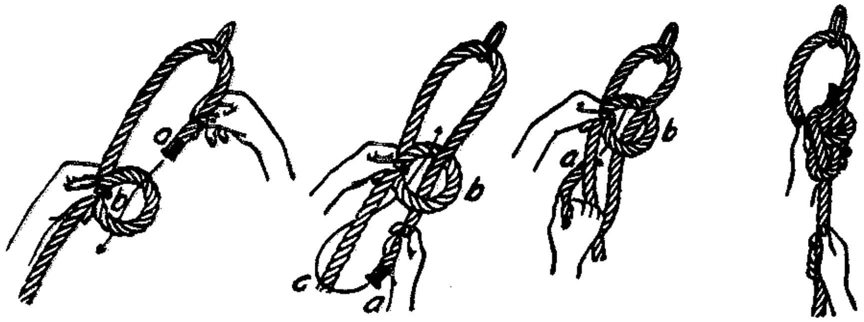
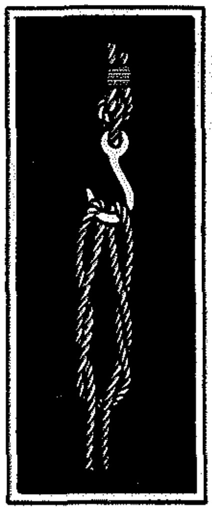


Fig. 19.16. A beginner's bowline knot.

Cat's Paw—The cat's paw provides a good method of fastening a rope to a hook.

1. Throw a double loop in the rope as shown in Fig. 19.17.
2. Give each loop 1½ or 2 turns, and place the loops on a hook.

Half Hitch—The half hitch is used for temporarily fastening a rope to a timber or to a pipe. It holds well while it has a steady pull against it. After the end



(Courtesy Hooven and Allison Co.)

Fig. 19.17. A cat's paw.

has been passed around the object, it is given a turn about the standing rope and then it is placed under itself, which binds the end against the object when a pull is exerted. (See Fig. 19.18.)

Timber Hitch—The timber hitch is a modification of the half hitch and holds more securely. The end is given one or two wraps back on itself, instead of being simply tucked under as in the half hitch. (See Fig. 19.18.)

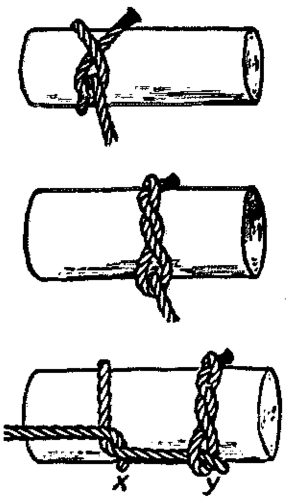


Fig. 19.18. Half and timber hitches.

Timber Hitch and Half Hitch—When a straight end pull is necessary for lifting or dragging long pipes and poles, a combination of the timber hitch and the half hitch as shown in Fig. 19.18 is much safer than either used alone. Make the half hitch first, then pass the end of the rope back and form the timber hitch.

Clove Hitch—This is one of the most useful hitches for fastening tent ropes and guy ropes to stakes or poles. When properly tied, it will not slip, but may be untied readily. Two methods of tying a clove hitch are often used:

1. *Sailor's Clove Hitch* (Fig. 19.19). Form a loop with the right hand and throw it over the top of the post. Hold the loop in place with the left hand, make a second loop with the right hand, and throw it over the post.
2. *Beginner's Clove Hitch* (Fig. 19.20). Throw two loops in the rope—one to the left, the other to the right. Move loop *z* over loop *y*. Place the hitch over the end of a post or stake and draw tight.

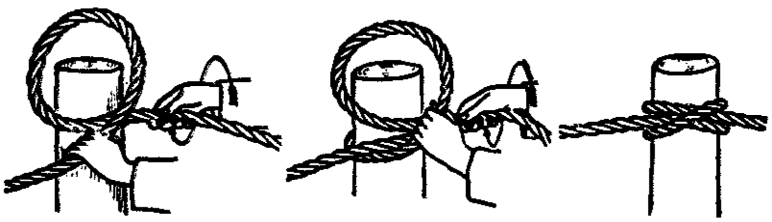


Fig. 19.19. A sailor's clove hitch.

Fig. 19.20. A beginner's clove hitch.

Adjusting the Length of a Rope

Sheepshank—It may be desirable at times to remove the slack in a rope or to shorten it without untying the ends. The sheepshank is the most satisfactory method of doing this.

1. Make two loops which are long enough to remove the slack (Fig. 19.21). Hold the loops with the left hand.
2. Make a half hitch, with the right hand, in the rope near one end of the loop and slip it over the end of the loop.
3. Make another half hitch over the other end of the loop. This completes the hitch.

The hitch may be fastened permanently by passing the ends of the rope through the loops. (See Fig. 19.21.)

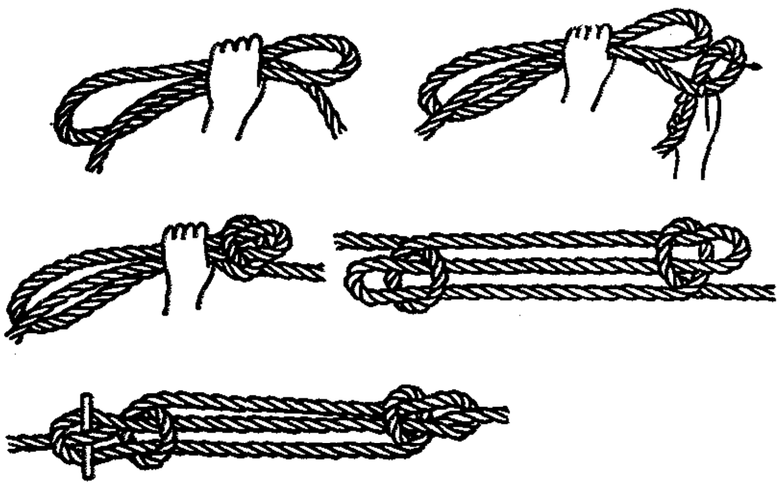


Fig. 19.21. A sheepshank.

Splicing Rope

The ability to repair broken strands or to splice a broken rope often saves time and money. A broken rope, for example, may delay an entire work crew and cause considerable monetary loss if no one is present who can make a smooth, strong splice that will run through pulleys. Such a splice is not difficult to make. But it does require close attention to the principles involved, patience in doing the detailed steps carefully, and practice or drill until skill has been developed.

Essentials of a Good Splice—A good splice must be strong. It must carry the same load as any other part of the rope; hence, it will weaken the rope to the extent of the weakness of the splice. It must be durable and wear as well as the rest of the rope. If a splice begins to fray and loosen, it should be cut apart and a new splice made. It must not greatly increase the diameter of the rope or it will not pass readily through pulleys.

Steps in Rope Splicing—There are three main steps involved in making a splice:

1. Unlaying the strands of the ends to be joined.
2. Fitting these ends together with the strands interlocking.
3. Relaying and weaving the ends of the strands into rope.

Short Splice—The short splice is used to join two ropes when it is not necessary for the rope to pass through a pulley. The splice is not as smooth as the long splice, but it is strong and satisfactory for straight pulling or lifting. (See Fig. 19.22.)

1. Unlay the ends to be joined about seven or eight turns.
2. Bring the two ends tightly together against the twisted parts so that the strands are interlocking, that is, each strand separated by a strand from the opposite end. Note that the strands of opposite ends lie in pairs.

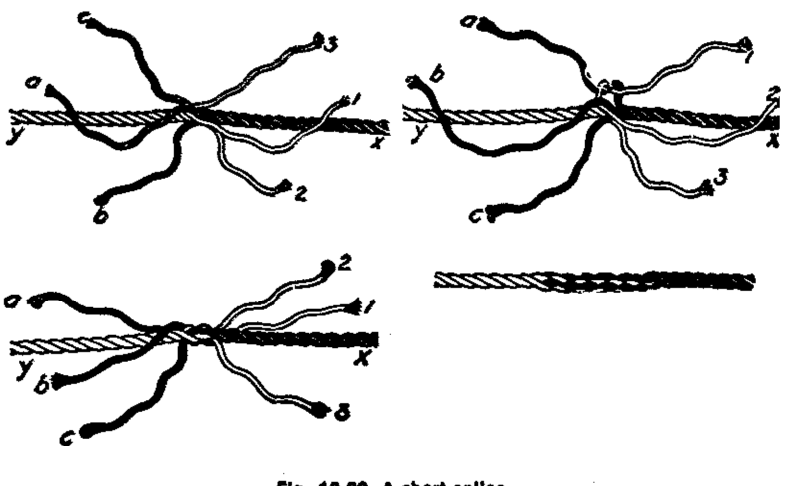


Fig. 19.22. A short splice.

3. Tie one of the pairs of opposite strands together with a right-hand overhand knot. Be sure you tie the right pair so the knot will lie smooth with the strands following their original twist.
4. Tie the other pairs of strands in similar fashion. Draw all knots tightly and securely so that the twisted parts of the rope are joined firmly.
5. Tuck or weave the strands back into the rope as directed for the crown splice (Fig. 19.11). Each strand is woven in diagonally to the left, passing over the main rope strand next to it, under the second strand, over the third, and so on. Give each strand one tuck at a time, twisting and working the strands to secure a smooth, even job. Each strand should be tucked under at least two or more times, depending upon the weight to be carried by the rope.
6. Remove the excess length of the strands, leaving ends about ½ inch long. Roll the splice under a shoe or block of wood to make it smoother. A neater finish may be given by thinning out a part of each of the strands, by tapering the strands towards their ends, and by giving them several extra tucks.

Long Splice—The long splice is the most satisfactory method of joining rope ends when the rope will have to pass through a pulley. It is a strong, durable splice and increases the diameter of the rope only slightly. It will, however, shorten the rope from 3 to 8 feet. (See Fig. 19.23.)

1. Unlay the strands of each end about 15 turns. A 1-inch rope should be unlaid about 3 feet.
2. Place the two ends together as directed for the short splice, so that the strands are interlocking and alternate.
3. Tie two of the pairs of strands together with overhand knots, as in the short splice, to hold ends securely while splicing the other pairs of strands. Draw knots tightly, joining the twisted parts of the rope securely and firmly.
4. Unlay carefully one of the untied strands, a turn at a time, and in its place lay the corresponding strand from the other end of the rope. Lay this strand carefully, twisting it tightly and laying it in place snugly and securely as though it were a part of the original rope. Continue until within 6 to 8 inches of the end of the relaid strand. Tie with an overhand knot.

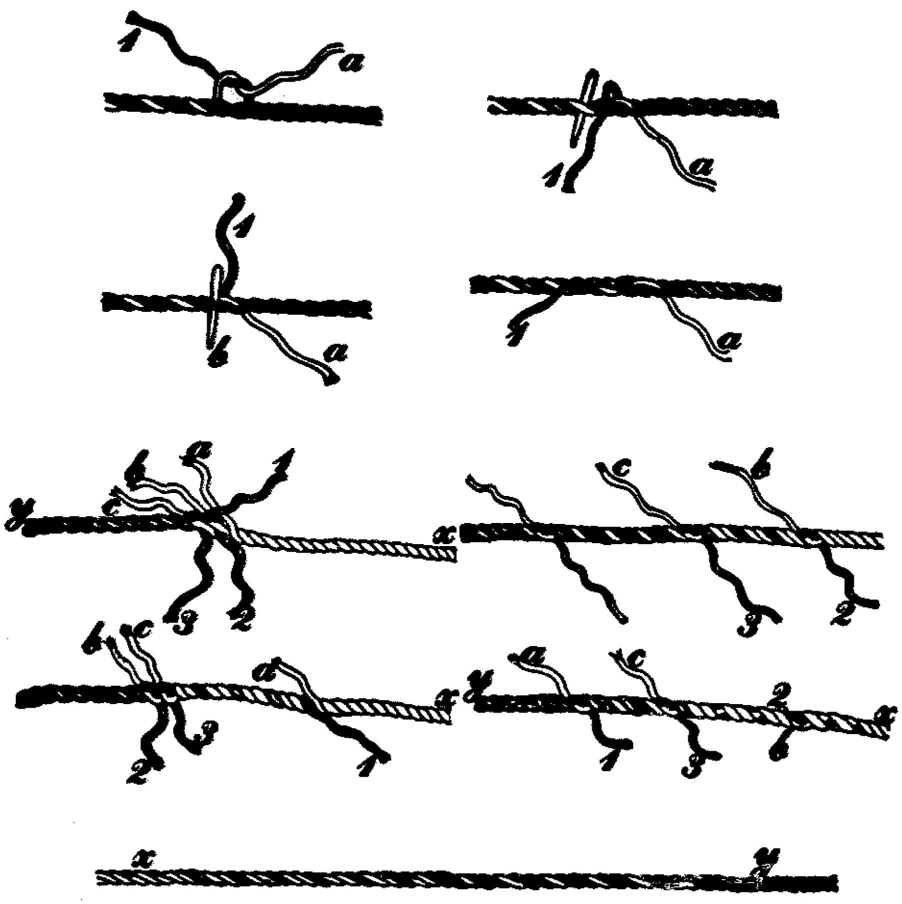


Fig. 19.23. A long splice.

5. Turn the rope end for end, and untie one of the other pairs of strands. Proceed as with the first pair of strands but in an opposite direction, unlaying one strand and relaying the other strand in its place. Tie with an overhand knot when near the end of the relaid strand. The splice now has the strands tied in three places along the rope. (See Fig. 19.23.)
6. Draw all knots securely, and tuck the ends of the strands into the rope as explained for the crown splice and the short splice. Each strand end should be passed diagonally to the left over the strand next to it, and under and over the following strands, passing under strands at least twice.
7. Remove the excess length of the ends and smooth the splice by rolling it under a shoe or with a block of wood.

Repairing a Broken Strand—If a strand is broken or badly frayed, it should be repaired by removing a portion of it and by laying a new piece in its place. (See Fig. 19.24.)

1. Unlay the ends of the strand as far as necessary.
2. Lay in its place, as described for the long splice, a new or sound strand of similar size and of sufficient length.
3. Tie strand ends with overhand knots, and tuck them over and under the main rope strands.

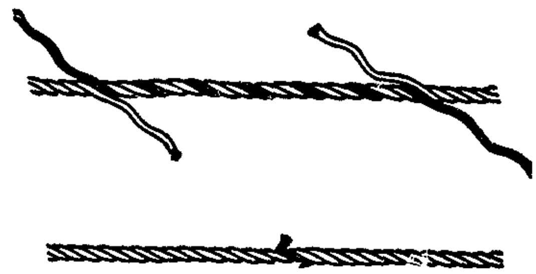


Fig. 19.24. Mending a broken strand.

Loop Splice—The loop splice consists of a small permanent loop in any part of a rope through which another rope or a part of the same rope may pass. Its chief use is in the construction of a rope halter. (See Fig. 19.25.)

1. Raise two strands in the rope where the loop is to be made.
2. Pass the long end *a*, which will be the lead rope of the halter, through the opening under the raised strands. It is important that the rope *a* cross under the two strands at right angles to the direction in which they are laid. (The dotted line indicates the *improper direction* for passing the rope under the strands.) Draw the loop to the desired size.
3. Raise two strands in the long part of the rope *a* as indicated.
4. Pass the short end of the rope through this opening.
5. Work the ropes closely together, completing the loop splice as shown in Fig. 19.25.

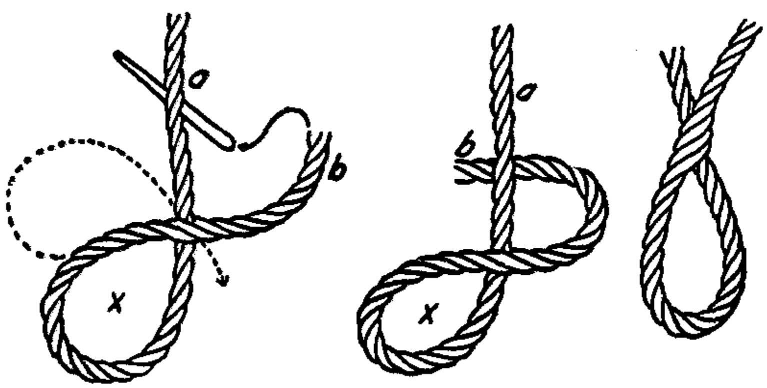


Fig. 19.25. A loop splice.

Eye Splice or Side Splice—This splice is used for making a permanent loop or eye in the end of a rope, or for splicing a rope, at right angles, into another rope. It is used in making a rope halter. It provides an excellent means of attaching a lead rope to a halter ring, or for attaching a rope to the ring of a pulley block. The procedure for making an eye or side splice is as follows (see Fig. 19.26):

1. Unlay the rope end about five turns.
2. Bend the rope end back on the main part of the rope to form a loop of

the desired size. The two outer strands should straddle the rope, the center strand lying on top of the rope.
3. Raise a strand in the main rope and pass the middle loose strand under it in a direction opposite to the twist of the main rope.
4. Weave this strand into the main rope, passing it over the strand next to it, under the second strand, and so on.
5. Tuck in the other two strands in the same manner. Make sure that each loose strand passes over and under but one strand at a time, and that each loose strand is separated by main rope strands.
6. The finished eye splice should have the appearance of the splice in Fig. 19.26.

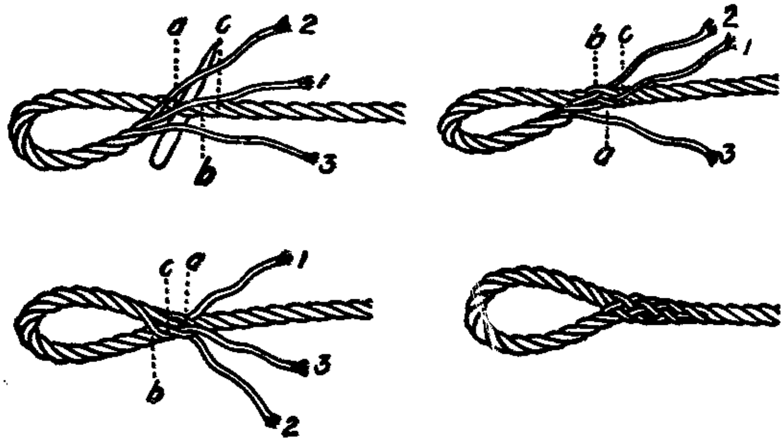


Fig. 19.26. An eye splice.

Making Rope Halters

Anyone who works with livestock will often find that the ability to make a rope halter is worthwhile. Such a halter is easily made and very serviceable for both horses and cattle. Halters for cattle are ordinarily made of ⅜-inch rope, but for large animals, horses and bulls, the rope should be ½ or ⅝ inch in diameter. A halter for a medium-sized animal will require about 12 to 14 feet of rope, allowing 6 feet for a lead. A halter may be made so that it is adjustable or nonadjustable. Each kind has certain advantages.

Nonadjustable Halter—Since this type of halter when completed cannot be adjusted to heads of different sizes, it is necessary to measure the animal's head in order to determine the length of rope needed for the head and nose piece. An advantage of this type of halter is that it will not loosen and slip down over the nose or head. Following is the procedure for making a single loop halter:

1. Determine the necessary length of nose piece and head piece by measuring the animal's head.
2. Make a small loop splice (see Fig. 19.25) toward the end of the rope, leaving the short end long enough to form the nose piece.
3. Measure, from the loop splice, the proper length for the head piece.

4. Fasten the end of the nose piece into the side of the standing rope with a side splice (see Fig. 19.26), making the head piece the correct size.
5. Pass the lead end of the rope through the loop splice, making the jaw piece.
6. Finish the end of the lead rope with a crown splice. (See Fig. 19.11.)

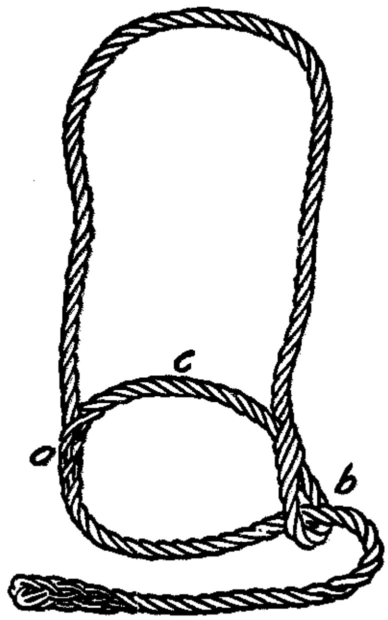


Fig. 19.27. A single loop halter.

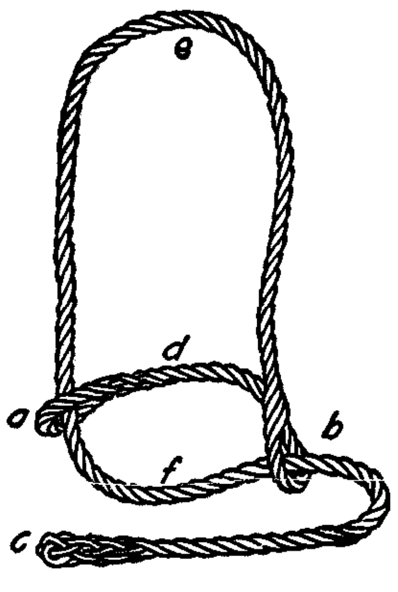


Fig. 19.28. A double loop halter.

Adjustable Halter—A halter which can be adjusted in size is often desirable, especially for horned cattle. Its disadvantage is that it may loosen and slip from an animal's nose.

The procedure for making an adjustable halter is as follows:

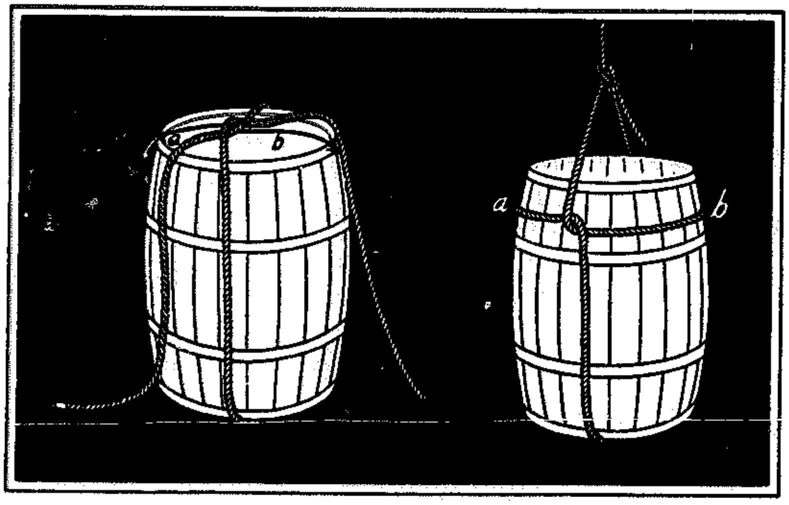
1. Make an eye splice (Fig. 19.26) in one end of the rope, *a*. The loop should be large enough to allow the standing part of the rope to pass through it.
2. Measure from the loop of the eye splice the distance that will be required to reach around the animal's nose.
3. Make a loop splice at this point, *b* (Fig. 19.28), with a loop the same size as the loop of the eye splice.
4. Pass the long end of the rope, *f*, through both loops, as shown in Fig. 19.28, forming the jaw piece of the halter.
5. Finish the end of the lead rope with a crown splice. (See Fig. 19.11.)

Making Slings for Hoisting

Sling—Following is the procedure for making a sling:

1. Lay the free end of the rope on the ground.
2. Set the object, such as a large bale of hay or a barrel, upright on the rope, leaving the free end about twice as long as the height of the object.
3. Bring both parts of the rope over the top of the object and tie them together with an overhand knot.
4. Draw the knot loose by pulling the ropes to the right and to the left sides of the object as shown in Fig. 19.29, forming a half hitch on the opposite sides of the object.
5. Complete the sling by tying the free end of the rope to the standing part of the rope with an overhand bowline knot. (See Fig. 19.16.)

Bag Sling—A bag sling is useful for raising or lowering bags of feed, seed,



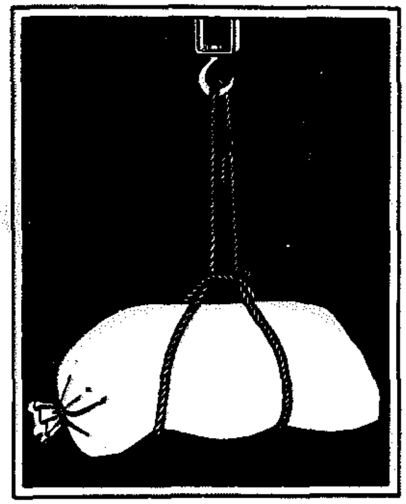
(Courtesy Hooven and Allison Co.)

Fig. 19.29. A sling used to hoist a barrel.

fertilizer, and cement. A rope about three times as long as the distance around the bag should be used.

Following is the procedure for making a bag sling:

1. Tie the ends of the rope together securely.
2. Lay the rope on the ground, forming an oval about 1½ feet across, and lay the bag across it.
3. Lift both ends of loop up and around the bag. Pass one loop through the other loop, and over the hook as shown in Fig. 19.30.



(Courtesy Hooven and Allison Co.)

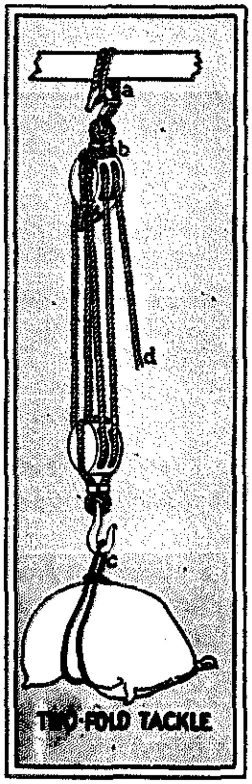
Fig. 19.30. A bag sling.

Pulleys, Blocks, and Tackle

If a rope must do strenuous work through a pulley, care should be taken that the pulley is of the correct diameter. See Table 19.1 for the recommended pulley size for ropes of various sizes. A pulley which is too small for the size of rope being used forces the rope to bend at too sharp an angle, which causes undue wear and strain on its fibers.

Greatly increased power for moving, lifting, or lowering heavy objects is secured by the use of a tackle, which is an arrangement of pulley blocks, hooks, and ropes. A *block* is a case or frame into which one or more pulley wheels or sheaves are fastened. A block is equipped with a hook or ring for fastening it to a support or to the object to be moved. Blocks are designated as single, two-, or three-fold, depending upon the number of pulleys in each block. Fig. 19.31 shows a two-pulley or double block. The block attached to the moving object is called the *fall* block, and the other block is called the *fixed* block. The end of the rope to which the power is applied is called the *fall* rope.

A tackle will increase the lifting power applied to the fall rope by approximately as many times as the rope passes *to* and *from* the fall block. For example, if



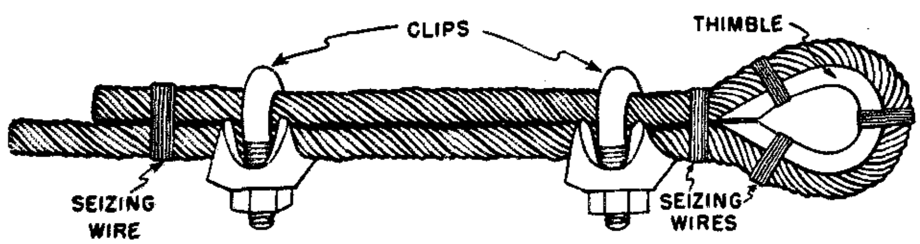
(Courtesy Hooven and Allison Co.)

Fig. 19.31. A two-fold tackle.

the rope passes to and from the fall block three times, a force on the fall rope of 50 pounds will lift a weight of nearly 150 pounds.

Wire Rope

The size of wire rope is indicated by the use of two numbers, for example, 6 × 7. The first number refers to the number of strands, and the second number refers to the number of wires in each strand.



(Courtesy U.S.D.A.)

Fig. 19.32. The use of clips, seizing wires, and a thimble to make an eye loop on a wire rope.

Wire rope is fastened with clips, sockets, and splices. Special tools are needed for socket and splice fastenings. The usual way of fastening wire rope is with U- or L-shaped clips. Wire rope thimbles are used when forming eye loops. Three clips are needed for fastening wire rope from $^7/_{16}$ to $^3/_4$ inch in diameter. Two clips are sufficient for smaller wire ropes. Since wire rope stretches, clips may need to be tightened occasionally. Wire rope needs to be lubricated with an oil or a grease recommended by its manufacturer.

CHAPTER 20

Repairing and Preserving Leather

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What equipment is needed for ordinary leather repair?
2. Why is a waxed end used for sewing? How is it made?
3. How are strap ends prepared for splicing?
4. How is a stitched splice made?
5. What are the advantages of using rivets for splicing? Disadvantages?
6. By what methods may snaps or buckles be attached?
7. How should leather be cleaned and oiled?

Leather Repair and Care—Leather work was very important when farms were worked with horses. Now most farmers do not use horses for power, but the number of horses for pleasure is increasing rapidly in both rural and urban areas. Also, there are pieces of leather equipment such as leather cattle halters and leather belts that may need to be repaired. This chapter describes the procedures used in stitching and riveting leather which are applicable to nearly all types of leather work.

Equipment Needed—The equipment necessary for making ordinary leather repairs is not extensive or expensive.

A clamp is needed to hold the work for sewing. This can be made at home or in the school shop. A vise may also be needed.

Sewing is done on heavy leather such as harness leather with No. 10 linen shoe thread. The thread may be waxed by hand. A waxing pad is made by melting wax and placing it on a piece of soft leather or canvas, which can be held in the hand and rubbed along the thread, giving it an even coating of wax. Special needles for leather work are used. Holes in the leather for the needles are made with an awl. A patented sewing awl using prepared thread is sometimes employed. It is more convenient to use, but the stitching is not usually as durable as when it is done by hand.

A small riveting outfit can be used to good advantage. Different types of rivets are used. Riveting is discussed in greater detail in later pages in this chapter.

The following equipment and supplies will probably be sufficient for most repair jobs:

1 ball of No. 10 linen shoe thread
1 ball of shoemaker's black wax
1 ball of beeswax
2 awl handles
3 two-inch awls
1 paper of assorted leather needles
1 pair of dividers
1 four-tube revolving leather punch
1 riveter and rivets
1 knife
Necessary repair parts such as leather straps, snaps, buckles, and rings

Preparing Thread for Sewing—An important step in leather repair is the preparation of the sewing thread or "waxed end," as it is often called. A "waxed end" consists of three or more linen threads waxed tightly together to form one strong, uniform, durable thread with a sewing needle attached to each end. The following steps in making a "waxed end" should be carefully observed:

1. *Measure a suitable length of thread for sewing.* The length needed for a particular piece of work can be estimated only after practice. A thread 5 to 6 feet in length is about as long as can be handled conveniently. Do not cut or break the thread.
2. *Tear the thread.* The thread should not be cut or broken off squarely, but it should be untwisted and the fibers torn off to make a long, tapering end. To do this, lay the thread across the right thigh, grasping the thread tightly with the thumb and fingers of the left hand. With the palm of the right hand roll the thread against the thigh in such a way that the fibers become loose and untwisted at that point. When completely untwisted, the thread may be pulled apart, making ends that are long, tapered, and suitable for waxing together. Repeat this procedure until three or four threads of the same length have been torn off. Three threads are usually sufficient for light work. For heavy pieces, five or six threads should be used in making a waxed end.
3. *Place the threads together.* The torn threads should be of the same length but should be placed together unevenly; that is, one end of the first thread should extend about an inch or so beyond the end of the second, and the third should extend beyond the second, so that when twisted together the combined ends will be long and will taper to a fine point which can be threaded into the needle readily.
4. *Wax the ends.* Place the middle of the assembled threads over a hook, holding both ends together with the left hand. Holding the waxed pad in the right hand, draw each of the tapering ends through the pad until each is slightly coated and sealed together with the wax.
5. *Twist and wax the threads.* With the ends still in the left hand, twist each end by rolling on the thigh with the palm of the right hand to twist the assembled threads together uniformly. Move the thread back and forth on the hook to equalize the twist. Keep the thread drawn fairly tight to prevent snarling. Do not release the ends, or the twist will be lost. Apply the wax by pinching the thread between the folds of the wax pad and rubbing the pad briskly up and down the thread. The friction melts the wax and distributes it evenly into the thread. Work all parts of the thread to get it smooth and uniform. The thread when finished should be round, hard, and black. After sufficient wax has been applied, the thread may be smoothed by drawing it between the thumb and forefinger of the right hand. To give the thread a hard finish, making it slip through the leather more readily, rub it with beeswax. Do not get beeswax on the ends of the thread, or the needles cannot be fastened securely.

6. *Thread the needles.* If the ends of the original threads have been properly torn, placed, and waxed, the waxed ends should be long and finely tapered so that they may readily be threaded through the eyes of the sewing needles. Draw the fine end of the thread through the eye for at least 2 inches. Double the end back along the thread and hold it with the left hand. With the thumb and forefinger of the right hand, twist the needle so that the short end of the thread wraps itself closely around the thread. The end should twist down into the wax so as to make a smooth, round wrap that will hold securely and is no larger than the main part of the thread. Attach a needle to the other end of the thread in the same manner; the thread is now ready to be used for stitching.

Making a Stitched Splice—The most satisfactory method of splicing a strap is by stitching with a waxed thread. A stitched splice is stronger than one made with rivets and is smoother and neater in appearance. More time, however, is required to make it.

1. *Prepare the ends to be spliced.* The ends to be sewed should be lapped 2 to 4 inches. For most of this distance they should be "skived" or shaved off" to a long beveled edge so that when lapped together the sewed ends will fit together smoothly. Skiving may be done with a sharp knife or with a block plane, and should be done on the rough or flesh side of the strap. Square the strap ends and trim off the sharp corners.
2. *Mark guide lines for stitching.* Place the beveled ends together, lapping them sufficiently. Make sure that the smooth or hair side of each strap is uppermost. As a guide to keep the stitches straight, mark a straight line about ⅛ inch from each edge of the top strap. A pair of dividers is very useful for marking leather for sewing. Set the points about ⅛ inch apart. Guide one point against the edge of the strap, applying pressure so that the other point makes a crease or mark. Do not cut the leather. The splice may be held in place temporarily with small tacks while it is being marked and sewed.
3. *Place the strap in a stitching clamp.* The marked side should be to the right. Clamp firmly with the upper guide line just above the edge of the clamp.
4. *Sew the splice.* The sewing should start at the middle of the splice, following the creased guide line toward the ends of the top strap. Pass the needles through the holes made with the awl. Keep the awl handle at right angles to the face of the strap when it is pushed through the leather. The long side of the awl blade should be slanted away from you, cutting across the guide crease at about a 45-degree angle. (Fig. 20.1)

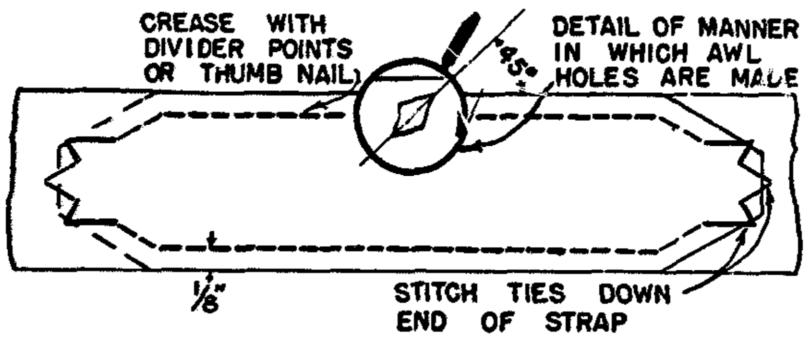


Fig. 20.1. Stitching a splice.

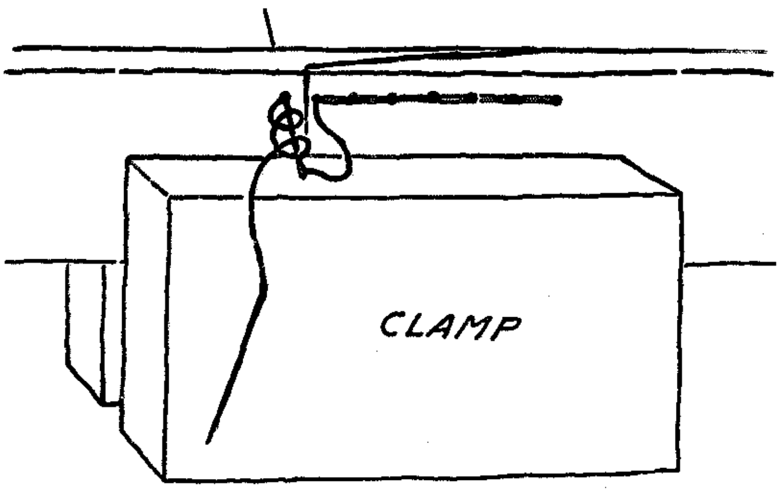
Make the first hole at about the middle of the top edge of the splice. Push one needle through and draw about half of the thread through. Make the next hole. Pass the left-hand needle through and draw the thread loosely. Pass the right-hand needle through the same hole in the opposite direction and draw that end of the thread through. Draw both threads tight.

Continue in the same manner until the end of the splice is reached, making one stitch at a time, passing both needles through each hole in opposite directions, and drawing each stitch tight.

Figure 20.1 illustrates an excellent method of stitching across the ends of a splice. It is important for the thin edge at the end of a splice to be fastened securely to prevent it from curling. The long cross-stitch frequently used across the end leaves a large amount of thread exposed, which soon becomes frayed and broken.

Turn the strap over, end for end, to stitch the other edge and across the other end. Reverse again to bring the stitching back to the starting point.

5. *Tie the ends of the thread.* When the sewing has been finished, the ends of the thread should be tied securely, as follows, to prevent their coming loose. Push the left-hand needle and thread through the last hole, and draw as usual; then push the right-hand needle halfway through the hole and while in this position wind the left-hand thread once or twice around the needle. Draw both threads tight as usual. The winding draws down into the hole, forming an overhand knot which prevents the ends from loosening.
6. *Smooth the splice.* Cut the sewing thread close to the strap. Trim the edges of the strap, if necessary, to give a neater appearance. With a round end of the awl handle or a similar smooth instrument, rub the stitching until it lies flat and smooth. If a fairly deep crease has been made as a guiding line, the threads will lie in it flush with the face of the strap. Tapping the splice lightly with a hammer on a flat surface will flatten and smooth it. A finishing wheel or marking wheel is sometimes run over the stitches to make them smooth.



(Courtesy New York State College of Agriculture, Cornell University)

Fig. 20.2. Tying the knot. The left needle and thread having been passed through the last hole, the right needle is inserted in the hole and the thread of the left needle is wound two or three times around the right needle and drawn tight. When the ends are stitched as shown, the knot will come in the middle of the splice where the stitching began.

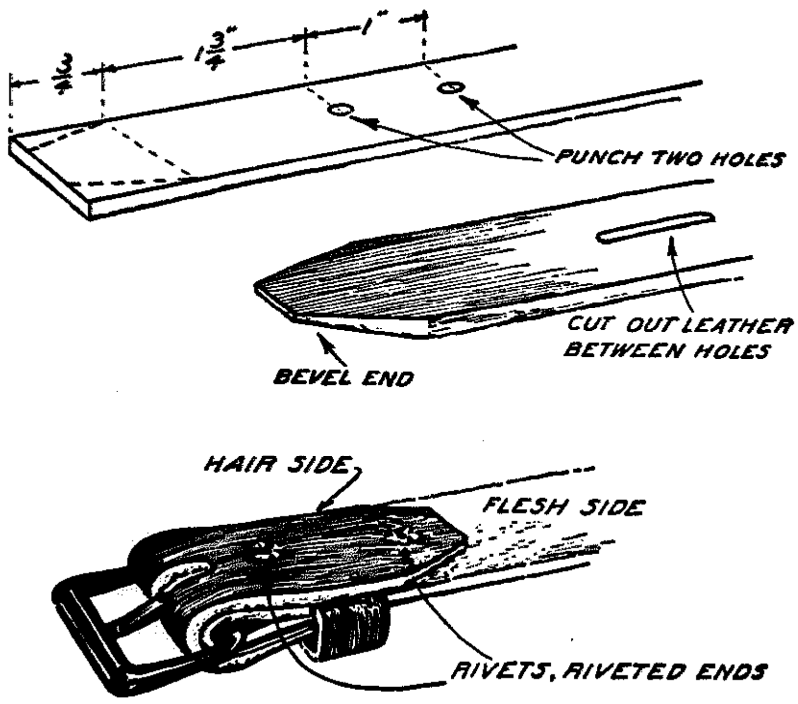
Making a Riveted Splice—A broken strap may be quickly and easily spliced by riveting. Such a splice ordinarily is not as serviceable as a well made stitched splice, but is often used, especially as a temporary fastening. In riveting, the strap ends are squared, slightly skived or beveled, and lapped together. Three rivets should ordinarily be enough for each splice. The method of riveting will depend upon the type of rivet used.

1. *Solid copper rivets* with burrs require punched holes to accommodate the rivets. A revolving type punch, the sharpened shank of the three-cornered file used with a brace, a hollow punch, or a drive punch may be used for making the holes. Place the rivet through the hole with the head on the smooth side of the strap. The end of the rivet should extend through the splice about 1/8 inch. Put on a burr or washer and rivet it by hammering with light blows around the edge of the rivet.
2. *Tubular rivets* require the use of a specially constructed but inexpensive riveter. The rivet cuts its own hole as it is forced through the leather. It is clinched on the opposite side by the riveting machine. The rivet should be on the smooth side of the strap.
3. *Split rivets* are placed by driving the rivets through the splice and clinching the ends on the opposite side. They are very convenient for a temporary splice, but they should be replaced at the first opportunity.

Attaching Snaps or Buckles—Any one of four methods may be used to attach a snap or buckle to a new strap or to repair a strap from which a buckle or snap has been torn.[1]

1. *Riveted loop* (Fig. 20.3)—Trim the corners of the strap, and skive or bevel the end for a distance of about 1 inch. If a buckle is to be attached, a slot must be cut for the buckle tongue. This is done as follows: Punch two holes with a punch about an inch apart, the first one about 2 1/2 inches from the end of the strap; cut out between the holes, making a slot an inch long and large enough for the buckle tongue to move freely. Place the buckle in position and rivet with two rivets, one close to the buckle, the other near the end of the strap. A slide loop may be attached just back of the buckle.
2. *Stitched loop*—The end of the strap is prepared in the same manner as described for the riveted loop and is fastened by stitching in the usual manner.
3. *Conway loop*—Square the end of the strap. On the center line of the strap, punch two holes large enough for the tongue of a Conway loop, the first hole 1/2 to 7/8 inch from the end of the strap, the second 3 1/2 to 5 inches from the first, depending upon the size of the loop needed. If a buckle is to be attached, cut a slot as described for the buckle tongue. Place the strap through the branches of the Conway loop, around the snap or buckle, and bring the end back underneath itself into the first branch of the Conway loop. Insert the tongue of the Conway loop into the hole at the end of the strap and then into the other hole. Draw tight.
4. *Buckle repair clip*—A buckle repair clip may be used when a strap is too short to spare the extra length necessary for making the other types of loop attachments. Square the strap end. Place the buckle in position in the repair clip, and fit the clip over the end of the strap. Mark the places for the holes. Remove the clip and punch the holes. Replace the parts and rivet the clip securely to the strap.

[1] F. G. Behrends, "Repairing Harness," Cornell University, Extension Bulletin 225, pp. 22–25.



(Courtesy New York State College of Agriculture, Cornell University)

Fig. 20.3. Attaching a buckle to a strap with rivets.

Cleaning Leather—Use the following procedure to clean leather:

1. Fill a tub about three-fourths full of warm water. Dissolve in it a cake of good castile soap or a handful of sal soda.
2. Place the leather in the tub and soak it until the crusted dirt softens.
3. Take out one piece of leather at a time on a drain board and scrub it thoroughly with a stiff brush until it is clean. A dull knife may be used to scrape away caked material.
4. Lay it in a clean place in the shade until dry or until ready for the application of oil.

Oiling Leather—A good grade of oil for leather should be used. It may be applied while the leather is still wet so the oil will penetrate the leather as the water evaporates. Use a sponge or rag, rubbing the oil into the leather. Allow the oil to dry overnight. If it is necessary to soften the leather, put on another coat. Warm oil may be used. Wipe off the surplus with burlap.

PART III

Agricultural Power and Machinery

AGRICULTURAL POWER FUNDAMENTALS

Student Abilities to Be Developed

1. Ability to appreciate the importance of engines used in agriculture.
2. Ability to classify engines, and to know the principal parts and the principles involved in the running of engines.
3. Ability to trace the gasoline engine cycle and to understand the difference between a four-stroke and a two-stroke cycle engine.
4. Ability to locate minor gasoline engine troubles and remedy them.
5. Ability to use various tests to diagnose gasoline engine difficulties.
6. Ability to select, service, and maintain gasoline engines.
7. Ability to clean and adjust a carburetor.
8. Ability to maintain ignition systems.
9. Ability to test, service, and maintain electrical systems.
10. Ability to replace distributor points.
11. Ability to lubricate a gasoline engine.
12. Ability to time a gasoline engine.
13. Ability to clean and grind valves.
14. Ability to adjust tappets.
15. Ability to fit piston rings and wrist pins and to adjust bearings.
16. Ability to service, adjust, and maintain hydraulic systems.
17. Ability to select and maintain tractors.

CHAPTER 21

Understanding the Fundamental Principles of Engines

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is an external combustion engine?
2. What is an internal combustion engine?
3. What are the principal parts of an internal combustion engine?
4. What principles are involved in the operation of engines?
5. What is meant by a gasoline engine cycle?
6. What is the difference between a four-stroke and a two-stroke cycle engine?
7. How does a diesel engine operate?
8. How should a diesel engine be maintained?
9. What fuels are used to operate internal combustion engines?
10. What is meant by compression ratio?

INTRODUCTION

Importance of Power Units—Since 1900, internal combustion engines have steadily increased in number and in importance. The work on farms and in non-farm agricultural businesses demands the application of power. The power of internal combustion engines relieves agricultural workers of much physical exertion, but their use requires skill. The successful and economical use of internal combustion engines in agriculture requires an understanding of their operation and care. An average agricultural worker should not attempt to do all the repair work on engines, because there are many repair jobs which require a skilled mechanic. There are many maintenance jobs, however, which an agricultural worker with a little training and practical experience should be able to do. Some of these are as follows:

1. Cleaning and adjusting the carburetor
2. Cleaning and adjusting spark plugs
3. Adjusting the timing

4. Cleaning combustion chambers and valves
5. Maintaining the lubrication system
6. Maintaining the cooling system
7. Locating the source of ignition troubles
8. Maintaining the fuel system

Jobs such as overhauling transmissions and differentials should not be attempted by the average agricultural worker; hence, they are not discussed in this book. High school students should not expect to become skilled mechanics from a study of internal combustion engines in an agricultural mechanics course, but they should learn how to service, maintain, and adjust internal combustion engines.

External Combusion Engines—Some engines, such as steam engines, burn their fuel outside the cylinder of the engine in a fire box beneath a boiler containing water. Engines of this type are known as external combustion engines. The piston within the cylinder is driven by the expansion of steam.

Internal Combustion Engines—In engines such as gasoline engines, the fuel when mixed with air in the proper proportions is drawn into the engine cylinder, compressed, and ignited. This type of engine is known as an internal combusion engine. When the fuel burns, the gases expand very rapidly, producing a high pressure against the piston.

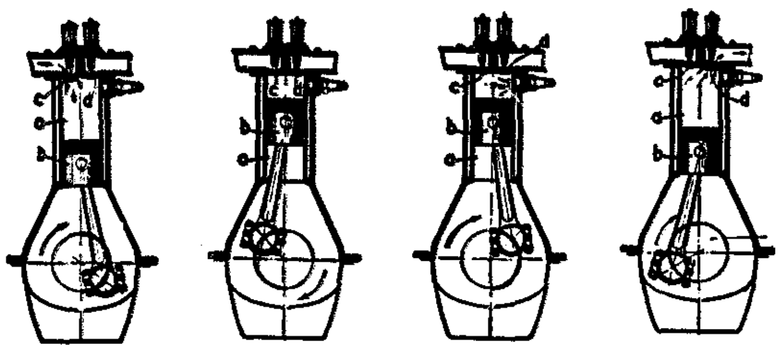
Principal Parts of an Internal Combusion Engine—Every engine must have certain parts in order to operate. The principal parts are as follows:

1. *Cylinder*—The part of the engine where the combustion takes place. The number of cylinders in an engine will vary from one to eight or more.
2. *Piston*—A cylinder plunger which works within a cylinder. Each piston contains rings which fit tightly against the inside of the cylinder walls, thus preventing air from leaking past the piston.
3. *Connecting rod*—A rod which connects a piston with the crankshaft, the rod being fastened to the piston by means of a wrist pin.
4. *Crankshaft*—A central crank-shaped shaft to which all the connecting rods are fastened.

WORKING PRINCIPLES OF INTERNAL COMBUSTION ENGINES

Internal combustion engines are mechanical devices which can transform certain fuels such as gasoline and oil into work. The fuel, which is in gaseous form when it enters the cylinders of an engine, is changed into an explosive mixture when united with the proper proportion of air. This explosive mixture is compressed and ignited in a cylinder, and the explosion forces the piston downward.

Gasoline Engine Cycle—A cycle of any kind is a series of events starting at a given point, going through a definite order of procedure, and returning to the same point. A four-stroke cycle gasoline engine (see Fig. 21.1) has a series of four events or strokes which must be completed with the cycle, namely:



(Courtesy The Socony-Vacuum Corp.)

Fig. 21.1 A four-stroke engine.

1. Intake stroke
2. Compression stroke
3. Power stroke
4. Exhaust stroke

On the *intake stroke*, the exhaust valve remains closed and the intake valve opens. As the piston moves downward, a mixture of fuel and air is drawn into the cylinder.

As the piston moves back toward the head or top of the cylinder, the *compression stroke* begins. The intake and exhaust valves are both closed and the fuel mixture is compressed, which raises its temperature, thus making it more explosive. At the end of this stroke the crank has made one complete revolution.

The fuel mixture, after being compressed, is ignited by a spark from a spark plug. The explosion of this fuel mixture drives the piston down on what is called the *power stroke*. Both valves are closed on this stroke.

The cylinder is now full of burned gas which is released by the exhaust valve, which opens as the piston returns to the top or head of the cylinder on the *exhaust stroke*. The piston is driven as far as it will go into the cylinder by the momentum of the flywheel, thus forcing out all the burned gas. The crank makes two complete revolutions during the process of these four strokes. A new cycle is now ready to begin. These four strokes are often compared to the loading, compressing, firing, and cleaning of a cannon.

Four-Stroke and Two-Stroke Cycle Engines—Most gasoline engines are of the four-stroke cycle type, also known as the Otto cycle. In this type of engine the piston makes all four strokes as mentioned in the previous paragraphs. A two-stroke cycle engine completes its cycle in two strokes, or one revolution of the crankshaft. As the piston moves upward, a vacuum is formed in the airtight crankcase, and fuel and air are sucked into the crankcase through a valve.

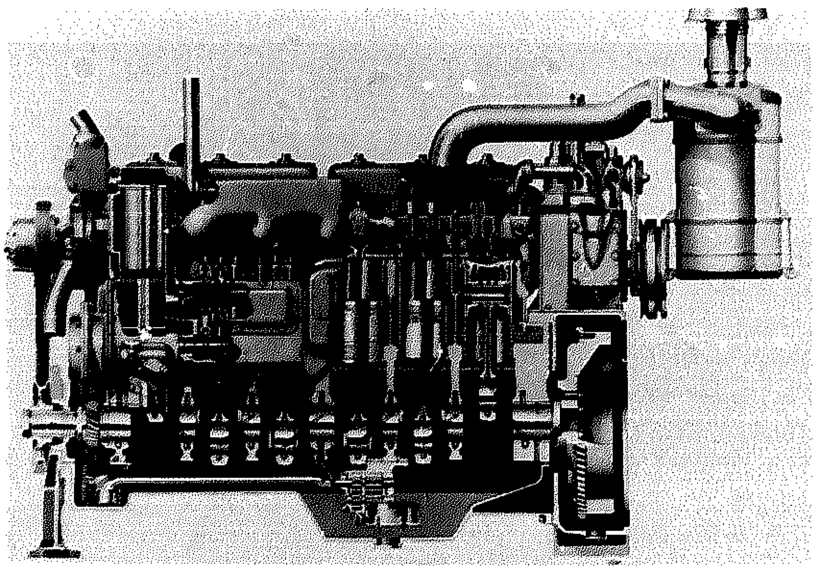
While this fuel mixture is being obtained, the mixture obtained previously is compressed in the upper part of the cylinder. When the compression stroke is nearly completed, the mixture is ignited and the explosion drives the piston downward. When the downward or power stroke is nearly completed, the exhaust port opens and permits the burned gas to escape.

DIESEL ENGINES

Diesel engines are becoming more popular on farms and in nonfarm agricultural businesses. They are available as two-stroke cycle and four-stroke cycle engines. A true diesel engine does not operate with spark ignition. There are some engines called diesels, however, that are spark-ignition fuel injection engines. Compression pressures in engines of this type may be the same as they are in engines with carburetors, but they are usually somewhat higher.

The main difference between the Diesel cycle and the Otto cycle (the common four-stroke cycle) is in the method of mixing the fuel and air, and igniting the charge for the power stroke. In the Diesel cycle a fuel injector squirts the fuel charge into the cylinder after the air has been compressed. The compression pressure is very high and heats the air hot enough to ignite the fuel injected into it. The burning mixture expands, furnishing the power stroke. The Otto cycle draws the mixed fuel and air into the cylinder, then compresses the mixture for a spark ignition. The Otto cycle "ignition event" is replaced by the "fuel injection event" in the Diesel cycle. A diesel engine does not have a carburetor or spark plugs, but it has a fuel pump and a fuel injector, the latter measuring the correct amount of fuel for injection at the right time.

A two-stroke cycle diesel engine completes its cycle of operations in one revolution of the crankshaft. There is only a compression stroke and a power stroke, but in between or during these events the intake of fuel and the exhaust of gases are accomplished. There is a power stroke every revolution; thus a two-cycle diesel can produce about twice the power of a four-cycle engine of the same size and approximately the same weight.



(Courtesy Caterpillar Tractor Co.)

Fig. 21.2. A cutaway view of a diesel engine.

Maintenance of Diesel Engines—Diesel engine repair should not be attempted without special training. The adjustments and repairs that can be made without special tools and instruments will usually be explained to the operator or will be discussed in the instruction book sent with the engine.

FUELS

The following fuels are frequently used:

1. *Gasoline* is the fuel used most frequently, especially in automobiles. A good, clean, high-grade gasoline should be used.
2. *Liquefied petroleum gas*, commonly called "LP gas" or "bottled gas," is usually composed of propane and butane. Several manufacturers build tractors designed to burn LP gas. Also, several manufacturers have conversion units for installing LP-burning equipment on standard makes of tractors. Special storage tanks and handling equipment are necessary for LP fuel. Generally it is necessary to obtain LP fuel for approximately two-thirds the price of gasoline to recover the extra cost of the equipment and to make the use of the fuel economical.
3. *Diesel fuel* is similar to kerosene, but impurities such as gums have been removed. It also has other special characteristics.

Some tractor engines are designed to use more than one grade of fuel. There is, however, a tendency for manufacturers to build engines that will perform best on only one grade of fuel. The manufacturer's recommendation should be followed in the selection of the fuel for a tractor.

Meaning of Compression Ratio—High-octane fuels are used in high-compression engines. The compression ratio of an engine is the ratio of the total volume within the cylinder (piston displacement volume plus head clearance volume) to the head clearance volume. Increasing the compression ratio increases the pressure within the cylinder at the end of the compression stroke. Thus, compression ratio expresses the compression of the fuel charge. For example, a compression ratio of 6:1 means that the piston at the top of its stroke has squeezed the contents of the cylinder into a space only one-sixth the size of the cylinder when the piston was at bottom dead center. The compression ratio of an engine should not be increased unless the manufacturer recommends it, because the rest of the engine must be built strong enough to withstand the increased power and stresses developed.

CHAPTER 22

Operating and Lubricating Engines

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What causes gasoline engine troubles?
2. What are some common gasoline engine troubles?
3. What should be done when a gasoline engine does not operate properly?
4. What tests should be used in diagnosing gasoline engine difficulties, and what do these tests tell you? How are these tests made?
5. How important is proper lubrication?
6. What are the various methods of lubricating internal combustion engines?
7. What is proper lubrication?
8. How often should the oil in a crankcase be changed?
9. How may the quality of a lubricant be maintained?

OPERATING ENGINES

Some Causes of Gasoline Engine Troubles—There are numerous causes of gasoline engine troubles, but the most common ones can ordinarily be traced to one or more of the following:

1. Improper fuel supply
2. Ignition system not working
3. Valves improperly timed
4. Spark occurring at the wrong time
5. Poor compression
6. Poor lubrication

Any of the above may interfere with the starting or the running of an engine.

Gasoline Engine Troubles—An engine, in broad terms, needs three things to make it run, namely, fuel, compression, and spark. Engine troubles, therefore, may be classified and listed with their possible causes as follows:

1. Engine will not start.
   a. Empty fuel tank
   b. Poor quality of fuel
   c. Foreign material in fuel tank or feed pipes

   d. Carburetor out of adjustment
   e. Too much fuel, "flooding" cylinder
   f. Poor compression
   g. Engine too cold (should bother only in very cold weather)
   h. Defective spark plugs—fouled, out of adjustment, or broken
   i. Weak spark
   j. Worn wires from spark plugs
   k. Breaker points dirty or out of adjustment
   l. Dirty or wet distributor
2. Engine misses. (Locate the cylinder.)
   a. Defective spark plug or improperly adjusted plug
   b. Loose or broken ignition wire
   c. Inadequate insulation on ignition wire
   d. Sticking valve or weak valve spring
   e. Improper valve stem clearance
   f. Burned or dirty valve
3. Engine fires irregularly.
   a. Wrong carburetor adjustment
   b. Spark plug electrodes improperly adjusted
   c. Defective ignition wire
   d. Poor compression
   e. Sticking valves or weak valve springs
   f. Improper valve stem clearance
   g. Foreign material in fuel or in feed pipes
   h. Too much oil in crankcase
   i. Weak spark
   j. Breaker points out of adjustment
   k. Air leaks between carburetor and intake manifold or between manifold and engine
   l. Governor sticking or controls bent
4. Engine stops.
   a. Fuel tank empty
   b. Foreign material in fuel tank, feed pipe, or carburetor
   c. Fuel tank vent hole plugged
   d. Faulty ignition
   e. Faulty valve mechanism
5. Engine knocks.
   a. Spark advanced too far
   b. Too lean a fuel mixture
   c. Carbon deposits in cylinders
   d. Engine overheated
   e. Pre-ignition with low-test fuels
   f. Loose connecting rod or crankshaft bearings
   g. Worn pistons, rings, or wrist pins
   h. Too much valve stem clearance
   i. Worn timing gears
   j. End play in camshaft or crankshaft
   k. Loose flywheel
6. Engine overheats.
   a. Water in radiator too low
   b. Slipping fan drive
   c. Spark retarded too far
   d. Low oil supply in crankcase
   e. Oil circulation not adequate
   f. Too rich a mixture from the carburetor
   g. Excessive carbon deposits in cylinders
7. Engine backfires through carburetor.
   a. Mixture too lean

   b. Intake valve stuck in open position
   c. Excessive carbon in cylinder
   d. Wrong connection between magneto or spark coil and spark plug
8. Engine lacks power.
   a. Too lean a mixture
   b. Too rich a mixture
   c. Poor compression
   d. Weak spark
   e. Overheated engine
   f. Spark retarded
   g. Clutch slipping
   h. Dragging brakes or dry wheel bearings
   i. Dirty spark plugs, valves, and engine
   j. Weak valve springs
9. Spark plugs foul quickly.
   a. Weak spark
   b. Exhaust valve not closing
   c. Defective spark plugs
   d. Poorly fitted or worn piston rings
   e. Crankcase oil too thin
   f. Too much crankcase oil
   g. Spark plug electrodes set too close
   h. Excessive carbon in cylinders

What to Do When an Engine Does Not Operate Properly—If an engine will not start, the following procedure is recommended:

1. The fuel tank should be examined to see whether or not a fuel supply is present; if a supply of fuel is available, the fuel line should be examined to see whether or not the fuel is reaching the carburetor. If the fuel contains water, it may freeze, thus preventing the fuel from entering the carburetor. Dirt or other foreign materials may also be present in the fuel line.
2. If the proper mixture of fuel is reaching the cylinders, the ignition should be checked to determine whether or not there is a loose or broken connection and also whether or not there is a spark. It may be that the spark plug points are improperly set or that the plugs are dirty. Likewise, the distributor points may be badly pitted or improperly set.
3. After these items are checked, if the engine fails to start, the timing of the spark should be checked, following the instructions of the manufacturer. The spark must occur at the proper time to ignite the fuel mixture.
4. The compression should be checked, as the fuel mixture must be compressed before it is ignited. Some mechanics check for the compression first when a motor fails to start.

A *compression test* is often helpful in diagnosing engine troubles. A compression tester costs only a few dollars, may be purchased at any automobile supply store or large mail-order company, and is relatively easy to use.

A compression test may be used to determine such difficulties as the following:

1. Cylinder wear
2. Ring wear
3. Faulty valves
4. Scored cylinder
5. Faulty gaskets

A compression test should be made before an engine tune-up is attempted because if the compression of an engine is faulty, it is impossible to tune the engine properly. Faulty compression will result in the loss of power and the use of an excessive amount of fuel. A compression test will help determine the need for an engine overhaul.

The procedure for making a compression test is as follows:

1. Operate engine until normal running temperature is obtained.
2. Shut off engine.
3. Remove spark plugs.
4. Open throttle.
5. Place nozzle of compression tester in spark plug hole in number one cylinder.
6. Use starter to turn engine several revolutions.
7. Record pressure obtained on pressure gauge of compression tester.
8. Test other cylinders in same way.
9. Obtain normal cylinder pressure for engine being tested from operator's manual or from dealer.
10. Interpret test.

If the pressure obtained for a cylinder is 10 or more pounds below the normal cylinder pressure of the engine, the cause should be determined and corrected. Often the cause of the difficulty may be determined by placing a teaspoonful of oil in the cylinders and repeating the test. If the difficulty is the excessive wear of the cylinders or rings, the oil may seal the leaks and cause the pressure to rise considerably. If the oil does not cause the cylinder pressure to rise, the valves may be faulty. A cracked cylinder head may be indicated if bubbles appear at the top of the radiator. Whatever the cause of the loss of compression, the difficulty should be corrected before an engine tune-up is attempted.

A *vacuum test* is often helpful in the tune-up of an engine. The cost of a vacuum tester is not great, and one may be purchased from any automobile supply store or from a large mail-order company.

A vacuum test may be used to determine such difficulties as the following:

1. Poor adjustment of carburetor
2. Faulty operation of fuel pump
3. Faulty operation of valves
   a. Sticking
   b. Burned and warped
   c. Tappet adjustment
   d. Weak valve springs
   e. Worn valve guides
   f. Leaking
4. Worn cylinders or rings

A vacuum gauge test may also be used to determine when an engine is timed properly and when the carburetor is adjusted correctly.

The procedure for making a vacuum test is as follows:

1. Attach the vacuum tester to the intake manifold. Often engines have a plug in the manifold which may be removed. A pipe nipple is placed in

the hole for the plug, and the vacuum hose is attached to the pipe nipple. If no way is found to attach the vacuum hose to the intake manifold, see the dealer selling the engine.

2. Operate the engine until it has reached normal operating temperature.
3. Set the throttle at a fast idling speed.
4. Observe the readings on the vacuum gauge.
5. Set the throttle so that the engine is operating at its rated load speed.
6. Observe the readings on the vacuum gauge.
7. Interpret the results.

If the vacuum gauge reading is steady and between 18 and 21 when the engine is operating at a fast idle and between 15 and 16 when operating at its rated load speed, the engine is in good condition and is tuned properly. If the gauge drops approximately four points intermittently, check the valves. This type of vacuum reading may be caused by burned or sticking valves or by insufficient clearance of tappets. If the vacuum gauge reading is low, check for leaking valves. If the valves are not leaking, check the adjustment of the carburetor. If the gauge reading is low after the carburetor has been adjusted, the low reading may be caused by worn cylinders or rings.

If the vacuum gauge needle vibrates when the throttle is opened, the valve springs are weak. If the needle of the vacuum gauge vibrates at low speeds, but is steady at high speeds, the valve guides are worn.

Diagnosing Diesel Engine Troubles—If a diesel engine is hard to start, the cause of the difficulty may be one or more of the following:

1. Insufficient fuel
2. Incorrect timing
3. Cold air temperatures
4. Compression losses
5. Dirty nozzles
6. Low battery
7. Incorrect valve clearance
8. Out of time fuel injection pump
9. Faulty fuel transfer pump
10. Faulty fuel injection pump

If a diesel engine overheats, the operator should check to determine whether or not the overheating is caused by one or more of the following difficulties:

1. R.P.M. too low under heavy load
2. Clogged radiator
3. Inadequate liquid in cooling system
4. Slipping fan belt
5. Collapsed radiator hose
6. Stuck thermostat
7. Broken expeller vanes in water pump
8. Overloaded engine
9. Diluted lubricating oil

If the operation of a diesel engine is irregular, suspect one or more of the following causes:

1. Out of time fuel injection pump
2. Low fuel pressure
3. Low operating temperature
4. Faulty fuel nozzles
5. Improper seating of valves
6. Uneven compression pressure
7. Binding governor control linkage

If a diesel engine knocks, the operator should check the following possible causes:

1. Incorrect timing
2. Plugged or leaking air cell
3. Too slow engine R.P.M.
4. Improper fuel
5. Overloaded engine

If the exhaust smoke of a diesel is excessive, the cause may be one or more of the following:

1. Excessive fuel to engine
2. Clogged air cleaner
3. Overloaded engine
4. Consumption of oil
5. Faulty fuel nozzles

If a diesel engine develops a loss of power, check the following possible causes:

1. Restrictions in fuel line
2. Clogged fuel filters
3. Defective transfer pump
4. Air in fuel line
5. Clogged air cleaner
6. Loss of compression
7. Faulty injection pump timing
8. Sticking valves
9. Faulty nozzles
10. Too slow high-idle R.P.M.
11. Incorrect valve clearance

The operator of a diesel engine should not attempt to make adjustments to the fuel system of a diesel unless he or she is a skilled diesel mechanic. An operator can make simple adjustments to correct the difficulties mentioned when a diesel engine starts hard, knocks, smokes excessively, operates irregularly, loses power, or becomes overheated. The operator's manual for the diesel engine should be consulted for instructions regarding the simple adjustments that can be made.

One adjustment should be made at a time. If the adjustment made does not improve the operation of the diesel engine, a return to the original setting should be attempted before another adjustment is made.

SERVICING AND LUBRICATING ENGINES

Periodical checkups to maintain an engine in good operating condition should be systematically provided.

The following units of an engine should be periodically cleaned, inspected, repaired, or serviced:

1. The fuel system, such as the fuel storage and handling equipment, fuel tanks, lines, screens, settling bowl, carburetor and manifold, and fuel pump.
2. The air supply equipment, such as the air intake pipe, air cleaner or filter, cleaner hose and connections, and pre-cleaner bowl.
3. The ignition system, such as the magneto or generator, battery, coils, distributor, switches, meter, wires, spark plugs, and self-starter.
4. The lubricating system, such as the oil filter, oil pump and screen, pressure gauge, oil feed pipes, crankcase breather, and crankcase filler screen and cap.
5. The cooling system, such as the radiator, radiator connections, fan and fan drive, water pump, and water chamber around cylinder head and block. If scale is deposited in the radiator, remove it with a good commercial radiator cleaning compound.
6. The valve mechanism, such as intake and exhaust valves, valve insert seats, valve tappets, springs, guides, camshaft, and timing gears.
7. The internal parts, such as pistons, rings, pins, connecting rods and pins, bearings, and crankshaft.
8. The clutch assembly, such as plates, bearings, control lever, and throw-out pulley and pulley brake.

Importance of Proper Lubrication—The successful operation and continued use of an internal combustion engine depend to a large degree upon its proper lubrication. The best oil is none too good for an engine. While good lubricants cost slightly more, they are cheaper in the long run. An internal combustion engine that is kept properly lubricated will require less repair than an engine which is given little attention or an engine which is lubricated with inferior lubricants. A new engine especially needs to be kept well lubricated with the proper lubricants.

Types of Engine Lubrication Systems—A lubrication system supplies oil to the following places:

1. Main bearings
2. Connecting rod bearings
3. Wrist pins
4. Pistons and piston rings
5. Camshaft bearings
6. Timing gears
7. Cams and valve lifters
8. Cylinder walls
9. All other working parts

There are several types of lubrication systems used:

1. *Splash System*—This is the simplest of the lubrication systems. The oil in

the crankcase is splashed to the various working parts of the engine by dippers or cups on the connecting rods.

2. *Oil Slinger System*—This system uses slingers attached to the camshaft. The system is often used in small engines.
3. *Circulating Splash System*—This system is slightly different from the straight splash system in that the oil is supplied to troughs under the connecting rods by a pump, which is located in the crankcase. The connecting rods splash oil from these troughs to all the working parts of the engine.
4. *Force Feed Splash System*—The oil is forced by means of a pump directly to all crankshaft bearings. The oil falls from these bearings into troughs below the connecting rod bearings. The connecting rods dip in these troughs and splash oil to the other working parts of the engine.
5. *Force Feed System*—The connecting rods do not dip in oil. The oil by means of a pump is forced directly into the main bearings and through drilled holes in the crankshaft to the connecting rod bearings. From these bearings the oil is thrown to the pistons, wrist pins, and cylinder walls.
6. *Full Force Feed System*—This system forces oil by means of a pump directly to the main bearings and through holes drilled in the crankshaft to the connecting rod bearings. The oil is then forced, through oil pipes attached to the connecting rods, to the wrist pins. The oil is then thrown to the pistons and the cylinder walls.

There may be slight variations in these systems in different internal combustion engines, but the general principles are the same.

Requirements of Proper Lubrication—Correct lubrication must perform the following functions:

1. Provide an oil film between the working surfaces in an engine so that wear will be reduced.
2. Aid in the cooling of the engine.

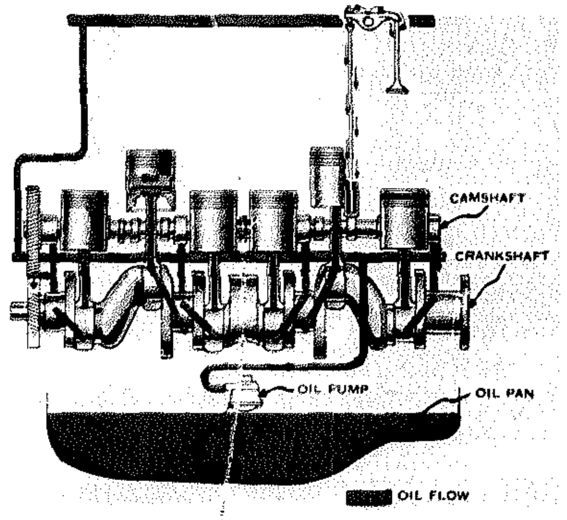


Fig. 22.1. A simplified schematic drawing showing an oil pressure system. The oil is forced, as indicated in the drawing, by a pump to the critical points in the engine, such as the crankshaft and connecting rod bearings, the pistons, and the valves. The parts of the engine not receiving oil under pressure obtain it through a "splash" system.

3. Prevent leakage between the piston and the cylinder wall.
4. Permit all parts to work freely.

To meet these requirements, the oil must be of the proper grade and quality. If the piston rings are not properly sealed by the oil, there will be a loss of compression, hence a loss of power. Oil will also leak by the piston rings, working into the combustion chamber, and produce carbon deposits on the valves, spark plugs, and cylinder head and walls. If the oil is too thin, it will not lubricate sufficiently. If it is too thick, it will not flow freely. Improper lubrication is often indicated by overheating, which produces a metallic knock in an engine.

It is best to follow the recommendations of the manufacturer as to the grade of lubricant to use.

Changing Crankcase Oil—It is difficult to suggest any definite frequency for removing old oil and refilling the crankcase with fresh oil, as this depends on a number of factors. Some of these factors are as follows:

1. The quality and grade of oil. It is only reasonable to expect an oil of high quality and of the proper grade to outwear an inferior oil of the improper grade.
2. The amount of continuous running of the engine. An engine, especially an automobile engine, when run continuously uses less oil, if run at the correct speed, than when it is run with frequent stops and starts.
3. The amount of starting and stopping in cold weather. An engine that is started and stopped frequently in the winter will soon have the oil very much diluted with gasoline. The choking of an engine adds gasoline to the oil.
4. The speed at which the engine is run. When an engine is run rapidly, much heat is generated, which burns the oil.
5. The time of year. Crankcase oil ordinarily should be changed more often in winter because of the necessary choking and because of the condensation of moisture on the cylinder walls and in the crankcase.
6. The cooling and ignition system. A cool-running engine uses less oil than one which becomes overheated.

The oil in a crankcase should be changed whenever it loses its body and film-forming ability. The oil should be maintained at the proper level at all times.

Factors in Maintaining the Quality of a Lubricant—All of the factors mentioned in the previous section should be considered in maintaining the quality of oil in an engine. Also see that the carburetor is properly set to avoid rich mixtures. Do not use the choke excessively, and keep the engine in proper running condition.

Oil Classification and Weights—Ability to flow, or viscosity, through an opening of a standard size at certain temperatures is used to classify oils used in engines. Viscosity at various temperatures indicates an oil's body, which is one of the very important properties of an oil.

A viscosity test is used to determine the grade of an oil. The Society of Automotive Engineers (SAE) classifies oil into grades based on standardized viscosity testing. These SAE grades are designated by numbers, such as SAE 10 and SAE 20.

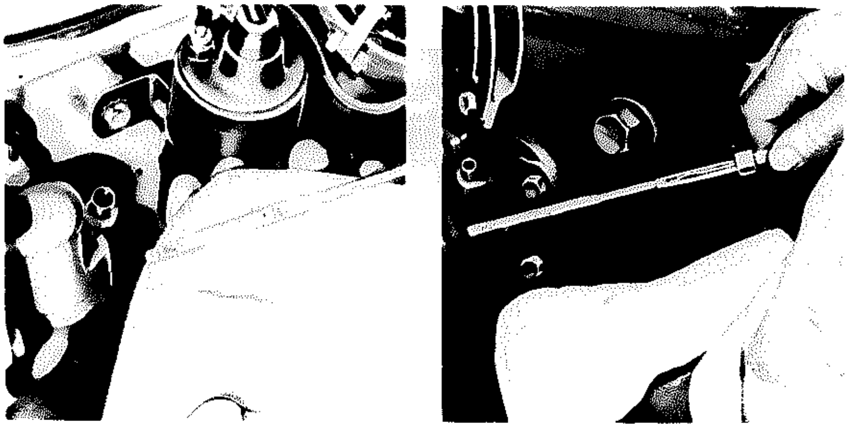


Fig. 22.2. Check the oil level in the crankcase and in the hydraulic system at frequent intervals. (Left) Crankcase oil level dipstick. (Right) Hydraulic oil level dipstick.

A "W" designation following the SAE number indicates that the oil does not go beyond an acceptable maximum viscosity at 0 degrees Fahrenheit for the cranking speed necessary to start an engine.

A multigrade oil, such as SAE 10W-30, has the characteristic of not thinning out at a high temperature such as 210 degrees Fahrenheit. Thus, an SAE 10W-30 oil has the characteristics of an SAE 10W oil at low temperatures and provides the protection of an SAE 30W oil at high temperatures.

All oils become thicker at low temperatures and thinner at high temperatures. If oil is diluted by the fuel burned in an engine, it will be thinned and will have less ability to lubricate properly.

A designation of SF for an oil indicates that it is for a gasoline engine.

CHAPTER 23

Maintaining and Adjusting Internal Combustion Engines

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is the function of a carburetor?
2. What are the principal parts of a carburetor?
2. What are some types of carburetors?
4. How should carburetors be cleaned and adjusted?
5. How should the air cleaner, sediment bowl, fuel lines, and thermostat be cleaned, serviced, and maintained?
6. What is the purpose of an intake manifold?
7. What methods are used in cooling internal combustion engines?
8. What is the function of an ignition system?
9. What are some types of ignition systems?
10. How should the spark plugs be set?
11. What are the steps in replacing distributor points?
12. How should the electrical system be tested, serviced, and maintained?
13. Why is it essential to have the valves properly timed?
14. How is an engine timed?
15. How are tappets adjusted?
16. Why is valve grinding important?
17. How should the carbon be cleaned from an engine, and why is its removal necessary?
18. What is the function of piston rings?
19. How may faulty piston rings be detected?
20. How should old piston rings be removed?
21. How should piston rings be installed?
22. What are wrist pins, and how are they installed?

FUEL AND CARBURETION SYSTEM

Functioning of a Carburetor—The carburetor is one of the most essential parts of a gasoline engine. Some of its functions are:

1. To vaporize liquid fuel.
2. To mix the proper amount of air and fuel for efficient combustion.
3. To control the proper mixture of explosive fuel for various speeds of the engine.
4. To deliver the fuel mixture to the cylinders.

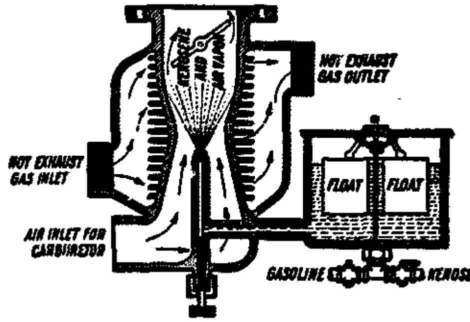
Many carburetors on the market today are very efficient and dependable when properly installed and adjusted.

Principal Parts of a Carburetor—Carburetors vary a great deal in their construction, but there are a few principal parts which are more or less common to all of them. Some of these are as follows:

1. A *bowl* where a constant level of fuel is maintained.
2. A *float* which keeps the proper amount of fuel in the bowl by shutting off the supply after it reaches a certain level in the bowl and by permitting more fuel to enter as it is needed.
3. *Jets* which permit air or fuel to enter the carburetor. There are usually two jets, one for high speed and one for low speed.
4. A *venturi tube* which is a part of the air tube. It causes a vacuum around the jet or nozzle, resulting in a better fuel mixture.
5. A *needle valve* which regulates the amount of either fuel or air.
6. A *choke valve* which is used to increase for a short period of time the amount of fuel in the fuel and air vapor. The choke valve is located in the air intake opening of a carburetor. Closing the valve increases the vacuum on the fuel jets and increases the amount of fuel or the richness of the fuel-air mixture.
7. A *butterfly* or *throttle valve* which regulates the flow of vaporized fuel going to the engine.

Atmospheric pressure pushes air into the engine when a vacuum is created by the pistons. At the same time, fuel from the carburetor bowl enters the carburetor as a fine spray. This fine spray or mist mixes with the air, forming a fuel mixture for combustion within the cylinders.

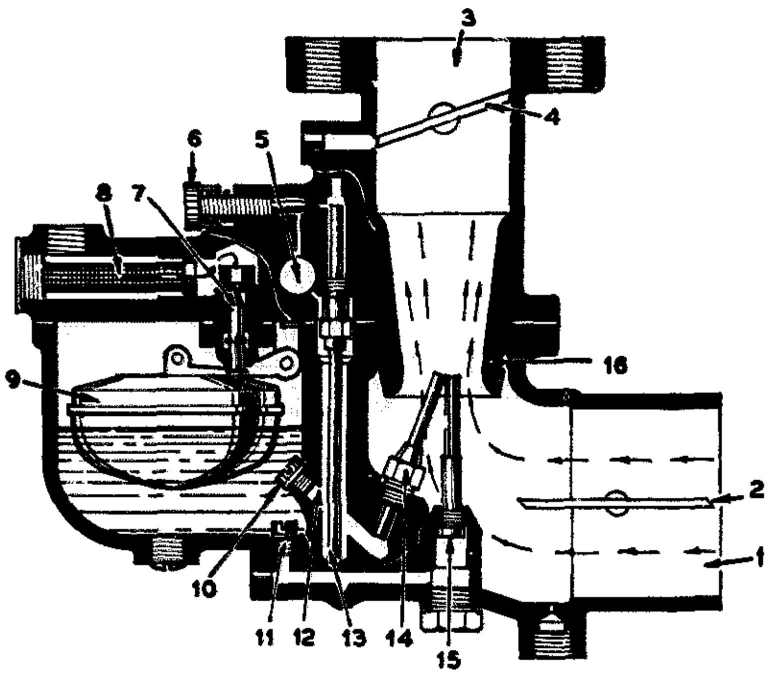
Types of Carburetors—While there are a number of types of carburetors, there are only a few which are frequently used. Some automobiles, trucks, and tractors require special types of carburetors. Special types of carburetors are also designed for special fuels such as propane and alcohol.



(Courtesy Standard Oil Co.)

Fig. 23.1 A float-feed carburetor.

The float-feed type of carburetor is often used. Located in the bowl is a float which keeps the fuel at a constant level at all times. Fuel pumps are often used with this type of carburetor. There are a number of different types of float-feed carburetors available.



(Courtesy University of Illinois)

Fig. 23.2. An automatic-type carburetor with an adjustable idling device. (1) Air intake, (2) carburetor choke, (3) outlet to engine, (4) butterfly throttle, (5) air passage supply compensating jet, (6) idling needle valve, (7) float valve cutoff and seat, (8) fuel screen, (9) float, (10) constant-flow opening supplying gas, (11) main jet feeder, (12) compensating well, (13) idling tube or jet, (14) compensating jet, (15) main fuel jet, (16) venturi tube. The carburetor may be the source of considerable engine trouble. A properly repaired and adjusted carburetor may often save 3 to 5 gallons or more of fuel for each day's use.

Cleaning and Adjusting Carburetors—A carburetor cannot give efficient service unless it is kept clean and properly adjusted. It is best to leave the carburetor alone as long as the engine is working properly. If it becomes necessary to clean the carburetor, it should be removed, carefully taken apart, and washed with a safe solvent. If possible, air should be forced through the jets and other small openings. Install new gaskets. Rebuilding kits are available which contain new gaskets and the parts that normally need to be replaced. Carefully reassemble and then reinstall the carburetor.

In adjusting a carburetor, use the following procedure:

1. Follow the directions supplied by the manufacturer of the engine.
2. Adjust the carburetor while the engine is running and is warm.

3. Turn the adjustment on the carburetor until the engine almost stops running, then open the adjustment until the engine runs smoothly. If there is more than one adjustment, each will have to be adjusted. If the engine seems to lope, it is getting too much gas; that is, the mixture is too rich. If the engine sputters, it is getting too much air; that is, the mixture is too lean. After the carburetor is set for the proper mixture, set the idle speed screw to regulate the idling speed of the engine.

Common Carburetor Troubles—There are relatively few causes of carburetor troubles. Dirt or other foreign material in a carburetor may plug the jets and prohibit them from functioning properly. If the engine spits, sputters, almost stops, and then starts again, there may be dirt in the carburetor. The float may stick and cause the carburetor to overflow. Improper adjustment of the carburetor, and worn, warped, or bent parts are causes of trouble.

The Purpose of an Intake Manifold—After the fuel is properly mixed in a carburetor, it must be delivered to the cylinders. This is done through an intake manifold which aids in the vaporization of the fuel mixture. Vaporization is hastened by the exhaust gas from the engine, which heats the manifold. Manufacturers have spent considerable money to develop manifolds which will aid in the vaporization of the fuel mixture before it enters the cylinders of the engine.

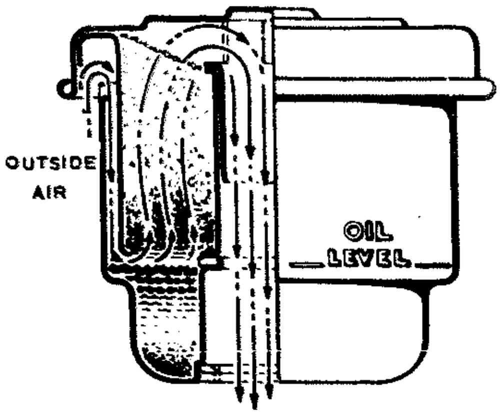
Fuel Injection Systems for Diesels—The fuel injection system and the combustion system are designed to be carefully coordinated. The combustion system receives the fuel as it is sprayed into the combusion chamber, completes the dispersion of the fuel by air turbulence, and thus influences the ignition of the fuel.

The fuel injection systems in diesel engines employ plunger-type pumps in which clearances range from 0.001 to 0.0003 inch. The individual pump system has a separate pump for each cylinder which meters at the right time a quantity of fuel at high pressure, generally from 1,000 to 3,000 pounds per square inch, to each cylinder. The fuel distributor system has a single pump which meters the required quantity of fuel through a distributor to the appropriate injector for each cylinder. The metering pump operates at moderate pressures of about 50 to 100 pounds per square inch.

The pump delivery is varied to suit the requirements of the engine by two methods. One is by the port by-pass method in which excess fuel escapes through a port uncovered by a plunger. The other method is by the variable stroke pump which admits fuel through a spring-loaded valve, the fuel delivery being varied by increasing or decreasing the length of the plunger stroke.

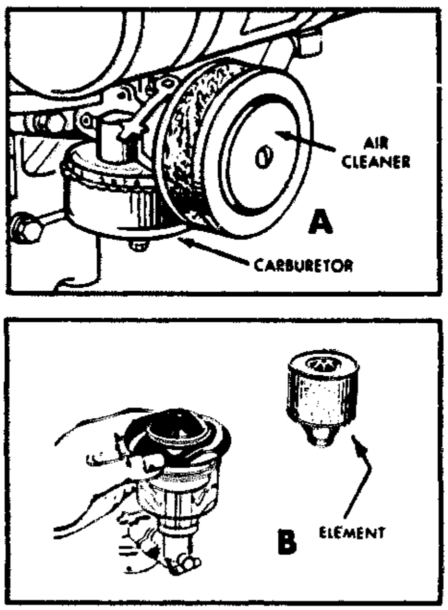
In this brief discussion, it is apparent that the fuel injection event in a diesel engine must be timed to occur before the end of the compression stroke. The means used to inject the fuel in a diesel engine replaces the ignition impulse mechanisms in an Otto cycle engine.

Air Cleaner—An engine requires lots of clean air to operate properly. A dirty air cleaner will not supply the clean air required. Dirt cleaned from the air by an air cleaner may be deposited in an air cleaner cup or in a paper element filter. If the air cleaner cup system is used, the cup must be cleaned periodically. If the air



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 23.3. An illustrative drawing showing the principle involved in the operation of an oil bath-type air cleaner.



(Courtesy Vocational Agriculture Service, University of Illinois)

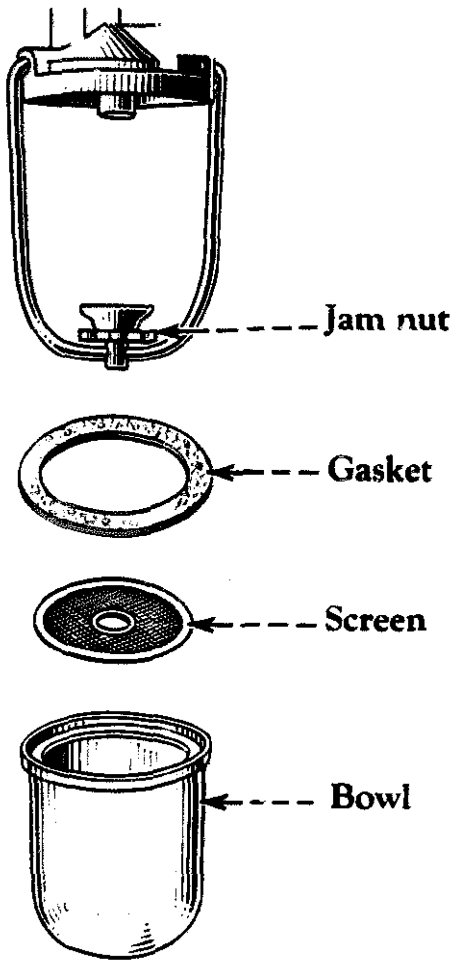
Fig. 23.4. Filter element-type air cleaners. (A) A filter element that can be cleaned. (B) A paper filter element that is discarded when it becomes dirty.

cleaner is the paper element type, replace the element when it gets dirty. The air lines from the air cleaner to the carburetor should be checked periodically for leaks.

Sediment Bowl and Fuel Lines—Periodic cleaning of the sediment bowl is not very difficult, but it is important for the continuing trouble-free operation of an engine. When cleaning the sediment bowl, first shut off the valves from the fuel tank. Second, loosen the nut under the bowl and swing the bail to one side. Remove the bowl with a twisting motion, and clean the bowl with a safe solvent. While the bowl is off, check the flow of the fuel from the fuel tank. If the fuel is dirty or does not flow freely, clean the fuel line. When the bowl is replaced, check the gaskets and check for leaks.

The tank cap should also be cleaned periodically and especially when the fuel does not flow freely to the sediment bowl. The vent on the cap may become clogged. A tank cap may be cleaned by washing it in a clean solvent and blowing out the vent with compressed air.

Periodically the fuel lines should be cleaned and inspected. The fuel line connected to the carburetor should be removed, and the screen in the fitting at the carburetor should be cleaned with a safe solvent. If the screen is gummy, use a commercial gum cleaner. The flow of fuel should be checked with the fuel line



(Courtesy International Harvester Co.)

Fig. 23.5. An exploded view of a fuel strainer and sediment bowl.

disconnected and the screen removed. If the flow is sluggish, clean or replace the line. Always check lines for leaks.

COOLING SYSTEM

An internal combustion engine must have a cooling system, because the burning of the fuel mixture produces much heat. If the cylinders were not cooled in some way, the engine would be destroyed. There are two common methods of cooling engines:

1. *Liquid Cooling.* This is the most common method in use at the present time. The cylinders and cylinder head are surrounded by jackets which are kept filled with a liquid which circulates through them and through a radiator. The liquid is cooled as it circulates through the radiator.
2. *Air Cooling.* This method has been used to a limited extent. When used, the cylinders are provided with ribs or fins to increase their radiating surface. A fan is used to force air over the ribs or fins. This method of cooling is most effective on small engines.

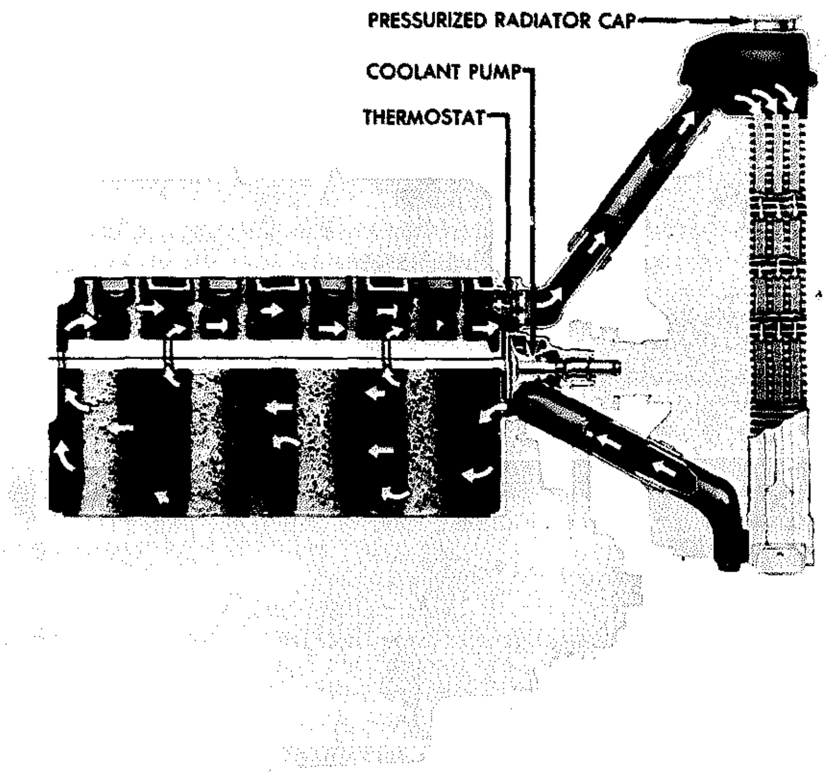
Modern liquid-cooled tractors usually have a forced circulation system. A pump is used to force the coolant through the system rapidly. A pressure cap is often used on the radiator to raise the boiling point of the liquid in the circulation system. A pressure cap that increases the pressure in the system by 6 to 7 pounds per square inch above atmospheric pressure will increase the boiling point of water, for example, from 212 to 230 degrees Fahrenheit. A 6- to 7-pound pressure cap has a valve that opens to prevent the pressure in the circulation system from increasing more than 6 to 7 pounds above atmospheric pressure.

If a liquid-cooling system is used, a commercial coolant, instead of all water, should be used in the radiator so that excessive deposits will not result and hinder the operation of the cooling system. Thermostats are provided on cooling systems to control the temperature of the liquid. Engines that burn gasoline are usually operated at temperatures of 165 to 185 degrees Fahrenheit.

If an engine overheats, check the thermostat. Also, if an engine heats slowly, check the thermostat. A faulty thermostat should be replaced with a new one of the same temperature range.

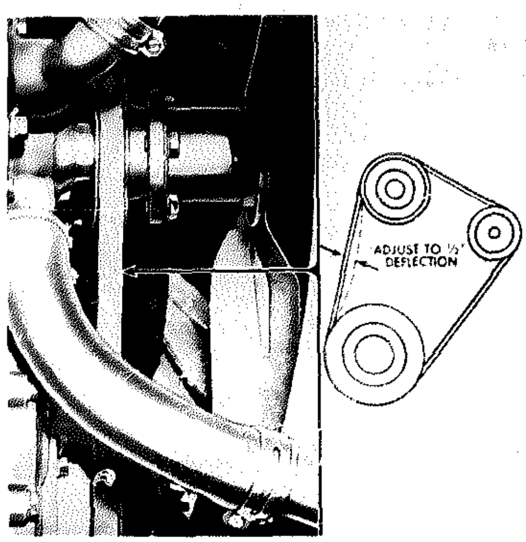
In checking a thermostat, first clean it with a solution of warm water and washing soda. Inspect for wear, lime deposits, and corrosion. The operation of a thermostat may be checked in a bucket. Fill the bucket with water and place a thermometer in the water. Immerse the thermostat in the bucket and heat the water. Observe the temperature at which the thermostat closes. Cool the water and observe the temperature at which the thermostat opens.

Another frequent cause of overheating of an engine is a clogged radiator and cooling system resulting from lime deposits. Often it is necessary to have a clogged radiator cleaned by a radiator servicing shop, but occasionally a radiator may be unplugged by the use of a flushing compound. There are many commercial flushing compounds on the market, but a homemade compound may be developed by mixing 3 pounds of washing soda with 7 gallons of water.



(Courtesy Tractor and Implement Division, Ford Motor Company)

Fig. 23.6. The cooling system of a tractor engine. Keep the radiator filled with coolant.



(Courtesy Tractor and Implement Division, Ford Motor Company)

Fig. 23.7 Adjust the tension of the fan and generator or alternator belt.

Some of the other causes of overheating are as follows:

1. Damaged radiator
2. Plugged or collapsed hoses
3. Faulty water pump
4. Loose fan belt

If an engine becomes overheated and is getting some flow of coolant, idle it for a short period of time before stopping it. Idling of an engine that is overheated often allows the pistons to cool enough to prevent serious damage.

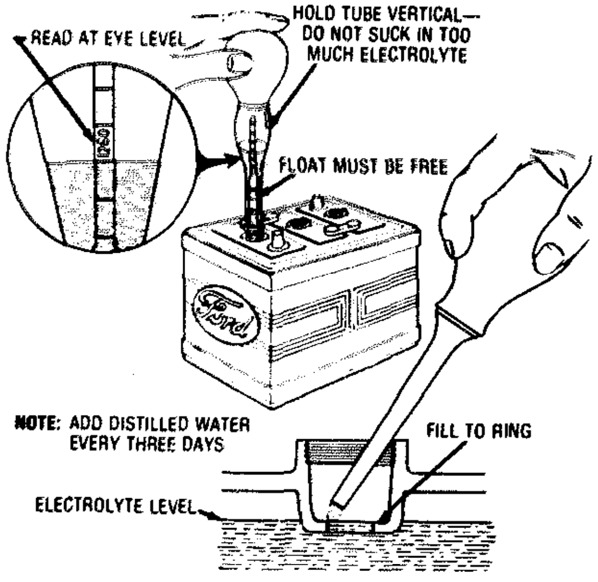
ELECTRICAL SYSTEM

The electrical system for a modern tractor usually involves a battery, lights, a starter, a generator or an alternator, fuses, an ammeter, and wiring. The battery supplies the electrical current for the ignition system.

Servicing and Testing the Battery—The battery is of prime importance in the successful functioning of the electrical and ignition systems and should be serviced frequently.

The level of the liquid or electrolyte in a battery should be maintained at the top of the rings in the cells of the battery. See Fig. 23.8. If distilled water is used to maintain the level of the electrolyte in a battery, the life of the battery will be longer. If the battery requires an excessive amount of water during normal usage, the trouble is probably due to overcharging of the battery.

The charge of a battery may be determined with a battery hydrometer. A



(Courtesy Tractor and Implement Division, Ford Motor Company)

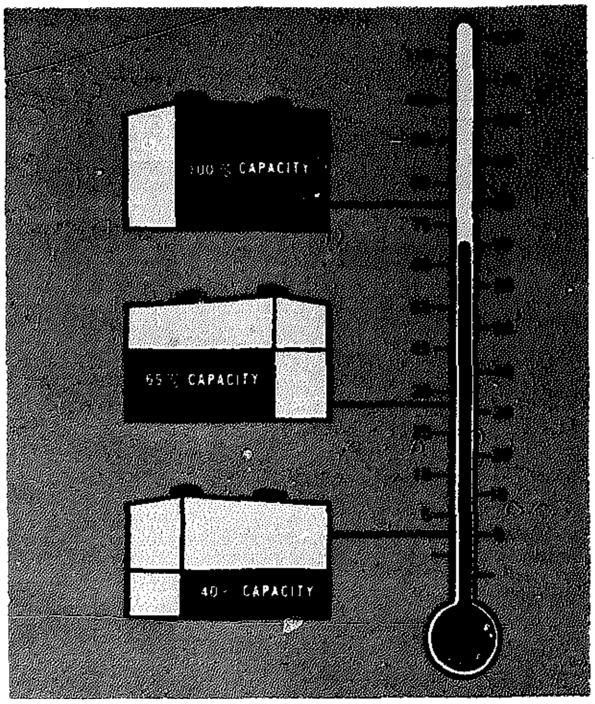
Fig. 23.8. Batteries should be checked frequently.

hydrometer is a floating instrument which is used to measure the specific gravity or strength of liquids.

A battery hydrometer is an inexpensive instrument and may be purchased from firms handling automotive equipment. Tractor operators should own a hydrometer for testing the charge of batteries. See Fig. 23.8, showing the use of a battery hydrometer. The charge of a battery is good if the hydrometer reading is between 1.250 and 1.295 at 80 degrees Fahrenheit. The charge of a battery is poor if the hydrometer reading is below 1.225 at 80 degrees Fahrenheit. The temperature of the electrolyte or liquid in a battery influences the readings obtained with a hydrometer. If the battery is very cold or hot, a correction factor of 0.004 should be used for each 10 degrees of temperature below or above 80 degrees. If any cell in a battery gives a hydrometer reading of 0.025 below the others, that cell is probably bad.

The ability of a battery or a cell in a battery to be charged is tested with a voltage tester. The cost of a high-discharge voltage tester is slight, and it may be purchased from stores handling automotive equipment. It usually consists of a voltmeter, two sharp contact points or prods, and a resistance connection.

In using this type of voltage tester, press the two sharp contact points against the terminals of a cell for approximately 15 seconds. If the battery is chargeable, the voltmeter should give a steady reading of 1.7 to 1.9. If the readings for the



(Courtesy Gulf Oil Corporation)

Fig. 23.9. How temperature influences battery efficiency.

cells vary more than 0.2 volt, or if the voltmeter reading drops during the test, the battery is in poor condition.

Battery terminals may corrode, or the battery may become soaked with acid. When this occurs, wash the terminals and battery with a soda solution. Use ¼ pound soda to a quart of water. When the washing has been completed, inspect the holes in the vent caps. These holes should be kept open.

In servicing batteries, inspect the clamps. If the inside of the clamps or terminals is corroded, the electrical charge will not be transmitted to the electrical system. If corroded, scrape off corrosion on clamps and terminals. Also check for frayed insulation on cables and for loose connections.

Batteries placed for storage during the off-season should be fully charged. They should be stored in a cool place. It is a mistake to store a battery in a heated building or a warm basement.

Checking the Ammeter—An ammeter is supposed to indicate the rate of charge or discharge of the battery. If the ammeter shows a discharge when no electrical current is being used, check for a short circuit in the wiring, which may be caused by frayed or worn wires. If the ammeter does not indicate a positive charge when it should, check for the following:

1. Broken connections or wires.
2. Faulty generator or alternator. Inspect the brushes. If they are worn, they should be replaced. If the commutator or brushes are dirty, clean them with grade 00 sandpaper. Do not use emery cloth. See Chapter 39 for information on replacing brushes and cleaning the commutator.
3. Faulty ammeter.

Checking the Light Circuit—If the light circuit fails, check the fuse. If the fuse is burned out, check the wiring for short circuits. If the fuse is not burned out, check the wiring for broken connections and for broken wires. Also, check the light bulbs to determine whether or not they are burned out.

Servicing the Starter—A starter is a motor powered by the battery. Periodic checks should be made of a starter's brushes and commutator. See Chapter 39 for information on servicing and cleaning electrical motors.

If a starter fails to operate, check for the following difficulties:

1. Loose or corroded battery connections.
2. Discharged battery. Use a battery hydrometer to determine the charge of the battery.
3. Loose connections or broken wires between the battery and the starter.
4. Faulty starter switch. Check whether the switch is making contact when it is turned on.
5. Faulty starter. See Chapter 39 for information on motor difficulties.

Servicing the Generator—The brushes and the commutator of a generator should be inspected periodically. When the brushes and commutator get dirty, use grade 00 sandpaper and hold it against the commutator with the engine running. See Chapter 39 for information on servicing brushes and commutators.

A generator is provided with a cutout relay, which is usually mounted on top of the generator, to close the generator circuit and protect the generator. If the cutout relay points do not close, the ammeter will register zero. If the cutout relay points do not open, the ammeter will show a "discharge." If the cutout relay does not work properly, remove the generator and have it serviced by an authorized mechanic.

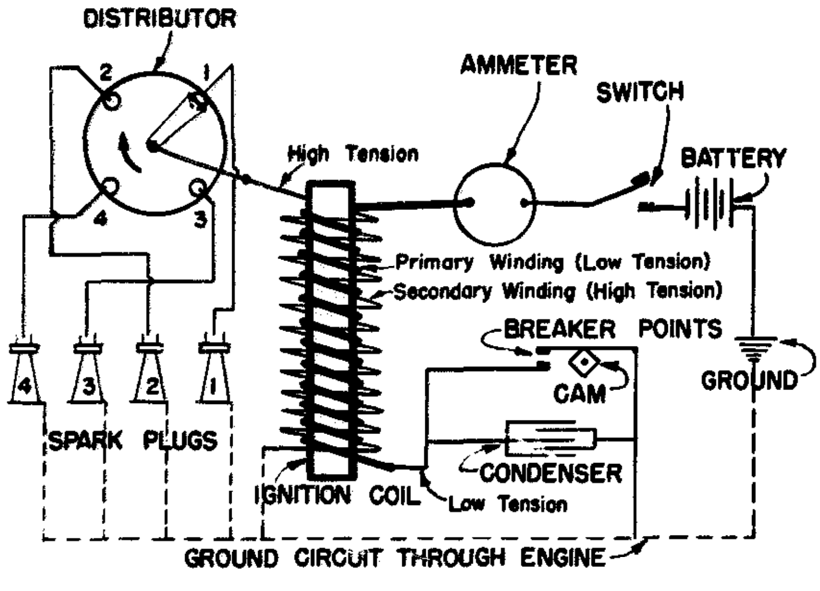
IGNITION SYSTEM

An electric spark must be provided in a cylinder to ignite the fuel mixture. This is the function of the ignition system. This spark must be of sufficient intensity not only to ignite the fuel mixture, but also to ignite it at the correct time. A good ignition system which functions properly is very important.

Battery Ignition System. This system involves the use of a battery, a high-tension coil, a switch, an ammeter, a distributor, wires, and spark plugs.

A battery ignition system is shown in Fig. 23.10. The current goes from the battery through the breaker points and the coil, through the engine, and then back to the battery. This circuit is known as the primary circuit and is essentially a low-tension circuit. As the breaker points start and stop the current, the waves of current cross the secondary coil, creating a high-pressure current called the secondary or high-tension current. This high-tension current is often in excess of that required to jump across the spark plug gap. A condenser takes care of the excess current or pressure and serves as a cushion of the system.

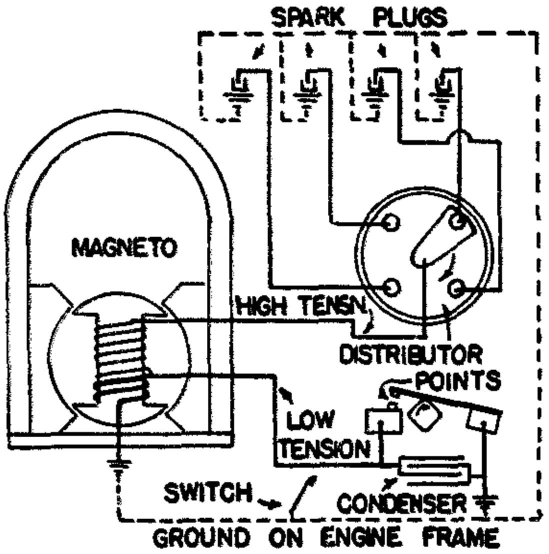
Magneto Ignition System. The operating principles involved in this system are the same as those involved in the battery system. The magneto generates a high-



(Courtesy Michigan State University)

Fig. 23.10. A diagram of a typical battery and high-tension coil ignition system of a four-cylinder engine. (The firing order shown is 1-3-4-2.)

tension current similar to the current provided by the battery and coil system. The magneto unit contains primary and secondary coils, breaker points, a condenser, and a distributor. The diagram of the arrangement of a high-tension magneto system is shown in Fig. 23.11.



(Courtesy University of Illinois)

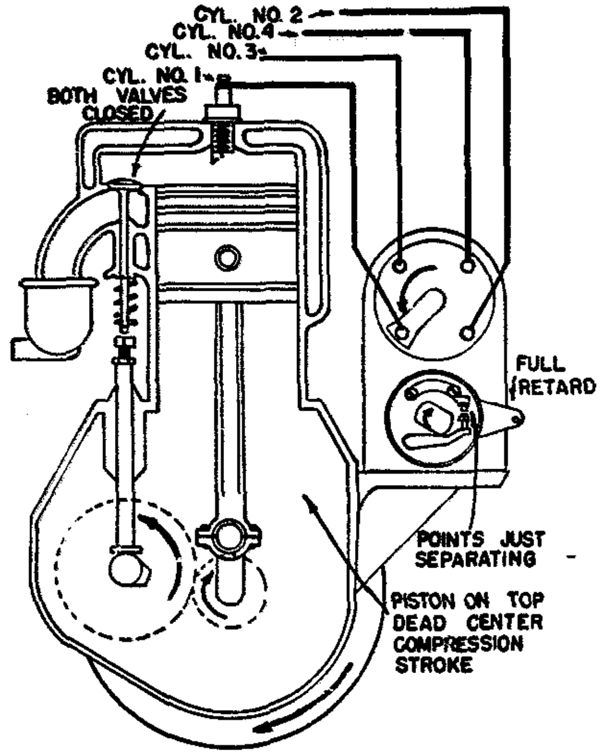
Fig. 23.11. A magneto high-tension ignition system.

Spark Plugs—Plug points should be set a uniform distance apart, about the thickness of a worn dime or a scant 1/32 inch apart. See Fig. 23.13 for an illustration of the method of measuring the gap with a round-wire gauge. Adjust the gap by moving the outside electrode up or down. Plugs should also be cleaned occasionally. The outside point of a spark plug should be somewhat U-shaped, so that any condensation of moisture on the point will run to the bottom of the U rather than collect in the gap between the points and short the plug. Testing machines are now available for testing plugs to see whether or not they are satisfactory.

Spark plugs are made for different heat ranges. In general, spark plugs should operate cool enough to give them a long life and hot enough to prevent the excessive formation of oil and soot. Constant fouling with sooty carbon indicates a need for a hotter plug, while blistered or cracked insulators and the rapid wearing of the electrodes indicate a need for a cooler plug.

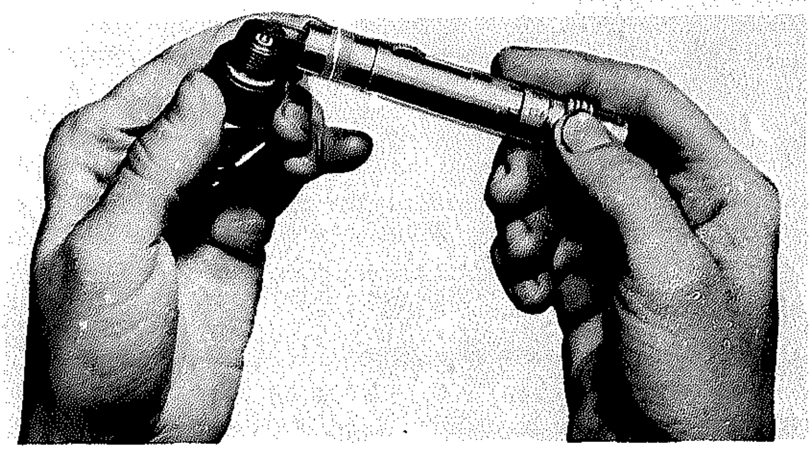
Distributor Points—A weak, irregular spark will decrease materially the efficiency of operation of an engine. Dirty or pitted points are often the cause of a weak or irregular spark. If the points are dirty or pitted, it is usually best to replace them. Observe the following steps in replacing points:

1. Mark the location of the rotor on the distributor cap.
2. Remove the distributor. Do not operate the engine with the starter or crank while the distributor is off.



(Courtesy College of Agriculture, North Dakota State University)

Fig. 23.12. The wires from the distributor lead in sequence to the cylinders 1-2-4-3, which is the firing order of the engine illustrated.



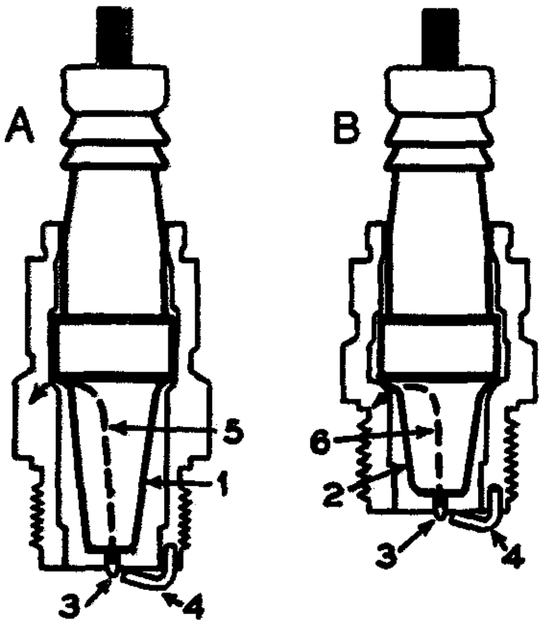
(Courtesy Tractor and Implement Division, Ford Motor Company)

Fig. 23.13. Remove, clean, and check gaps of spark plugs after each 240 to 300 hours of use.

3. Replace the points.
4. Adjust the point gap. Turn the distributor shaft until the arm is on the high point of the cam and then adjust the gap. When the arm is on the highest point of the cam, the points are at their widest position. Use a feeler gauge to determine the gap. See the operator's manual for the gap specified. If the gap is not correct, loosen the screws holding the fixed or stationary point, and turn the cam until the correct gap is obtained. Tighten the screws and recheck the gap.
5. Grease the cam with a high-temperature grease.
6. Replace the rotor.
7. Turn the rotor to the mark placed on the distributor cap when the rotor was removed.
8. Put the distributor back on the engine.

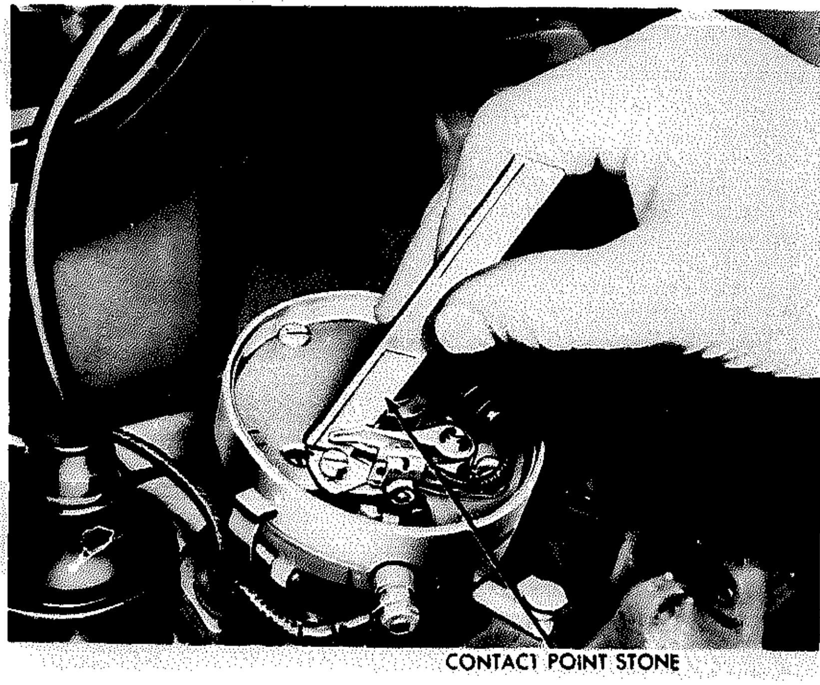
Distributor Timing—An engine must have the spark introduced into the cylinders at the right time to operate correctly and efficiently. The timing of the distributor determines when the spark is supplied. In timing a distributor, observe the following procedures:

1. Crank or turn the engine until the number one piston is on top dead center of its compression stroke.
2. Determine when the number one piston is on top dead center of its compression stroke by removing the spark plug. Place your thumb over the spark plug hole and feel for the pressure produced by the compression stroke.
3. Determine the position of the piston on the compression stroke by aligning the marks on the flywheel with the inspection opening provided



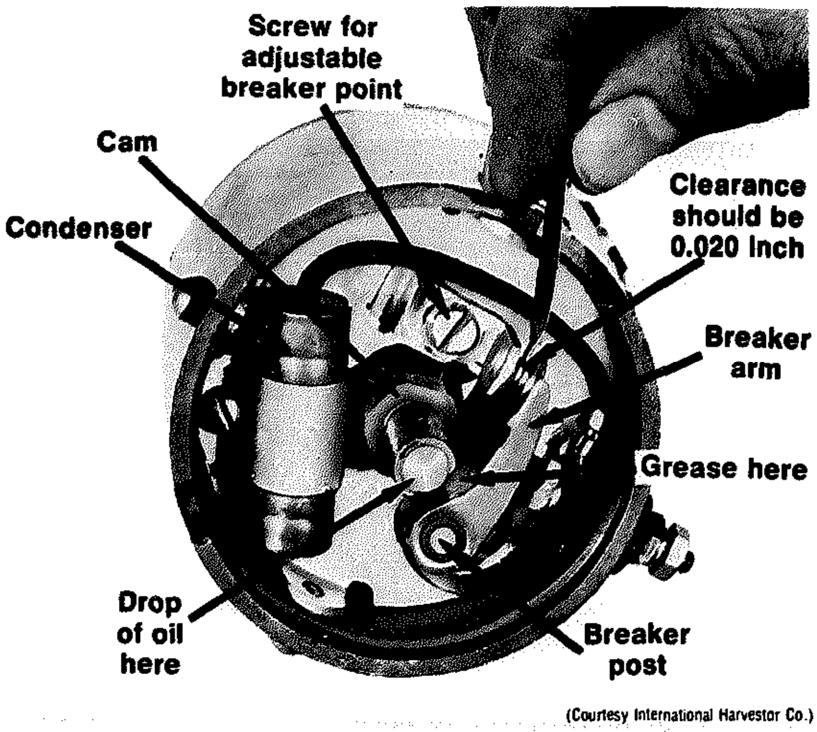
(Courtesy University of Illinois)

Fig. 23.14. Two types of spark plugs: (A) hot, (B) cold. (1) Long porcelain, h 'ds heat in the plug; (2) short porcelain, allows heat to escape rapidly; (3) center electrode; (4) outside electrode; (5) and (6) distances heat must travel to escape from the porcelain.



(Courtesy Tractor and Implement Division, Ford Motor Company)

Fig. 23.15. Use a contact point stone on the distributor contact points to remove small pits.



(Courtesy International Harvester Co.)

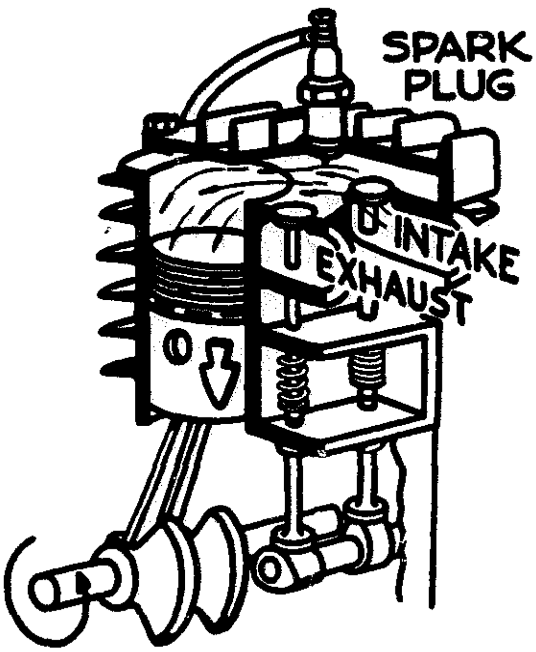
Fig. 23.16. Adjusting distributor breaker points.

by the manufacturer. Consult the operator's manual for instructions on finding the inspection opening provided by the manufacturer.

4. Turn the distributor in the direction opposite to the direction the rotor turns. Turn the distributor as far as possible in this direction.
5. Remove the wire from the center of the distributor.
6. Hold this wire near the block of the engine.
7. Turn on the ignition key.
8. Turn the distributor forward slowly until a spark is obtained.
9. Tighten the nut locking the distributor in place.
10. Fasten a timing light to the number one spark plug.
11. Direct the light at the inspection opening for observing the timing marks on the flywheel. If the engine is timed correctly, the timing light will illuminate the timing marks on the flywheel.

Proper Valve Timing Essential—An engine must be timed properly if it is to perform properly. If an engine is timed too fast, it may miss, run too rapidly, knock, overheat, or not idle properly. If an engine is timed too slow, it will not have the proper pickup and will be sluggish. The valve timing of an engine should be checked occasionally to determine whether the engine is working efficiently.

Principles—Before an engine can be timed, one cylinder must be on top dead center. That is, the piston must be in the cylinder as far as it will go so that when pressure is applied to the top of the piston it will not move downward. When a piston is in this position, it is known as top dead center (TDC). When a piston is drawn out of the cylinder as far as possible, it is on bottom dead center (BDC).



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 23.17. An illustrative drawing of the *intake stroke* on a four-cycle engine, showing action of valves, gases, and the piston.

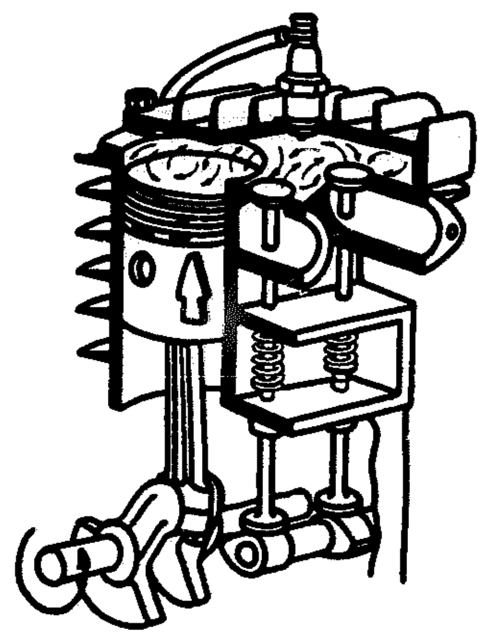
Most engines are marked so that the operator can tell when the engine is on dead center.

In overhauling an engine, the operator should note whether or not the gears are marked showing when the timing is correct. If they are not, they should be marked with a center punch before being removed. This will aid in putting them together in the correct position.

Ordinarily, it is best to check the valve timing when the piston is at the end of the exhaust stroke. When timing a multiple-cylinder engine, turn the crankshaft until the exhaust valve closes and the intake valve is just ready to open. Then put the timing gears in place. An engine is timed by first getting it on dead center in respect to one cylinder. Usually this can be determined by observing the valve action or by inserting a small rod through the spark plug hole onto the top of the piston. The timing is then checked through the distributor box. Observe the firing order of the engine—that is, the cylinder order, for example, 1-2-4-3—in which the spark is to occur.

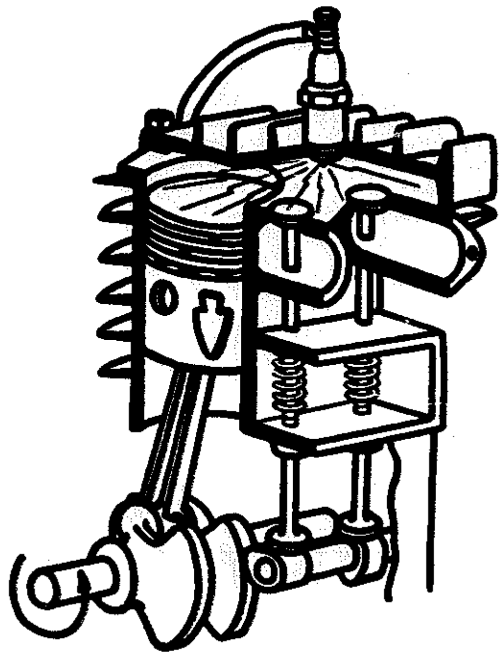
The intake valve begins to open when the crankshaft has rotated about 10 degrees past TDC, and it remains open until the crankshaft has rotated about 30 degrees past BDC. The range of operation of the intake valve is about 200 degrees. The compression cycle starts about 30 degrees after and ends on TDC at the end of the first revolution of the crankshaft. Compression is thus developed during about 150 degrees of a revolution of the crankshaft.

Ignition occurs at TDC, after compression, and the power stroke carries



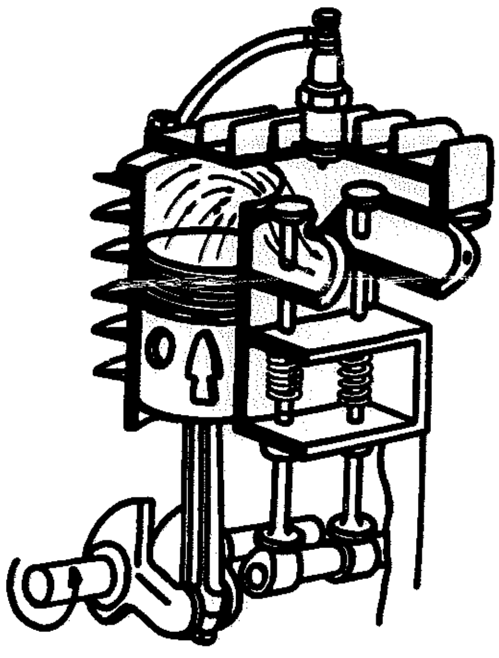
(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 23.18. An illustrative drawing of the *compression stroke* on a four-cycle engine, showing position of valves and action of the piston.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 23.19. An illustrative drawing of the *power stroke* on a four-cycle engine, showing position of valves and action of the spark plug and piston.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 23.20. An illustrative drawing of the *exhaust stroke* on a four-cycle engine, showing position of valves and action of gases and the piston.

through until the crank is about 45 degrees ahead of BDC, when the exhaust valve starts to open. The power stroke is therefore effective for about 135 degrees of a revolution of the crankshaft. The flywheel and any counterbalances "smooth out" the crankshaft rotation and "carry over" the power of the engine until the next power impulse.

The exhaust valve opens about 45 degrees ahead of BDC and remains open until about 5 degrees past TDC, or for about 230 degrees. This completes the second revolution of the crankshaft, and the four-stroke cycle is complete.

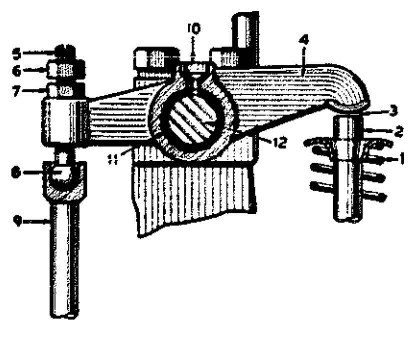
ADJUSTING TAPPETS

The proper adjustment of the valve tappet clearances is essential to efficient engine performance. Farmers and nonfarm agricultural workers operating engines should understand the principles of valve timing, but should not attempt to change the timing of the valves of engines except as the timing is adjusted in the process of proper tappet adjustment. Tappets that are adjusted with excessive clearance are noisy. Excessive clearance also changes the valve timing slightly, which may reduce the efficiency of the engine.

Tappets with inadequate clearance will not close tightly. This may produce overheating, valve warping, and loss of power.

In adjusting valve tappet clearances, proceed in the following manner:

1. Operate the engine until it reaches normal operating temperature.
2. Remove the spark plugs.
3. Turn the engine until the number one piston is on top dead center (TDC) on the compression storke. The piston is on TDC on the compression stroke when both valves are closed and the piston is as high as it will go. This can be measured with a wire through the spark plug hole. Be sure the wire is not on the top of a valve.
4. Use a flat feeler gauge to check the gap between the valve stem and its rocker arm. Determine the recommended clearance by consulting the operator's manual for the engine.



(Courtesy University of Illinois)

Fig. 23.21. A detailed view of overhead valve and rocker-arm clearance adjustment. (1) Valve spring, (2) valve stem, (3) valve clearance, (4) rocker arm, (5) rocker-arm adjusting bolt, (6) and (7) lock nuts, (8) ball-and-socket joint, (9) push rod, (10) oil hole, (11) removable bronze bushing, (12) rocker arm and shaft.

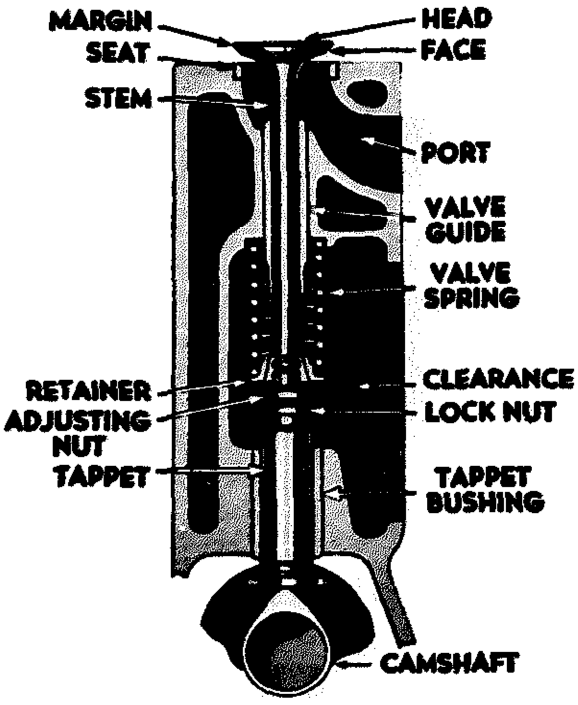
5. Loosen the lock nut and turn the adjusting screw with a screwdriver until the desired clearance is obtained.
6. Repeat the procedure on the other cylinders.

VALVE GRINDING

Importance—An engine will not have the proper compression unless the valves fit perfectly. If the valves do not fit properly in their seats, compression will leak by them. The exhaust valves often become burned, pitted, or warped and will have to be refaced and ground. If badly warped, they should be replaced. The intake valves, while not ordinarily damaged badly, should be ground at the same time the exhaust valves are ground.

Essential Tools and Supplies for Valve Grinding—Special equipment has been developed for use in refacing and reseating valves. This type of equipment is expensive, and its use requires considerable skill. Consequently, it is not usually available in school agricultural mechanics shops and in farm or agricultural business shops. The valves may be removed for checking or for refacing or grinding at a commercial garage. The following is a partial list of equipment and supplies which will be needed for the removal of valves.

1. Valve lifter
2. Valve spring tester



(Courtesy University of Illinois)

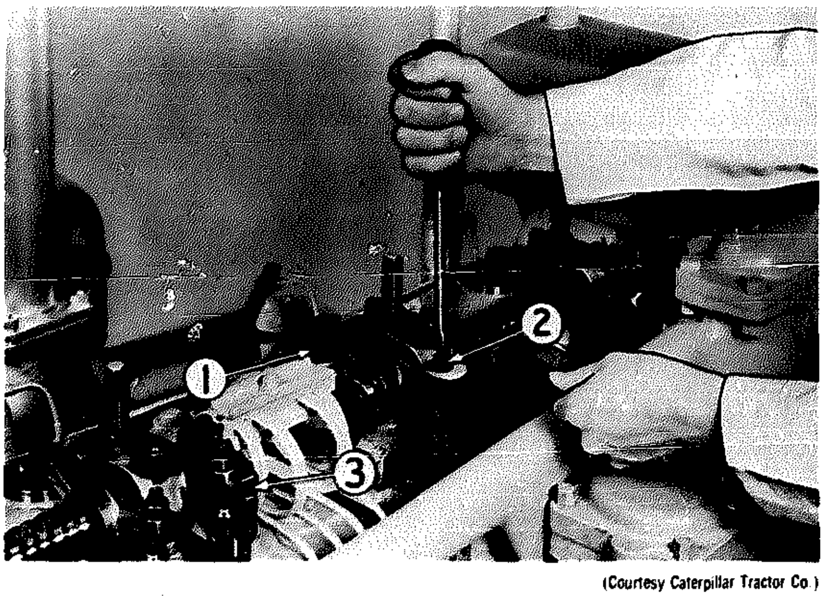
Fig. 23.22. A detailed view of an L-head valve assembly.

3. Valve tool for use in replacing valve keepers
4. Emery cloth
5. A good grade of oil
6. Cotton waste
7. Cleaning solvent

Valve Grinding Operation—With modern gasoline engines, it is usually best to have the valves refaced and the valve seats reamed by a qualified mechanic, who uses equipment especially designed for that purpose. Operators of engines usually do not have the tools or the necessary skill to reseat and reface valves.

In removing and replacing valves, use the following procedure:

1. Remove the head of the engine.
2. Remove the springs and pins or keepers holding the valves.
3. Remove the valves, marking them if they are not already marked, and put them in a valve rack to keep them in order so that they will be replaced in their proper places.
4. Examine the valves and have them commercially refaced, if needed. If the valves are warped or have thin edges, replace them with new ones.
5. Replace the valves.
6. Clean, test, and replace the valve springs and keepers.
7. Put the cylinder head in place, using new gaskets.
8. Tighten the cylinder head bolts or nuts, following the manufacturer's instructions.
9. Retighten the bolts or nuts after the engine has been operated.



(Courtesy Caterpillar Tractor Co.)

Fig. 23.23. Check valve clearance after each 240 to 300 hours of use.

Removing Carbon- Carbon should be cleaned from an engine when the valves are removed. All carbon should be removed from the cylinder head, valves, and pistons. A putty knife and a wire brush are very satisfactory tools to use in performing this job.

Following are a few of the troubles which are caused by carbon deposits:

1. They may interfere with the action of the valves, not permitting them to seat properly.
2. They may cause the engine to heat.
3. They may cause a knock, especially when the engine is hot and pulling.

Carbon deposits reduce the efficiency of an engine and may indirectly cause numerous other difficulties.

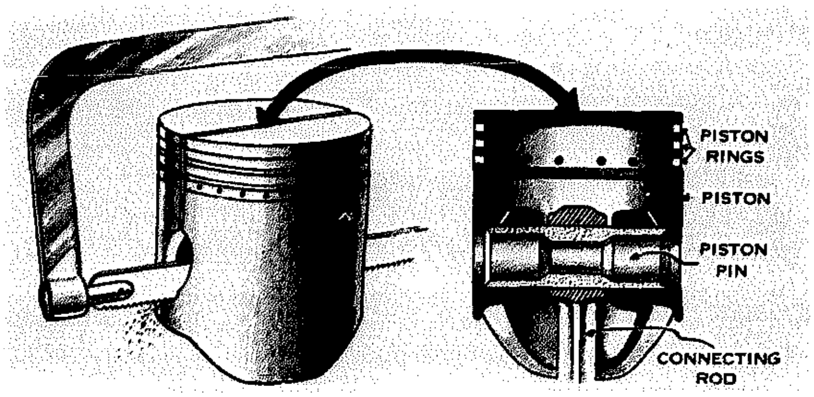
FITTING AND ADJUSTING PISTON RINGS AND PISTON PINS

Function of Piston Rings—Piston rings are used to form a gas-tight fit between the piston and the cylinder. They prevent gas leakage and the loss of an excessive amount of oil. They also aid in giving good compression to an engine.

Detecting Faulty Piston Rings—Some of the ways faulty piston rings may be detected are as follows:

1. Excessive oil consumption by an engine indicates that the piston rings are not properly sealing the space beween the cylinder wall and the piston.
2. Loss of power and compression indicates worn piston rings which permit a leakage of gas between the piston and the cylinder wall.
3. An excessive amount of smoke from the exhaust indicates that oil is escaping past the rings.

Removing Old Rings—Before new rings can be installed, the old rings must be removed. This may be done by breaking the rings or by slipping three or four strips of metal or old hacksaw blades, which have had the teeth filed off, under the rings. These strips permit the rings to be lifted out of the grooves in the piston. After the piston rings have been removed all carbon deposits should be removed from the grooves in the pistons. A screwdriver the same size as the grooves or a piece of broken piston ring may be used to remove the carbon.



(Courtesy General Motors Corp.)

Fig. 23.24. A schematic drawing of a piston, rings, and a piston pin.

Installing Piston Rings—Piston rings are constructed so that they will expand against the cylinder walls; consequently, when they are not in the cylinders they are larger in diameter than when they are compressed within the cylinder walls. Piston rings are split on one side to permit them to spring within the cylinder walls. When installing rings, by sure to select rings which are of the correct size for the cylinders. This may be determined by inserting the rings in the cylinders. A ring should touch all edges of a cylinder wall. While a ring should come in contact with the cylinder wall, it should have sufficient space between the split ends to allow for expansion. If it does not, the ends may be filed slightly. Use the engine manufacturer's recommendations for ring gap clearance. It is usually 0.002 inch clearance per inch of cylinder diameter. The rings should come in contact with the sides of the grooves in the pistons, but they should move freely. If they are too tight, they may be made slightly smaller with an emery cloth. The rings should be put in place by sliding them down over strips of metal. After the rings are in place, the pistons should be oiled and placed in the cylinder. The rings may be compressed with a compressor made for that purpose.

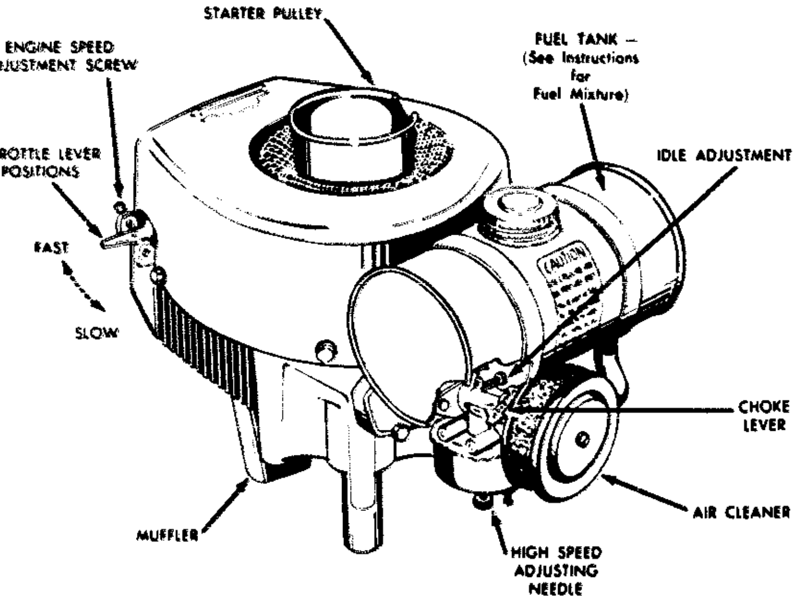
Installing Piston Pins—The pins which fasten the pistons to the connecting rods are called piston pins, or wrist pins. These pins are fitted in bushings, which prevent excessive wear. Loose wrist pins are easily detected by a definite knock when the engine is idling. Slightly loose pins do little damage, but it is very annoying to the operator to hear a knock of this kind in an engine. The bushings are ordinarily put in the piston under pressure, and the pins are made to fit snugly in the bushings.

SMALL ENGINES

Small gasoline engines are frequently used in farming and in related agricultural businesses. They are used on chain saws, weed cutters and mowers, air compressors, water pumps, and garden tractors. Small gasoline engines may be either four-cycle or two-cycle engines. (See Chapter 21 for a discussion of the principles of operation of two-cycle and four-cycle engines.) Two-cycle engines may be built so that they are smaller in size and lighter in weight than four-cycle engines. They are often used, therefore, as a source of power where size and light weight are important, such as for a chain saw.

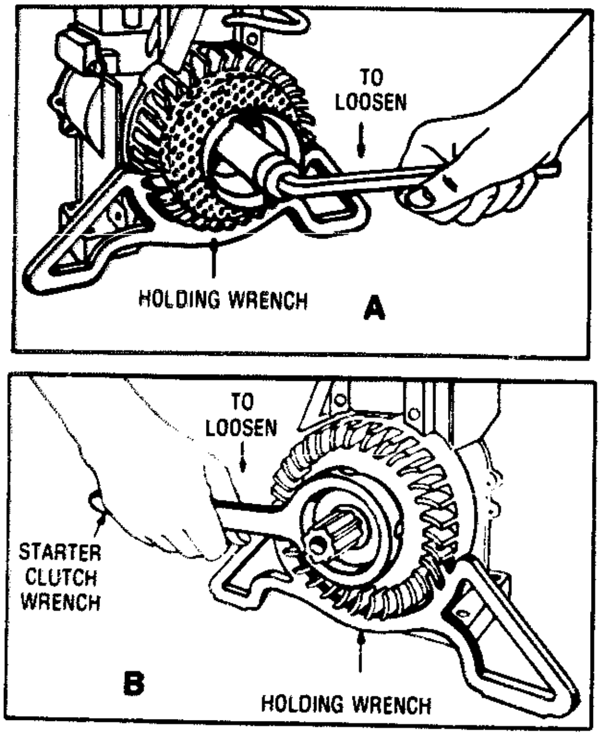
Principles of Operation—The principles of operation of small engines are the same as for larger engines. These principles are presented in Chapter 21, "Understanding the Fundamental Principles of Engines." See Chapter 22, "Operating and Lubricating Engines," for the principles relating to these two activities. For the principles of the carburization system, the cooling system, and the electrical system, see earlier sections in this chapter, "Maintaining and Adjusting Internal Combustion Engines." The principles of overhauling engines are also discussed in this chapter.

Small engines may be water-cooled or air-cooled. However, most small engines are air-cooled. The cylinder and the cylinder head often have ridges or fins.



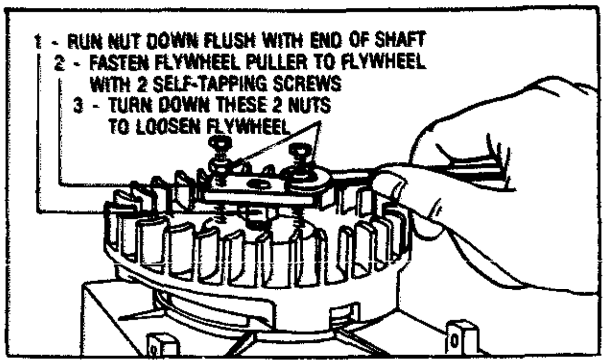
(Courtesy Clinton Engine Co.)

Fig. 23.25. A two-cycle small engine.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 23.26. A special holding wrench for loosening the flywheel on small engines. (A) Removing a holding nut that has a left-handed thread. (B) Removing a holding nut that has a right-handed thread on the starter clutch.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 23.27. For some small engines a special puller is required to remove the flywheel.

These ridges or fins increase the area exposed to the air, which promotes cooling. The ridges or fins also provide strength, which permits the walls of the cylinder and cylinder head to be thinner. They also promote cooling.

The cylinder and cylinder head of air-cooled engines must be kept clean to prevent overheating. Dirt and grease on the cylinder and cylinder head will quickly decrease the cooling capacity of the engine.

Work Procedures—When working on engines, either small or large, follow certain essential work procedures. The following is a list of those procedures:

1. Before work is started, secure the manuals, booklets, and information supplied by the manufacturer for the engine.
2. Before work is started, secure the tools to do the job, to the extent possible. Certain specialized tools are needed for small engine work. They are:
   a. flywheel holder
   b. recoil mechanism wrench
   c. flywheel puller
   d. valve ring compressor
   e. piston ring expander
   f. thickness gauges
   g. micrometer
   h. telescoping gauges
   i. torque wrench
   j. cylinder ridge reamer
   k. valve grinder
   l. valve facer
   m. point file
   n. miscellaneous tools—box-end wrenches, Allen wrenches, diagonal cutting pliers, needle nose pliers, screwdrivers, center punch, pin punch, hammer, open-end wrenches
3. Secure, also before work is started, the following miscellaneous items:
   a. clean wiping cloths
   b. flat pan for cleaning solvent
   c. safe cleaning solvent—*not* gasoline or carbon tetrachloride
   d. small brush for cleaning parts
   e. trays or small cans for storing parts

   f. clean working surface
   g. safety containers for gasoline removed from engine and for adding to engine
   h. oil storage container
4. Before starting work on engine, clean exterior of engine.
5. Place all bolts, studs, and screws removed in a container and label each item.
6. Remove gaskets carefully and label. When reassembling, it is usually advisable to use new gaskets.
7. Use center punch to mark parts to help in their reassembly. This is especially important for parts that can be reversed. Before marking parts, look for assembly marks that may have been provided by the manufacturer.
8. Drain gasoline from engine before work is started.
9. Drain oil from crankcase and air cleaner.
10. Select correct tool for job.
11. Be careful to return parts to original location when reassembling.
12. Consult manuals provided by manufacturer for correct disassembly and assembly procedures.
13. Use operator's manual for adjustment and tolerance specifications.
14. Clean all parts as they are removed.
15. Lay out all parts removed on work surface in "exploded fashion."
16. Locate timing marks on crankshaft, camshaft gear, and magneto gear.
17. Sketch parts before and during disassembly if difficulty is anticipated in reassembly.
18. Coat movable parts with light oil before reassembly.

Trouble Shooting and Tune-Up—Often the major difficulty with a small engine is trouble in starting. When a small engine is difficult to start or will not start, the compression, the carburetion, and the ignition should be checked. First, check the compression. Turn the flywheel quickly and note whether or not it rebounds on the compression stroke. If the flywheel rebounds, the compression should be sufficient for starting the engine. If it does not rebound, remove the spark plug and place a tablespoon of oil in the cylinder. The piston should be in a vertical position when the oil is placed in the cylinder. This will prevent the oil from getting on the valves. Replace the spark plug and again turn the flywheel quickly. If the flywheel rebounds, it probably indicates that the piston, cylinder, or rings are worn. The oil has produced a temporary seal. Give the oil time to drain to the crankcase. Check the compression again. If the flywheel does not rebound after a quick turn, the engine needs to be overhauled.

If the oil added through the spark plug hole does not increase the compression of the engine, suspect leaking or stuck valves. An overhaul or valve grinding job is indicated.

If the compression is satisfactory, check the carburetion. First, check whether or not the gasoline tank contains gas. In fact, when an engine does not start, this should be the first check to make. Many small engines have a gravity-fed fuel system. If the tank contains fuel, check the fuel line. First, loosen the fuel line at the carburetor to determine whether or not fuel runs out. If it does, empty and clean the sediment bowl, assuming the engine has a sediment bowl. Be sure to clean the screen in the sediment bowl. Check the vent hole in the cap for the tank and make certain it is open.

For a suction carburetor, remove the fuel line and check for stoppages. Clean the foot valve. Fill the line full of fuel and check whether or not the foot valve is working properly.

Next, check the needle valve settings for the carburetor. See the operator's manual. After closing the valve, open it the number of turns recommended in the operator's manual. If a manual is not available, experiment by opening the main valve 1½ turns and the idling valve ¾ turn.

When an engine does not start, it may be due to flooding. If flooding is the cause of the failure to start, remove the spark plug and wipe it dry. Then turn the engine over several times with the spark plug removed to eliminate the excess fuel. Replace the plug and attempt to start the engine.

Flooding of a small engine may be caused by excessive choking or by a dirty, plugged air cleaner. If the air cleaner is the cause of flooding, clean it. If, after the carburetion and the compression are checked, the engine does not start, the trouble may indicate that the carburetor needs to be completely overhauled.

In addition to checking the compression and the carburetion, check the ignition when the engine does not start.

First, check the condition of the spark plug. Put in a new spark plug if the electrodes on the old plug are fouled, corroded, or burned. Check the spark by laying the connected plug on top of the engine head and turning the engine over. The breaker points are probably the cause of the difficulty if the spark is missing, irregular, or weak.

Consult the operator's manual for locating or getting to the breaker points and for directions on setting them. The breaker points are often behind the flywheel, which means that the flywheel must be removed to set the breaker points.

Clean the breaker points and make certain they are free from oil. Set the breaker points gap so that the points close completely and so that they open to the gap specified in the operator's manual. After the preceding suggested checking, the engine should start. If it does not, a complete overhaul of the ignition system may be needed.

After an engine is started, following trouble shooting or an overhaul, a final tune-up of the carburetion is needed. Let the engine warm up, then adjust the idle-speed valve. See the operator's manual for recommended idling speed. Adjust the idling adjustment screw until the engine runs at the desired speed. Then, run the engine at full speed and adjust the main fuel valve. First, turn the screw back until the engine falters and then turn it forward until the engine runs smoothly. Also adjust it under load.

Overhaul—Major overhaul of a small engine is often more costly than the purchase of a new engine. If a major overhaul is undertaken, first consult the operator's manual and also review Chapters 21, 22, and this chapter.

TRUCKS AND TRACTORS

Student Abilities to Be Developed

1. Ability to select trucks and tractors which will best meet individual needs on farms and in nonfarm agricultural businesses.
2. Ability to use trucks and tractors properly.
3. Ability to lubricate trucks and tractors correctly.
4. Ability to recognize common truck and tractor troubles.
5. Ability to perform the ordinary truck and tractor repair jobs.
6. Ability to maintain trucks and tractors.

CHAPTER 24

Selecting, Operating, and Maintaining Trucks

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What factors should be considered in selecting a truck?
2. What factors should be considered in loading a truck?
3. How can the life of tires be increased?
4. How should a truck be driven?
5. How often should a truck be lubricated?
6. What precautions are necessary in the care and maintenance of a truck?
7. How should a truck be housed?

Selecting a Truck—Some of the factors to consider in selecting a truck for agricultural purposes are as follows:

1. The purpose for which the truck is to be used.
2. The size and type of truck which will best meet farm or nonfarm agricultural business needs.
3. The cost and the money available.
4. The size of the agricultural business.
5. The amount of annual use of the truck.
6. The number and kind of trucks already available.
7. The economy of operation.
8. The availability of repair parts.

Carefully consider all of these factors before securing a truck.

Proper Maintenance Essential—The proper *preventive maintenance* of a truck will help to prevent many breakdowns which may be costly and result in a considerable loss of time. It is desirable to maintain a truck in a way that will eliminate, insofar as possible, the need for repairs. This can be accomplished through such activities as:

1. Lubricating the truck at frequent intervals with the correct grade of lubricant.
2. Checking essential parts at regular intervals.
3. Driving carefully and at the proper speed.

4. Loading properly.
5. Caring for the cooling system and ignition system properly.
6. Keeping the tires properly inflated.
7. Protecting the truck from the weather when it is not in use.

Loading the Truck—When loading a truck, distribute the weight properly (1) to prevent excessive weight on certain working parts such as springs and axles, (2) to help prevent accidents, and (3) to avoid undue wear on certain tires. The overloading of a truck is false economy and an unwise procedure. The maximum load should not be greater than that recommended by the company which built the truck.

Caring for the Tires—The life of the tires and the amount of use obtained from them is influenced by the care given them. The following precautions should be taken:

1. Keep the tires properly inflated according to the recommendations of the manufacturer.
2. Keep the wheels in alignment.
3. Rotate the tires every 2,000 to 3,000 miles. With a rear-wheel drive, the tires on the right side of the truck often wear faster than those on the left side, and the rear tires often wear faster than the front tires.
4. Drive at a reasonable speed. Increasing the speed of a truck increases the loss of rubber.
5. Have damaged tires repaired at once.
6. Keep the truck protected from the weather when it is not in use.

Driving a Truck—The careful driving of a truck is an important part of its preventive maintenance. The following precautions should be taken:

1. Let the engine become warm before starting to drive.
2. Drive at a reasonable and safe speed. This will depend on the load, roads, weather, and condition of the truck. Avoid driving at an excessive speed.
3. Have all lights operating with the proper size bulbs when driving at night.
4. Drive at a safe speed around curves and corners.
5. Avoid overpulling while in high gear; change gears.
6. Avoid starting or stopping quickly.
7. Make sure the brakes, windshield wipers, and horn operate properly.

Lubricating the Truck—A little grease and oil, if correctly applied at the proper time, can save many costly repair bills. The following parts should be lubricated:

Engine—Keep the oil in the crankcase at the proper level as shown on the dipstick. It is a good practice to check the oil each time gasoline is put in the tank. Use a grade of oil with specifications as recommended by the manufacturer.

Generator and Starting Motor—Use engine oil SAE No. 20, two to four drops.

Steering Knuckle—Use pressure gun grease.

Steering Connections—Use pressure gun grease.

Clutch Pedal Linkage—Use engine oil SAE No. 30.

Pedal Arm Hub Bearing—Use engine oil SAE No. 20.

Parking Brake Linkage—Use engine oil SAE No. 20.

Clutch Release Shaft—Use engine oil SAE No. 20.

Propeller Shaft Splines—Use pressure gun grease.

Universal Joints—Use only a good grade of pressure gun grease. If joints have needle point bearings, disassemble and repack with pressure gun grease.

Spring Shackles—Rubber-mounted spring shackles require no lubrication; for the metal bushing type, use pressure gun grease.

Front Wheel Bearings—Remove the wheel and bearings and pack the bearings with wheel bearing grease. Replace the wheel and adjust the bearings. Do not fill the hubcap.

Steering Gear—Fill through the fitting with a recommended steering gear lubricant (light for winter and heavy for summer).

Distributor—Remove the distributor cover and the rotor. Lubricate according to the manufacturer's directions.

Transmission—Use only lubricant with specifications as recommended by the manufacturer, and fill to the level of the filler plug hole.

Rear Axle—Use only lubricant with specifications as recommended by the manufacturer, and fill to the level of the filler plug hole or according to the manufacturer's instructions.

Rear Wheel Bearings—Remove the wheels and follow the manufacturer's recommendations.

Water Pump—Where the water pump is pre-packed with lubricant, under normal operations it should require no additional lubricant. On water pumps having fittings, use a good grade of special water pump lubricant.

Speedometer Cable—Every 10,000 miles lubricate with SAE No. 90 mineral oil. Check for leakage where the speedometer cable enters the transmission.

Other Precautions in Preventive Maintenance—Some other essentials in preventive maintenance are:

1. Keep clean distilled water above the plates of the battery at all times. Check often.
2. Keep connections to battery clean and tight.
3. Keep brakes properly lined and adjusted.
4. Keep fluid in the master cylinder at the proper level for hydraulic brakes.
5. Check alternator.
6. If truck has a generator, check voltage regulator, generator, and ammeter occasionally to see whether or not they are working properly. A faulty voltage regulator may cause the generator to burn out or overcharge the battery.
7. Clean the fuel filter occasionally.
8. Keep the air cleaner clean.
9. Protect the finish of the truck.
10. Paint when needed. Thoroughly clean all rusted areas before painting.

Essentials of Correct Performance—There are a number of essential items which affect efficient performance of a truck used for agricultural purposes. They may be grouped under five headings: (1) Carburetion, (2) Ignition, (3) Compression, (4) Fuel System, and (5) Miscellaneous.

Carburetion—Efficient vaporization of fuel is necessary to give smooth and economical performance. See Chapter 23 for information on carburetion.

Ignition—A hot spark at the right instant is especially important. See Chapter 23 for information on ignition.

Compression—The lower the speeds at which trucks are driven, the more evident the faults in compression become. At high speeds, loss of compression through faulty valves, ill-fitting pistons and rings, and scored cylinder bores is reduced to a minimum because of the speed at which the pistons travel. For efficient and economical operation at low speeds, compression should not vary more than 10 pounds among cylinders. If it does, steps should be taken to bring it up to normal in all the cylinders.

Fuel System—The fuel system presents no problems peculiar to low-speed operation, but for smooth, economical performance, there must be no interference with the steady flow of gasoline to the carburetor bowl. The causes of faulty fuel distribution are:

1. Fuel pump strainer screen clogged.
2. Fuel pump sediment chamber dirty or leaking.
3. Fuel pump diaphragm, valve, or shaft leaks.
4. Fuel pump pressure too high or too low.
5. Tank or line leakage.
6. Clogged gasoline lines.
7. Poor grade of gasoline.

Miscellaneous—The following should not be overlooked in any service to make a truck give peak performance.

1. Tires—pressure too low.
2. Clutch slippage.
3. Interference with free rolling of vehicle.
4. Front wheel misalignment—excessive toe-in or -out.

Housing a Truck—It is important to keep a truck protected from the weather when it is not in use. Various types of housing facilities may be provided, such as a garage for an auto, a truck, and a tractor; a building for a shop, a truck, and a tractor; or an implement shed in which there may be space for a shop, a truck, a tractor, and other farm machinery.

CHAPTER 25

Selecting, Operating, and Maintaining Tractors

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What factors should be considered in selecting a tractor?
2. What should a farmer, or a tractor operator in a nonfarm agricultural business, know about the care and repair of tractors?
3. How should a tractor be maintained?
4. How should the hydraulic system be serviced, adjusted, and maintained?
5. How should tractors be prepared for storage?
6. What procedures should be used in starting tractors that have been in storage?

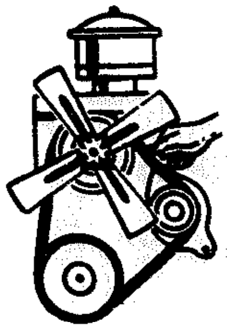
SELECTING TRACTORS

Selecting a Tractor as a Power Plant—A tractor should be selected only after the advantages and disadvantages of the different types available are considered. Original cost, adaptability, soil conditions, work to be done, annual use, economy, and timeliness of operations are factors to consider in selecting a tractor. The ability of an operator to operate, maintain, and adjust the tractor selected is also important.

MAINTAINING TRACTORS

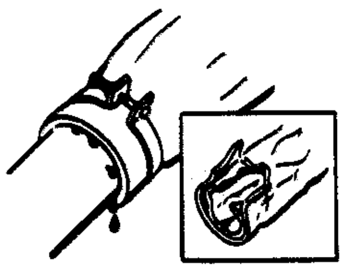
Proper Care Important—The proper care and preventive maintenance of a tractor are very imporant so that field delays are reduced to a minimum. *A tractor should be maintained and operated so that the need for repair is reduced to a minimum.* Repairs are expensive, and there may be long delays in getting the desired parts and in getting them installed. *Preventive maintenance* is the best insurance against breakdowns, costly repairs, and trouble.

What a Tractor Operator Should Do—A tractor operator should have the



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 25.1. In maintenance checks, examine the fan belt for correct tension and for wear.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 25.2. In maintenance checks, examine all hoses. Look for both external checking and internal deterioration.

ability to operate, adjust, and maintain the tractor. The operator should have the knowledge and skill necessary for doing unspecialized tractor repair jobs. The more specialized jobs such as reboring cylinders, building up worn parts, and overhauling the transmission or differential should in most instances be done by a specialized mechanic or under the supervision of a mechanic. The repair work a tractor operator should do should depend on the person's ability to perform the job and on the time and facilities available.

Engine—Since most tractor service work includes the engine, the repair and adjustment information given in the chapters on engines is applicable.

Clutch—A clutch permits the gradual application of power from the engine to the load. It permits the disengagement of the engine from the drive mechanisms for starting, for shifting of gears, and for idling. A clutch is a disk mechanism operating on a friction basis.

Check the clutch periodically. The clutch linkage wears with use and may need adjustment. The clutch pedal should have "free travel," the distance the pedal can be depressed before the clutch begins to disengage. See the operator's manual for the amount of "free travel" of the clutch pedal recommended and for the method of adjusting the linkage. Lack of clearance or "free travel" of the clutch pedal may cause a loss of power and overheating, and may result in a necessary early replacement of the clutch facing.

Transmission—Usually when a tractor's transmission needs repairing, special equipment is needed, and someone familiar with this work should do the job or assist with it. Following are some checks on the transmission that can be made by the operator of a tractor:

1. Check for oil leaks past the shafts extending from the housing. If leaks are present, the oil retainers, packing, or gaskets need tightening or replacing.
2. Check the play in the gears by jacking up each rear wheel and rocking the wheels back and forth. Undue wear will be indicated by excessive play. If the play seems excessive, have the gears examined by a mechanic.
3. Check the play or wear in the axle bearing by lifting each wheel up and down with a bar, and by pushing and pulling each wheel sidewise. Too much wear in the axle bearings will result in oil leakage. However, the oil retainer glands should also be examined, because they alone may be the cause of the leakage of oil.
4. Check rear wheel brakes for wear and for the adjustment needed. High-speed tractors should have their brakes adjusted evenly, and their brakes should not grab.

Differential and Final Drive—The differential contains gears that permit the inside wheel of a turning tractor to travel slower and the outside wheel to travel faster. The final drive gears consist of the gears that drive the wheels. Usually the differential and final drive gears are located in the same housing and are lubricated with the same lubricant.

The operator's manual for many tractors recommends that the differential and final drive be drained and refilled after each 1,200 hours of use. Check the operator's manual for recommendations regarding frequency of oil change and type of lubricant to use.

Power Take-Off—The power take-off on a tractor is powered directly from the engine and may be used to operate machines. The power take-off is usually controlled by a separate disk clutch which is operated hydraulically. Thus, the motion of the tractor does not influence the speed of the power take-off shaft, and the starting or stopping of the power take-off shaft does not influence the speed of the tractor.

Tractor operators often become entangled in power take-off shafts. Always stop the shaft before dismounting from a tractor. Always keep the power take-off shaft covered with a shield.

The clutch for a power take-off should not be slipped in attempts to free plugged equipment. Slippage will damage the clutch.

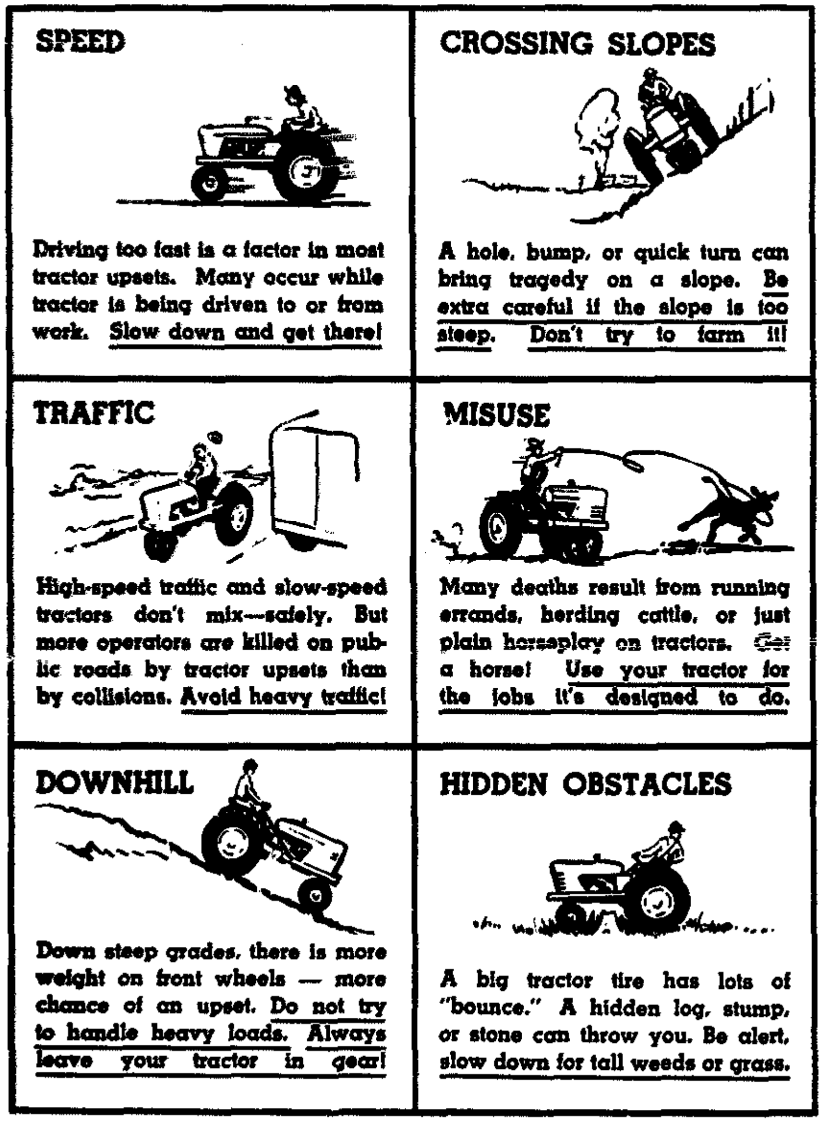
Consult the operator's manual for instructions on the operating and servicing of the power take-off.

Steering Mechanism—Many tractors have power steering. If the steering is of the hydrostatic type, there is no mechanical connection between the steering wheel and the front axle. In the hydrostatic system there is a fluid rather than mechanical linkage.

Power steering is part of the hydraulic system of the tractor. Consult the operator's manual on the operating and servicing of hydraulic systems when the tractor has power steering.

If the steering mechanism has a mechanical linkage, the linkage should be lubricated periodically following recommendations of the operator's manual. Periodic checks should be made for excessive wear in the steering linkage. Consult the operator's manual for instructions on adjustment of steering linkage.

Brakes—Tractors are often equipped with power brakes that are hydraulically operated. The brake mechanism needs to be checked periodically. The pedals



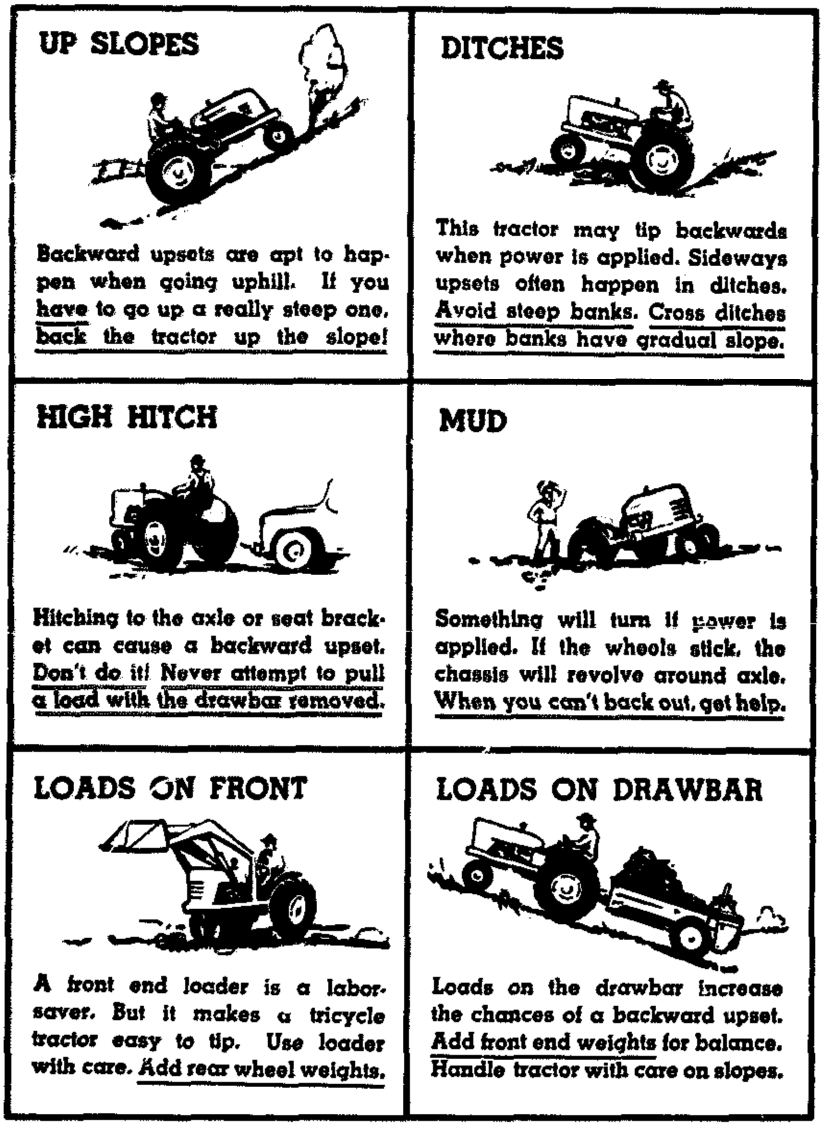
(Courtesy *Farm Safety Review*, National Safety Council)

Fig. 25.3. Suggestions regarding the safe operation of tractors.

should have the amount of "free travel" recommended by the manufacturer of the tractor. A check should be made to determine whether or not the pedals remain in alignment when an equal force is applied to each. The two pedals should remain at the same height.

Consult the operator's manual for instructions on the following operations:

1. Adjusting for the wear of brake linings
2. Adjusting of the hydraulic brake valve
3. Bleeding of the hydraulic brake system
4. Adjusting of the brake pedals



(Courtesy *Farm Safety Review*, National Safety Council)

Fig. 25.4. Suggestions regarding the safe operation of tractors.

Hitching Equipment to the Tractor—All trailing equipment must be attached to the drawbar of the tractor. Tractors come equipped with different types of drawbars, such as fixed drawbars, swinging drawbars, cross drawbars for a three-point hitch, and cross drawbars for a two-point hitch. Consult the operator's manual for instructions regarding hitching and for instructions regarding the adjustment of the drawbar.

The center of pull should be straight ahead from the center of resistance of the trailing equipment. The width of the tread of the tractor may often be adjusted to permit the center of pull to be approximately straight ahead of the center of resistance. The operator's manual should be consulted for instructions regarding adjusting the width of the tread of the tractor.

Wheels and Chassis—The wheels, steering mechanism, fenders, seat, platform, drawbar, and other chassis parts do not often cause trouble and for this reason are often neglected until trouble or failure occurs.

1. Check the rear and front wheels for loose rims, lugs, or other parts. Track-type tractors should be inspected, adjusted, and repaired according to the instruction book supplied by the manufacturer.
2. Remove the front wheels once a year, wash the bearings, and repack with a front wheel bearing lubricant. Follow the instructions given by the manufacturer or by oil companies for the type of lubricant to use. A special lubricant is usually necessary.
3. Check for wear in the bearings of the front wheels. Use the method given for checking rear wheel bearings.
4. Check the "seal" of the wheel bearings.
5. Inspect the steering mechanism for wear and for repairs and adjustments needed. Watch for bent rods or damaged parts. Replenish the lubricant in the steering gear housing according to the manufacturer's instructions.
6. Check fenders, seat, platform, and drawbar to see that all bolts or fastenings are in good condition and tightened properly.
7. Inspect rubber tires for cuts and bruises. Have needed repairs made at once. Follow the manufacturer's instructions regarding the proper air pressure and correct weight to add to tires to prevent slippage.

Servicing Tires—Correct tire inflation is important. Correct inflation will increase the life of a tire. Underinflation causes excessive wear of sidewalls of tires. Overinflation increases the incidence of fabric breaks in tires. Determining excessive underinflation and overinflation is often possible even without a tire gauge. An underinflated tire will be buckled on the underside when the tractor is standing. The tread bars of the tire will not touch the ground at the outside edge when the tire is overinflated. On a correctly inflated tire, there will only be a slight buckling of the underside of the tire, and the entire length of the tread bar should be in contact with the ground. Check tire inflation frequently. Also check the pressure gauge for accuracy.

A special tire gauge is needed if liquid weighting is used in the tire to increase traction. Tires partially filled with a solution should be tested when they are cold, and the valve should be at the bottom of the tire. In a tire partially filled with solution, the pressure may be satisfactory when the tire is hot, but may be much underinflated when the tire cools. Solution-filled tires must be watched carefully,

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The center of pull should be straight ahead from the center of resistance of the trailing equipment. The width of the tread of the tractor may often be adjusted to permit the center of pull to be approximately straight ahead of the center of resistance. The operator's manual should be consulted for instructions regarding adjusting the width of the tread of the tractor.

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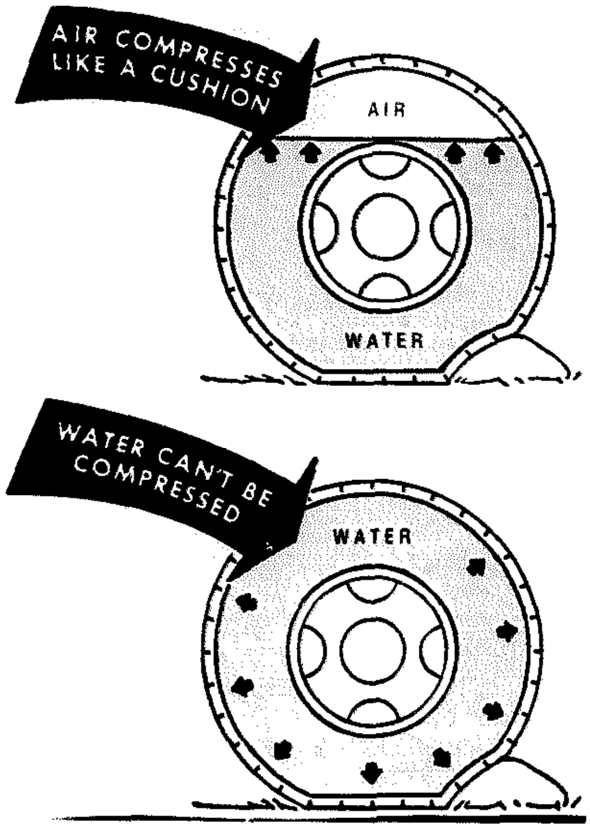
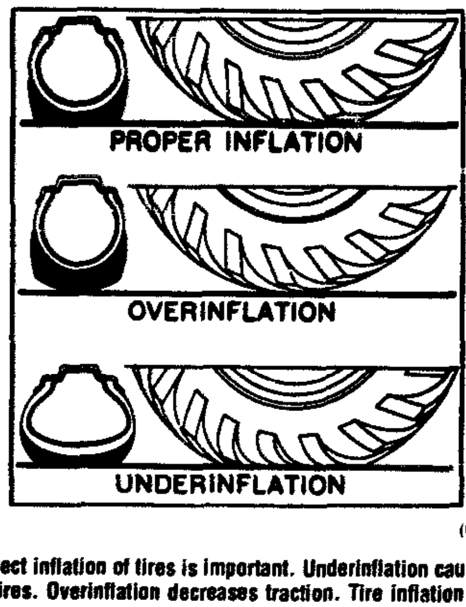


(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 25.5. Do not overfill tires with a liquid solution, such as water. Liquid solutions cannot be compressed.



(Courtesy Standard Oil Co.)

Fig. 25.6 Correct inflation of tires is important. Underinflation causes the breakage of the cord fabric in tires. Overinflation decreases traction. Tire inflation should be checked periodically.

because only a small loss of air will cause a large decrease in pressure. After checking tire inflation, replace the valve cap to keep dirt out of the valve; dirt may cause the valve to leak.

When a tractor operates with a tilt, such as in plowing, the air pressure in the tire toward the tilt needs to be increased, usually by about 4 pounds. If a tractor is operated on the side of a hill, back and forth, the pressure of the tires on both sides of the tractor should be increased.

Periodic Service—Many manufacturers and oil companies furnish service cards or check-up records which make it easy to keep a record of when certain items of maintenance were done, when they should be done again, or how often they should be done. Following is a useful type of periodic check-up chart:

10 Hour Check-Up[1]

PART	WHAT TO CHECK	WHAT TO DO
Air Cleaner	Dirt on filter	Replace filter.
Crankcase Breather	Dirt on filter	Clean filter mat, then moisten with motor oil.
Crankcase	Oil level	Fill to the proper level.

120 Hour Check-Up

PART	WHAT TO CHECK	WHAT TO DO
Water Pump	For leaks	Tighten or replace packing.
Fan Belt	Tightness and condition	Tighten or replace.
Brakes	Adjustment	Tighten or reline.
Fuel Line	Sediment bowl	Clean bowl and screen.
Oil Consumption and Leaks	Quarts used	If high, check seasonal grade of oil, bearings, pistons, and rings.
Oil Filter	Sludge	Clean or replace.
Tires	Cuts, wear, pressure	Repair cuts, check alignment.
Battery	Water	Fill to proper level with distilled water.
Transmission	Level	Fill to proper level.
Final Drive	Level	Fill to proper level.

[1] "Harvest Gold," Texas Company.

240–300 Hour Check-Up

PART	WHAT TO CHECK	WHAT TO DO
Compression	Uniformity in all cylinders	If uneven or low, check valves, rings, or cylinders.
Spark Plugs	Condition and gap	Clean and set clearance.
Radiator	Coolant and air circulation	Flush system and clean fins.
Breaker Points	Condition and clearance	Smooth and set clearance.
Ignition Cable	Condition	If rotted, replace.
Front Wheel Bearings	Lubrication	Clean and repack.
Valve Tappets	Clearance	Adjust.
Carburetor	Dirt in fuel strainer	Clean.
Air Cleaner	Clogged screen	Remove cleaner and wash.

Keep a daily record of hours of tractor use. Don't guess at check-up intervals.

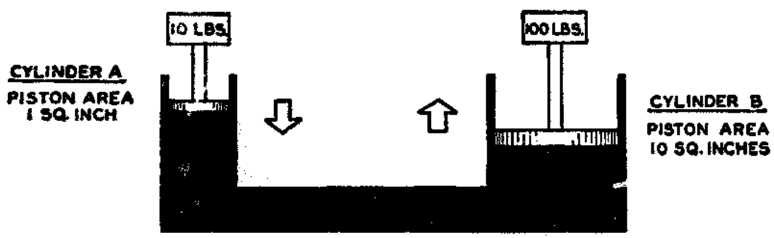
HYDRAULIC SYSTEM

Modern tractors are equipped with a hydraulic control unit to raise and lower implements and to control their depth or height.

Remote control hydraulic units are used to control implements hitched to or trailing the tractor. A remote control unit consists of a cylinder piston and hose, and is attached to the trailing implement. The fluid is conducted under pressure to the remote control unit by hoses from the tractor's hydraulic system.

Operating Principles—Air confined in a closed space may be compressed. Liquids confined in a closed space such as a hydraulic cylinder are not compressed in an appreciably smaller space when pressure is applied.

A pressure applied to the surface of a liquid will be transmitted undiminished

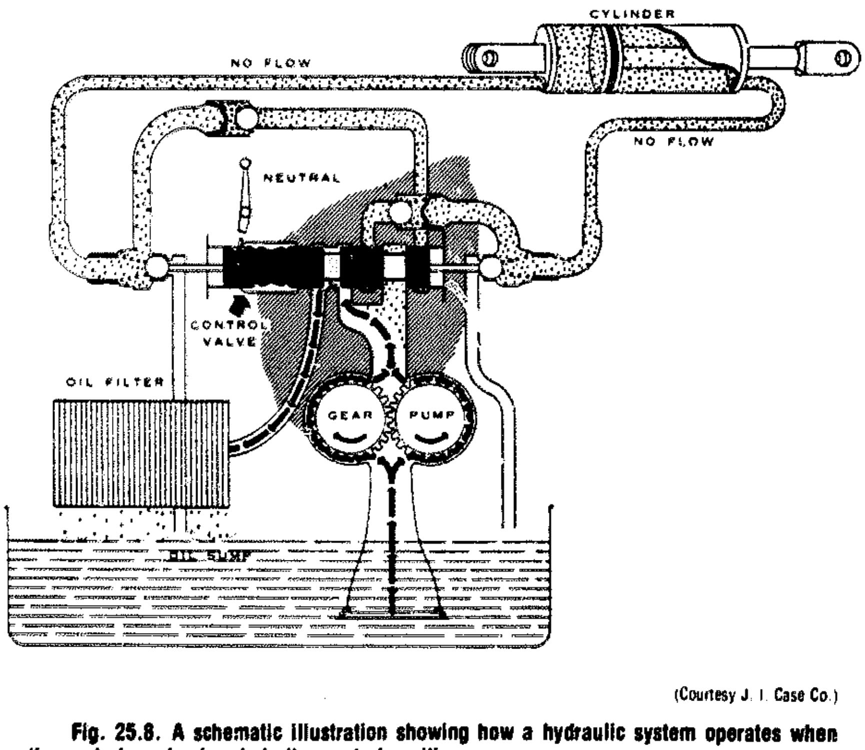


(Courtesy International Harvester Co.)

Fig. 25.7. A schematic illustration of why a hydraulic system works. Pascal's Law is illustrated.

through the liquid to all other surfaces of the liquid. This is "Pascal's Law." For example, if a pressure of 10 pounds is applied to a piston with 1 square inch of surface, as shown in Fig. 25.7, this pressure of 10 pounds per square inch is transmitted to the larger piston. Since this larger piston is 10 times as large as the smaller piston, it is capable of producing 100 pounds of force. Thus a small pressure may be used to produce a larger force in a hydraulic system. What is gained in power, however, is lost in speed. For example, the larger the piston in a remote control cylinder, the slower the action of the piston if the pressure is held constant.

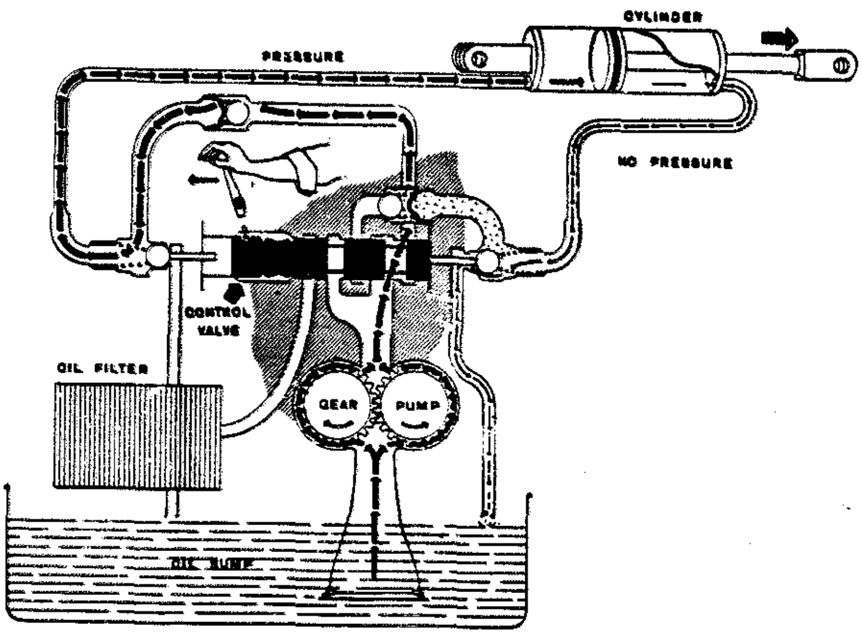
Figures 25.8 through 25.10 illustrate schematically how a hydraulic system on a tractor operates. Figure 25.8 illustrates the action when the control lever is in neutral. There is no flow of oil. Equal pressure is applied to both sides of the piston. The piston, therefore, does not move and the implement being operated is held in its present position.



(Courtesy J. I. Case Co.)

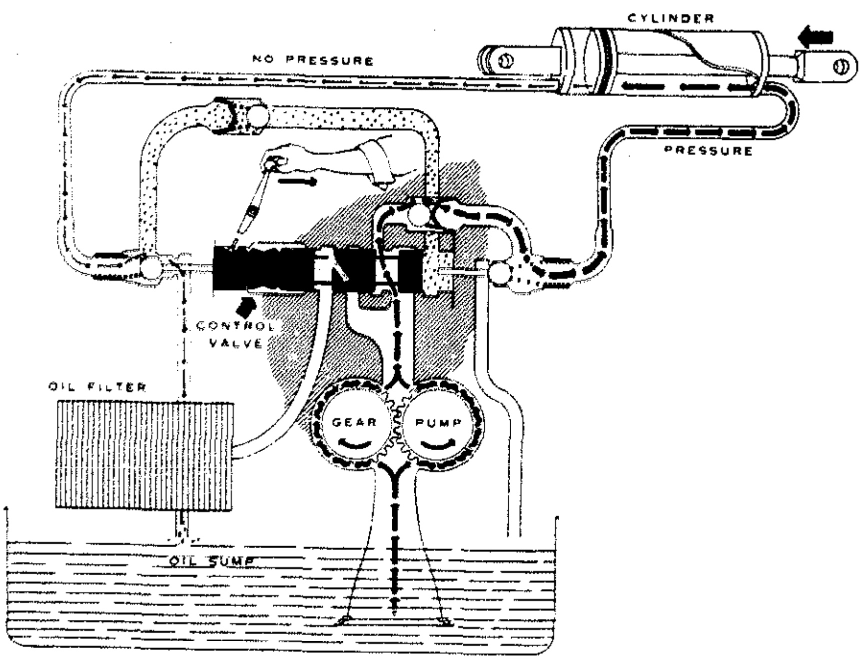
Fig. 25.8. A schematic illustration showing how a hydraulic system operates when the control mechanism is in the neutral position.

Figure 25.9 shows schematically the action of the hydraulic system when the control lever is moved forward. Movement of the control lever forward opens a new passageway for the oil that leads to the piston. Movement of the control lever, as shown in Fig. 25.10, closes the passageway shown in Fig. 25.9 and opens a new passageway for the oil that leads to the opposite end of the piston. Thus, the piston moves under the oil pressure in the opposite direction. The piston therefore can be used to raise or lower an implement.



(Courtesy J. I. Case Co.)

Fig. 25.9. A schematic illustration showing how a hydraulic system works when the control mechanism is moved forward. The cylinder shown is double-action. With a double-action cylinder an implement may be moved in two directions.



(Courtesy J. I. Case Co.)

Fig. 25.10. A schematic illustration showing how a hydraulic system works when the control mechanism is moved to the rear.

Care and Maintenance—A hydraulic control unit consists of a pump, a system of valves, a master cylinder, and hose connections. A high-grade oil is the fluid used most frequently in hydraulic control units.

The oil used in a hydraulic system should be of a type that does not foam. The oil used should also not be highly influenced by temperature changes. In other words, it should not become excessively heavy in cold weather or very thin in hot weather.

In maintaining a hydraulic system, exercise care to prevent the entrance of dirt into the system. A small amount of dirt in a hydraulic system will prevent it from operating properly.

The internal adjustments for a hydraulic system are usually made at the factory, and no further adjustments should be attempted by the tractor operator. The adjustments which may be made by the tractor operator are described in the operator's manual. The hydraulic unit on a tractor, for example, is often equipped with a control valve on the pump which may be adjusted. This valve controls the flow of the hydraulic fluid into the cylinder. The speed of action of the hydraulic unit is thus changed by adjusting this control valve. See your operator's manual for information on the types of adjustments possible for the hydraulic unit on your tractor.

In servicing a hydraulic system, check the oil level. If a hydraulic system fails to operate, check the oil level and check for broken connections. If the pump makes an abnormal amount of noise, check for oil bubbles in the system, for loose connections, or for a broken line. When servicing a tractor, always check for oil leaks in the hydraulic system. In attaching hoses or remote control units, be careful to avoid getting dirt into the hydraulic system.

Diagnosing Difficulties—Two primary types of difficulties may be encountered in the operation of a hydraulic system: failure to raise or lower an implement and overheating.

If the hydraulic system fails to raise or lower an implement, the difficulty may be caused by insufficient oil in the oil reservoir. Check the oil level, and add oil to the reservoir if low. The difficulty may be caused by use of oil other than the type specified for the hydraulic system. If this is the cause, drain the system and refill with the type specified. The difficulty may also be caused by the engine's being run too slowly. Operate the engine at full governor controlled speed, and check whether or not this is the cause of the difficulty.

The failure of the hydraulic system to raise or lower an implement may also result because the load exceeds the capacity of the hydraulic system. Try reducing the load.

If the failure of the hydraulic system is not due to any of these situations, check for faulty operation of the valves, linkages, or pump. See the dealer of the tractor for repairs needed.

Overheating of a hydraulic system may be caused by (1) a low oil level, (2) the use of the wrong type of oil, (3) an excessive load, or (4) the operation of the engine at too low a speed.

STORING TRACTORS

There are on farms, and in some nonfarm agricultural businesses, many gasoline engines that may not be used for considerable periods of time. The life of engines left unused for considerable periods of time is materially reduced if they are not prepared properly for inactive duty and if they are not correctly placed back in service. Manufacturers give complete information on storing engines and starting engines that have been in storage. It takes only a few minutes' time to take care of an engine properly. Sometimes batteries are removed, but if they are not, the engine should be started occasionally and run until the battery is charged. Removed batteries should be stored on a rack or bench (not directly on concrete) in a cool, dry place where the temperature remains above freezing. Check batteries at least once a month for water level and specific gravity, and keep them charged to about 1.250.

Gasoline Engines—The following simple procedure is suggested for a gasoline engine that is to remain unused for a considerable period of time:

1. Clean the engine and accessories, including radiator and air cleaner, of all external grease, dirt, and corrosion. A safe solvent may be used.
2. Run the engine, if it has been operating on leaded gasoline, on unleaded gasoline for at least 10 minutes after running the leaded gasoline out of the lines and the carburetor (see item 4 below).
3. Drain the oil from the crankcase while the engine oil is as hot as it is at the end of a day's run. If the engine is equipped with an oil filter, drain and clean or change the element.
4. Fill the crankcase to the proper oil level with preservative lubricating oil and operate the engine for the unleaded gasoline run (see item 2 above).
5. Start slowly pouring a small stream of flushing oil into the carburetor intake at the completion of the unleaded gasoline run and while the engine is running at a fast idle (about half speed). Gradually increase the amount until approximately 1 pint of oil has been used. If the last part of the oil is poured in rapidly, the engine will stall or stop. Shut off the ignition switch.
6. Remove spark plugs and pour (or spray) preservative lubricating oil into the combustion chambers through each spark plug hole while the engine is being turned by starter or hand crank. Six to 10 tablespoons of oil per cylinder will insure cylinder walls, pistons, rings, valve stems, and other parts against rust.
7. Remove valve tappet cover and spray or coat springs, tappets, and valve stems with preservative lubricating oil while you are turning the engine.
8. Seal all openings such as breather pipe, air cleaner intake opening, and exhaust pipe with moisture-proof tape or plugs.
9. Do not disturb the engine until it is needed for regular duty.
10. If the engine has battery ignition, remove the battery and store it in a cool, dry place above freezing temperature and not directly on concrete.
11. When the engine is needed again, replace the battery, untape the openings, remove the spark plugs, and turn the engine over a few times to blow excess oil from the combustion chamber. Replace spark plugs and start the engine.

The preservative lubricating oil can be used for operating the engine until oil needs to be added; then drain it out and refill with crankcase oil.

Diesel Engines—In preparing diesel engines for storage, check with your dealer or manufacturer.

Some diesel makers recommend the use of preservative lubricating oil in a manner similar to its use in a gasoline engine. The combustion chambers, piston tops, fuel pump, injectors, governor, and so forth are protected against corrosion when this procedure is followed.

Other makers of diesels recommend pouring a small quantity of oil through the injection valve openings every month, then turning the engine a few turns every week to distribute the oil. The engine should be set in the *start* position, or the compression of the oil into the small space might damage the engine.

Starting Gasoline Engines That Have Been in Storage—It often happens that an engine is left idle without being serviced for storage. An engine which has not been stored properly will probably have dry cylinder walls which will be damaged when the engine is started—if it starts. Use the following procedure in starting engines that have been unused for a considerable period of time, but not properly prepared for storage:

1. Remove the spark plugs and pour 2 tablespoons of a mixture of one-half gasoline and one-half light lubricating oil into each cylinder.
2. Remove the valve cover and flush the valve mechanism with the same mixture.
3. Crank the engine rapidly to blow the excess oil out the spark plug holes.
4. Drain the crankcase and flush with flushing oil. Refill with lubricating oil. Service the oil filter and replace the element.
5. Service the rest of the engine for fuel, cooling solution, and grease.
6. Clean the air cleaner, and service as required.
7. Clean the spark plugs, adjust gaps, and install them.
8. Start the engine and let it run slowly. Observe if any valves are sticking; if so, pour a small quantity of kerosene on the valve stems until they become loose. Replace the valve cover.

Gum will form in fuel tanks, lines, and the carburetor when an engine is not used. It can be dissolved with acetone or a 50-50 mixture of alcohol and benzol.

TRANSMISSION OF POWER

Student Abilities to Be Developed

1. Ability to appreciate the importance of the proper care and use of belts in agriculture.
2. Ability to use and maintain belts to obtain the maximum service from them.
3. Ability to align shafts properly.
4. Ability to select the proper types and sizes of pulleys.
5. Ability to use and maintain chains and sprockets properly.
6. Ability to use and maintain gears, and understand how they work.
7. Ability to use and maintain clutches.

CHAPTER 26

Transmitting Power by Belts, Chains, Gears, and Clutches

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. To what extent are belts used on farms and in nonfarm agricultural businesses?
2. Why is a knowledge of belts of value to an agricultural worker?
3. What points should be taken into consideration in selecting a belt for agricultural use?
4. What types of belts are frequently used?
5. What care and maintenance should be given to chains and sprockets?
6. What types of gears are used on agricultural machinery?
7. Why are gears used on agricultural machinery?
8. Why are clutches used?
9. How should gears be maintained? Clutches?

Power may be transmitted in various ways such as by shafts, pistons, clutches, gears, chains, and belts. An attempt will not be made in this chapter to discuss all means of power transmission. Some of the fundamentals, however, regarding the transmission of power by belts, chains, gears, and clutches will be covered.

Belts

Use of Belts—Belts are used to transmit power or motion from one pulley to another or, in other words, to connect two machines, thus causing them to work together. Directly connected shafts and gear wheels are often used to accomplish the same results. Belt-driven machines and mechanisms of one kind or another are found where electric motors or gasoline engines are available to furnish the motive power.

The principal problems involved in the use of belts are (1) determining the proper sizes of pulleys necessary to drive machinery or mechanisms at their recommended speeds and (2) connecting these pulleys properly by means of shafts and belts. Like many other jobs in agriculture involving mechanics, the installation of a power plant is not extremely difficult, but it requires considerable knowledge of the principles involved and careful attention to the details of construction.

Sizes and Speeds of Pulleys—The speed at which a shaft revolves and the speed at which a machine is driven by belts are regulated by the size of the pulleys used. It is obvious that two pulleys of the same size which are connected by a belt will revolve at the same speed if there is no slippage. If one of the pulleys is only one-half the diameter of the other, it will make two revolutions while the larger pulley turns but once. That is, it will run at twice the speed of the larger pulley. If the larger pulley, an 8-inch pulley, makes 200 R.P.M. (revolutions per minute), the smaller pulley, a 4-inch pulley, will run at 400 R.P.M.

The diameter of one pulley multiplied by its speed is equal to the diameter of the other pulley multiplied by its speed.

From this fact it is easy to calculate the sizes of pulleys needed to obtain the speed at which various machines should be driven.

1. Suppose the driver pulley is 4 inches in diameter and runs at 200 R.P.M. The driven pulley is 8 inches in diameter. What will be its speed?

   $4 \times 200 = 8 \times$ (? R.P.M.)

   RULE: Multiply the diameter of the driver pulley by its R.P.M. Divide by the diameter of the driven pulley to find the R.P.M. of the driven pulley.

   $\frac{4 \times 200}{8} = 100$, the R.P.M. of the driven pulley.

2. Suppose the driver pulley on a shaft is 4 inches in diameter and runs at 250 R.P.M. The driven pulley on a machine must be operated at 100 R.P.M. What size of driven pulley will be required?

   $4 \times 250 =$ (? Dia.) $\times 100$.

   RULE: Multiply the diameter of the driver pulley by its R.P.M. Divide by the R.P.M. of the driven pulley to find the diameter of the driven pulley.

   $\frac{4 \times 250}{100} = 10$, the diameter (in inches) of the driven pulley.

3. Suppose a machine with a 10-inch pulley must be driven at 75 R.P.M. The line shaft has a speed of 150 R.P.M. What size pulley must be used on the shaft?

   (? Dia.) $\times 150 = 10 \times 75$.

   RULE: Multiply the diameter of the driven pulley by its R.P.M. Divide by the R.P.M. of the driver pulley to find the diameter of the driver pulley.

   $\frac{10 \times 75}{150} = 5$, the diameter (in inches) of the driver pulley.

Alignment of Shafts and Pulleys—All pulleys on engines, shafts, and driven machines must be in line. Excessive slippage, wear, and vibration may result if they are not in line. The shafts of all connected pulleys must be parallel, so that the belts will run at a 90-degree angle to them.

Selecting Belts for Use in Agriculture—Belts are of several types, and of many grades and qualities, which makes the problem of selecting the most satisfactory and most economical belt for a given purpose very difficult. Belts purchased from a reliable dealer are generally dependable and bear the manufacturer's guarantee. When given complete information about the job to be done, the dealer or manufacturer can be of great service in selecting the most suitable belt. When a belt is to be selected, information on the following points is needed:[1]

1. Horsepower to be transmitted—
   (a) average (b) least (c) most
2. Diameter of driving pulley
3. Diameter of driven pulley
4. Number of revolutions per minute made by one of them. State which one.
5. Distance between pulley centers
6. Position of drive, vertical or horizontal
7. Location of tight side of belt, top or underneath
8. Conditions of operation such as dampness, fumes, flying grit, changes from light to heavy loads, high speed over small pulleys, quarter twist of belt, and use of idlers, mule pulleys, and stepped or flanged pulleys

V-Belts

V-belt drives for equipment are efficient, flexible, dependable, easy to install, and compact. They are used for electric motor drives; for tractor power drives of feed grinders, silo fillers, wood saws, irrigation pumps, and other belt-driven machines; and for power transmission drives on many farm machines such as mowers, combines, choppers, and blowers. The V-belt is often used as a clutch on garden tractors and on self-propelled machines such as combines and corn pickers.

The V-belt drive is becoming so common that it is possible to obtain the belts and sheaves in most implement and supply stores. Manufacturers of V-belts are in a position to recommend the type of pulley sheave and the belt cross section best adapted for a certain purpose, and they should be consulted regarding their recommendations before sheaves and V-belts are purchased.

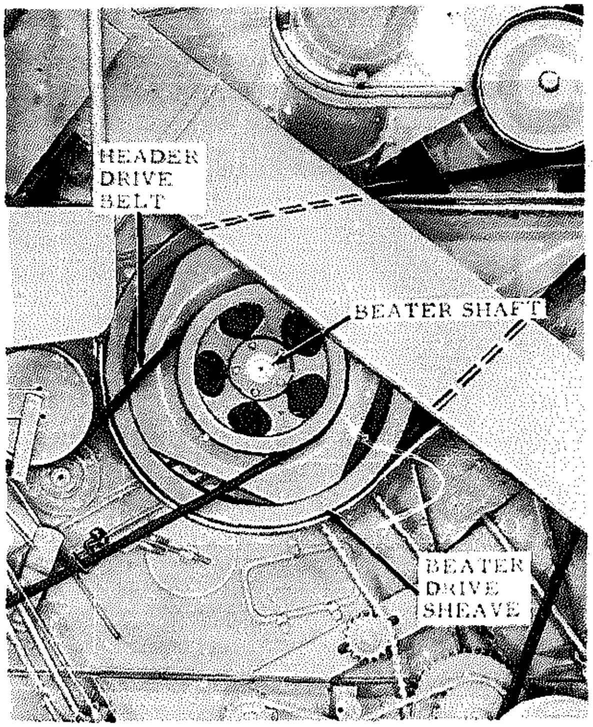
Types of V-Belt Drives—There are five standard sizes of agricultural V-belts which are specified by their cross section measurements. The width of the belt is the width of the outer section, and the thickness is the depth of the section. The five standard sizes are termed HA, HB, HC, HD, and HE. In addition, there are V-belts designed for light loads, and these are commonly designated as sizes No. 1, No. 2, and No. 3.

There are four standard sizes of agricultural double V-belts, HAA, HBB, HCC, and HDD.

Agricultural adjustable-speed belts are available in four standard sizes designated as HJ, HK, HL, and HM. The cross sections of these belts are measured in the same way as the cross sections of standard V-belts.

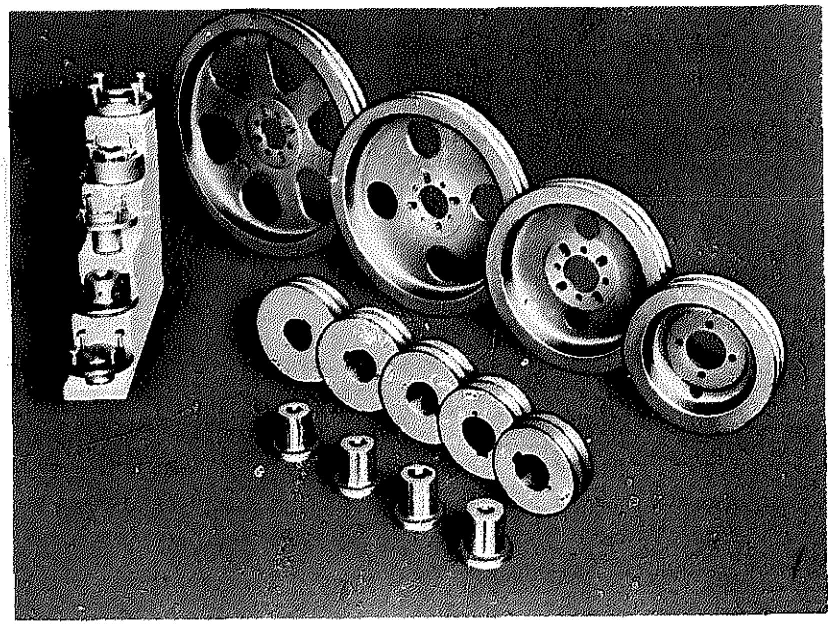
In a V-V drive both pulleys are grooved. This is the type of V-belt drive used most frequently on agricultural machinery.

[1]"Short Cuts to Power Transmission," Flexible Steel Lacing Co.



(Courtesy J. I. Case Co.)

Fig. 26.1. Belts and sheaves used for power transmission on a combine.



(Courtesy Gates Rubber Company, Denver)

Fig. 26.2. V-belt sheaves, adapters, and flanges used to equip tractors and machines with V-belt drives.

Selecting V-Belt Drives—Before selecting a V-belt for a drive, it is necessary to determine the following:

1. The speed (R.P.M.) and horsepower rating of the electric motor, gasoline engine, or tractor used as the source of power.
2. The speed the driven machine should run.
3. The center distance between the driver and the driven sheave pulleys.

There are minimum pulley diameters which may be used successfully with V-belts of certain cross sections. The power transmitted by a V-belt decreases as the arc of contact of the belt with the pulley decreases below 180 degrees.

The maximum power transmitted by belts of different cross sections depends upon the velocity of the belt and upon its arc of contact with the sheaves. Table 26.1 lists the approximate maximum horsepower transmitted by V-belts of various cross section sizes at the speeds indicated, assuming a 180-degree arc of contact.

Table 26.1—Approximate Maximum Horsepower Transmitted by V-Belts of Various Cross Sections[1]

V-Belt Cross Section Size (Inches)	R.P.M. of Faster Shaft	Diameter of Small Sheave (Inches)	Maximum Horsepower Transmitted by V-Belt
$^{1}/_{2} \times {}^{5}/_{16}$	3,600	5	3.4
$^{21}/_{32} \times {}^{13}/_{32}$	2,600	7	5.5
$^{7}/_{8} \times {}^{17}/_{32}$	1,600	13	13.4
$1\,^{1}/_{4} \times {}^{3}/_{4}$	1,000	18	24.1
$1\,^{1}/_{2} \times {}^{29}/_{32}$	760	28	41.5

[1]Based on data from Gates Rubber Company, Denver.

Designing a V-Belt Drive—In designing a V-belt drive, you will find the following steps to be helpful:

1. Determine the speed ratio of the power unit to the driven machine by dividing the R.P.M. of the faster unit by the R.P.M. of the slower unit. For example, if a 1,750 R.P.M. electric motor is to drive a shop tool at 1,000 R.P.M., then 1,750 ÷ 1,000 = 1.75, which is the speed ratio. The first "Speed Ratio" column in Table 26.3 applies in this case.
2. Find the corrected horsepower by multiplying the rated horsepower of the motor by a factor selected from Table 26.3. To use the table, locate a machine similar to yours, then read across to the column which applies to your speed ratio. For example, if a motor having a factor of 1.6 is rated at $^{1}/_{2}$ H.P., then 1.6 × 0.5 = 0.8, the corrected horsepower.
3. Find the V-belt cross section in Table 26.2, using a horsepower value that is equal to or slightly larger than the corrected horsepower obtained in the computation suggested in step 2. In the example cited, the 1,750 R.P.M. motor has the smaller pulley. The horsepower rating of 0.09 is found in the column headed by the $^{1}/_{2}$" × $^{5}/_{16}$" size of V-belt.

Care of V-Belts—V-belts are very serviceable, but this fact should not lead to abuse in their use and care. Pulleys that are too small cause belts to flex too much,

Table 26.2—Horsepower Transmission Ratings for Single V-Belt Strands with a 180-Degree Arc of Contact on Recommended Sheave Diameters[1]

R.P.M. OF SMALL SHEAVES	Size of V-Belt, Inches							
	13/32 × 7/32	17/32 × 9/32	11/16 × 11/32	1/2 × 5/16	21/32 × 13/32	7/8 × 17/32	1 1/4 × 3/4	1 1/2 × 29/32
	Minimum Recommended Sheave Pitch Diameter, Inches							
	1 1/2	2 1/2	4 to 4 1/2	3	5	9	13	20
	Horsepower Rating per Single Strand V-Belt							
200	0.02	0.08	0.25	0.1	0.3	1.4	3.5	8.4
400	0.04	0.15	0.45	0.2	0.7	2.7	6.8	15.8
600	0.05	0.20	0.60	0.3	1.0	4.0	9.9	21.5
800	0.06	0.30	0.80	0.4	1.3	5.2	12.4	24.6
1,000	0.08	0.30	0.90	0.5	1.6	6.3	14.4	24.8
1,200	0.09	0.37	1.00	0.6	1.9	7.3	15.6	
1,400	0.09	0.40	1.20	0.7	2.2	8.1	15.8	
1,600	0.10	0.45	1.50	0.8	2.4	8.7		
1,750	0.11	0.48	1.60	0.9	2.6	9.1		
2,000	0.12	0.50	1.70	1.0	2.9	9.4		
2,200	0.12	0.55	1.75	1.1	3.1			
2,400	0.13	0.57	1.80	1.2	3.2			
2,800	0.13	0.60	1.90	1.4	3.4			
3,000	0.14	0.63	2.20	1.4	3.5			
3,200	0.14	0.65	2.20	1.5				
3,600	0.14	0.67	2.25	1.6				

[1]Based on data from Gates Rubber Company, Denver.

Table 26.3—Factors for Corrected Horsepower[1]

Driven Machines	Speed Ratio Less than 2.50	Speed Ratio 2.50 to 6.50	Speed Ratio Over 6.50
Centrifugal pumps	1.3	1.4	1.6
Fans and blowers	1.1	1.2	1.3
Generators	1.3	1.4	1.6
Heating and ventilating fans	1.3	1.4	1.6
Refrigerators	1.6	1.8	2.0
Home workshop machinery	1.4	1.6	1.7
Small machine and woodworking tools	1.6	1.8	2.0

[1]Based on data from Gates Rubber Company, Denver.

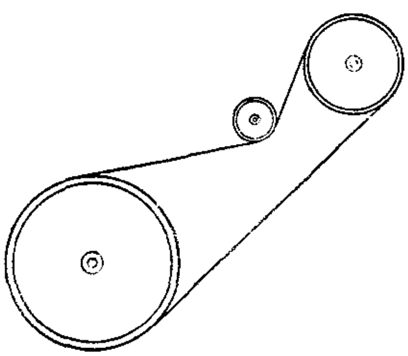
which will eventually crack them. Dust does not harm most V-belts, and they can operate in moist conditions without being harmed.

Rubbing against sharp surfaces or objects may cause considerable damage to a V-belt, however. A V-belt should not be removed from its sheaves without releasing its tension, because the edges of the flanges may damage the belt.

When V-belts are not in use, they should not be left exposed to the sun for extended periods of time, but should be removed and hung in a cool, dark place. They may also be shielded from the elements without being removed from machines.

Belt dressing should not be used on V-belts to prevent them from slipping. Clean V-belts with a cloth. Oil and grease should not be allowed to come in contact with the belts and the sheaves.

In adjusting the tension of V-belts, permit a little slack or bow to be present in the slack side of the belt. Pulsating loads require a tighter belt than smooth-running loads. Also, the belts for short drives will have to be tighter than the belts for long drives. Small electric motors are often hinged at the end toward the driven machine, letting the weight of the motor furnish the correct tension for the belt.



(Courtesy Flexible Steel Lacing Co)

Fig. 26.3. The use of an idler pulley.

CHAINS AND SPROCKET WHEELS

Chains and sprockets are used to transmit power on many machines used in agriculture. They provide a positive method of power transmission. Unlike belts, there is no possible slippage. Most chains can be installed or removed easily, and most will withstand or absorb slight shocks.

Types of Chains—Three types of chains are frequently used:

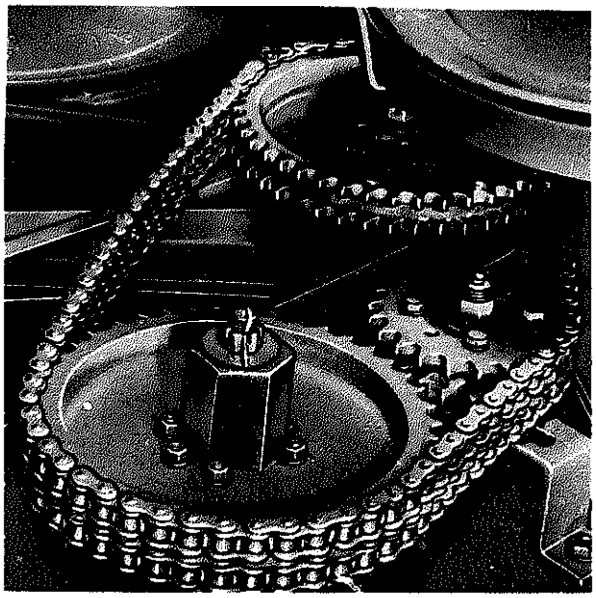
1. Roller chain
2. Pintle chain
3. Hook-link or detachable link chain

The most economical type of chain to purchase is the hook-link chain. It may be used to transmit power if the sprocket wheels operate at a relatively low speed and if little strain is put on the chain. The hook-link chain is not nearly as strong as a roller chain or a pintle chain.

Links may be removed from a hook-link chain by kinking the chain. Each link has a slot on the hook end. When the chain is kinked sharply, the bar end of the link may be driven out of the slot on the hook end of the adjoining link.

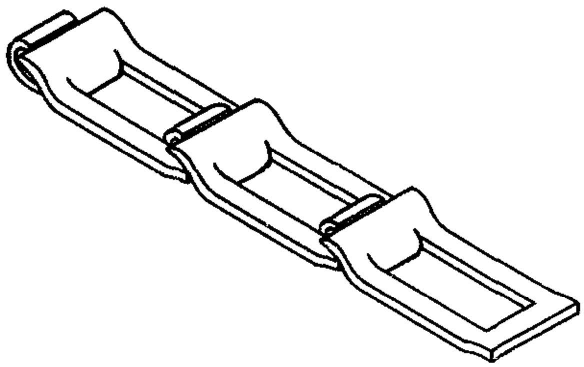
A hook-link chain should be run with the hook end forward and with the slot to the outside if the drive sprocket is large and the driven sprocket small. Running the chain this way will help prevent wear on the chain and on the sprockets. If the drive sprocket is small and the driven sprocket is large, the hook-link chain should be run with the bar end forward.

Roller chains are strong and are used for heavy-duty work. The links of a



(Courtesy International Harvester Co.)

Fig. 26.4. Roller chains used on a combine.



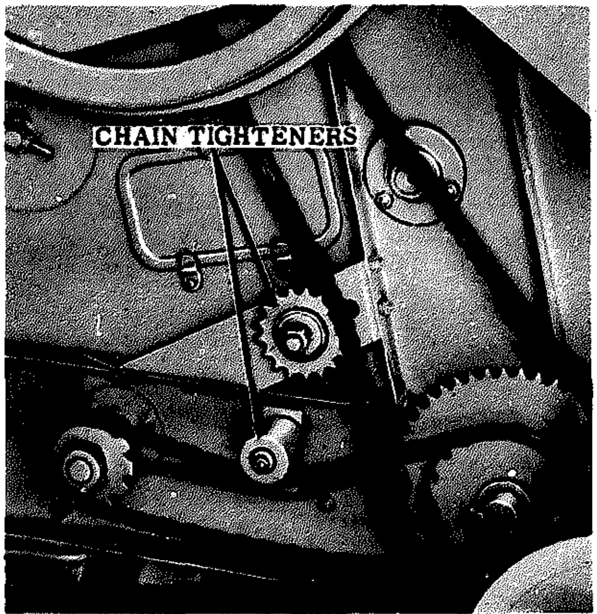
(Drawn by Ronald Ipsen)

Fig. 26.5. A hook-link or detachable link chain.

roller chain have parallel sides. These parallel sides are connected by a pin, and around the pin is a roller. (See Fig. 26.4.)

A pintle chain looks similar to a roller chain, but the sides of the links are not parallel. Pintle chains are used for heavy-duty work and slow speeds.

Care of Chains—The tension of chains should be checked periodically. Chains are provided with idler sprockets or tightener rollers as shown in Fig. 26.6. Chains should be tightened so that they will remain on the sprockets. If chains are too tight, an excessive load is placed on the shafts. See the owner's manual for the machine for specific instructions for tightening the chains on the machine being operated.

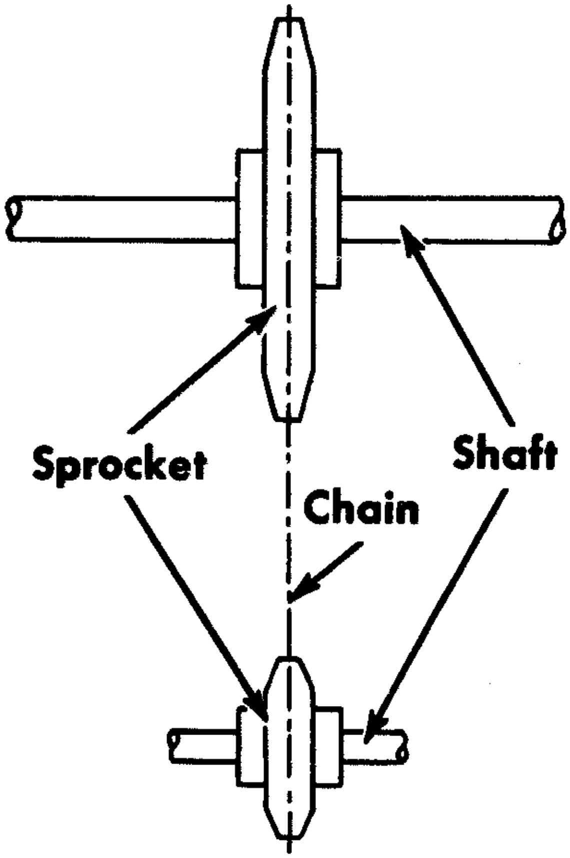


(Courtesy J. I. Case Co.)

Fig. 26.6. Two types of chain tighteners in use on a combine.

Chains should be cleaned periodically and lubricated frequently. When chains are being operated where the soil is sandy or gritty, it may be advisable not to lubricate to prevent the oil and sand from becoming mixed and forming an abrasive compound.

The drive sprocket and the driven sprocket must be kept in alignment, as shown in Fig. 26.7. The drive sprocket and the driven sprocket may be aligned by moving them on their shafts. Idler sprockets may usually be aligned by removing or adding washers behind their hubs.



(Courtesy International Harvester Co.)

Fig. 26.7. The correct chain and sprocket alignment.

Sprockets should be checked for wear. A worn or damaged sprocket will wear out a chain much faster than normal.

In storing machines with chains, remove the chains and soak them in a safe solvent. Scrub chains with a stiff brush, if necessary. Then dry the chains and replace them on the machines. The final step is to lubricate the chains. Use a grease or heavy oil if the machine is to be stored for a considerable period of time. Use a light oil if the machine is to be stored for only a short period of time.

GEARS

Gears of various types are frequently used to transmit power on agricultural machinery. Gears provide positive transmission of power without slippage. In addition to being used as a means of power transmission, gears are also used to reduce or to increase the speed of various parts of machines.

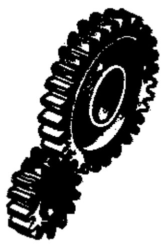
Types of Gears—A gear is a wheel with projections called teeth. A gear is fastened to a shaft. Either the shaft drives the gear or the gear drives the shaft.

Gears are classified as follows:

1. Spur gears
2. Helical gears
3. Herringbone gears
4. Spur bevel gears
5. Spiral bevel gears
6. Worm thread gears

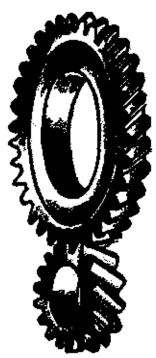
The spur gear is a simple type of gear. Its teeth are straight across and parallel to the shaft to which the gear is attached. Spur gears are used frequently on agricultural machinery.

A helical gear is similar to a spur gear, except the teeth are cut at an angle.



(Courtesy General Motors Corp.)

Fig. 26.8. Spur gears.



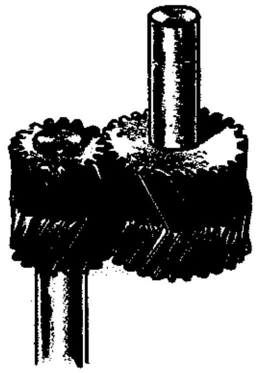
(Courtesy General Motors Corp.)

Fig. 26.9. Helical gears.

The teeth of the gear that meshes with a helical gear must also be cut at the same angle. A helical gear operates more quietly than a spur gear.

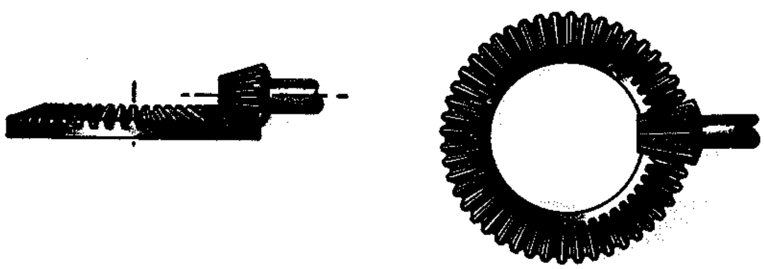
A herringbone gear may be thought of as two helical gears fastened together with the angle of teeth on each gear being cut in the opposite direction.

Spur bevel gears are used when the power transmission must turn a corner. The teeth on a spur bevel gear are cut on the corner or edge of the gear wheel, as shown in Fig. 26.11.



(Courtesy General Motors Corp.)

Fig. 26.10. Herringbone gears.



(Courtesy General Motors Corp.)

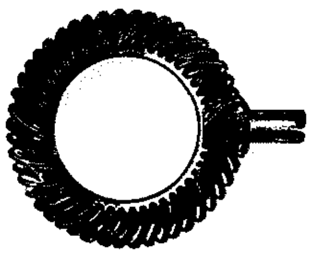
Fig. 26.11. Spur bevel gears.

Spiral bevel gears are similar to spur bevel gears, but the teeth are curved as well as beveled, and cut on the edge of the gear wheel.

A worm thread gear is shown in Fig. 26.13. It is used when there is a large difference in the speed of the drive and driven parts of the machine.

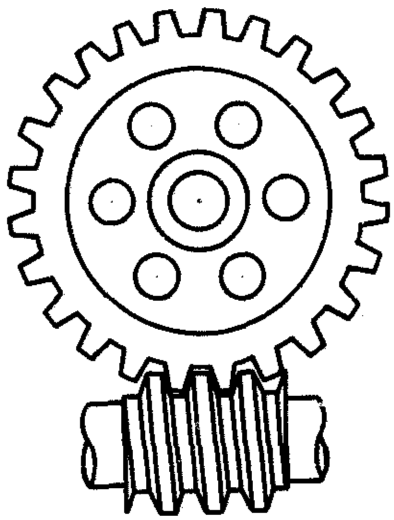
Gears are used to decrease speed and increase power, or to increase speed and decrease power. For example, if an engine powers a shaft on which a small gear is fastened, the power of the engine to drive another shaft will be increased if the small gear meshes with a larger gear. Thus it may be possible for an engine to drive another shaft which it could not drive if connected directly.

If a drive gear has 10 teeth and the driven gear has 40 teeth, the ratio is 4 to 1. The drive gear will make 4 revolutions to each revolution of the driven gear, and the torque or twisting power will be multiplied by 4.



(Courtesy General Motors Corp.)

Fig. 26.12. Spiral bevel gears.



(Drawn by Ronald Ipsen)

Fig. 26.13. Worm thread and worm wheel gears.

If the engine has ample power, and greater operating speed is desired for a machine, the size of the drive gear is increased and the size of the driven gear is decreased.

Care of Gears—Gears need to receive proper lubrication. Often gears operate in oil. See the owner's instructional manual for the weight and type of oil to use. If gears operate in the open, they must be lubricated frequently.

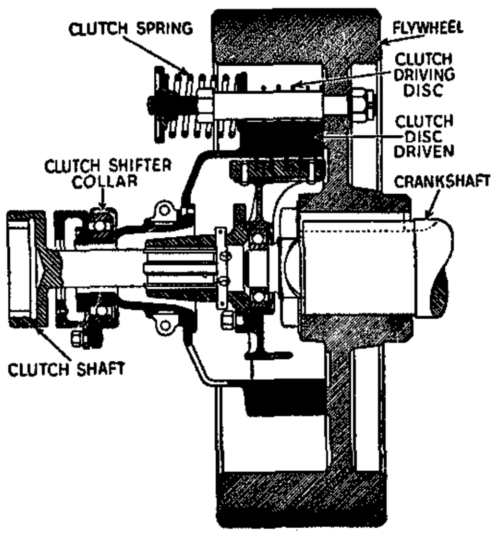
CLUTCHES

A clutch is a means of power transmission found on tractors and other machines used in agriculture. A clutch is often used to connect or disconnect gradually a machine from its source of power. For example, on a tractor the clutch is used to disconnect gradually the engine from the mechanism that drives the rear wheels.

Types—The primary types of clutches may be classified as (1) positive action and (2) friction. Friction clutches are used on tractors. A friction clutch consists of a driving plate and a driven plate. The plates are held together by spring tension or by an over-center mechanism. With a spring tension clutch, a foot pedal is used to disengage the clutch or release the spring tension so that the driven plate and the driving plate are allowed to separate. The driving plate of the clutch on a tractor is attached to the flywheel of the engine.

Positive clutches are used on machines that do not usually have their own source of power, such as planters, grain drills, and other machines operated at slow speeds. A positive clutch consists of two parts that have jaws that lock together.

Some machines have *safety clutches* that permit slippage or disengagement when the machines become overloaded or strike an obstruction. These clutches disengage under severe load and prevent damage or breakage of machine parts. A safety clutch consists of two plates with notches. These notches are held together by spring tension. Safety clutches do not slip under normal loads.



(Courtesy American Oil Co.)

Fig. 26.14. A cross section drawing of a multiple disk-type friction clutch for a tractor.

Care of Clutches—A clutch needs lubrication, but where the lubrication is to be applied and how much are important considerations. Care must be exercised not to overlubricate the clutch on a tractor. The plates of safety clutches should not be lubricated. The operator's manual should be consulted regarding the care of the clutches on a machine.

After each 250 hours of use of a tractor, the "free movement" between the clutch-release levers and the release bearing should be checked. The "free travel" or "free movement" is reduced by the wear on the clutch facing. Lack of adequate "free movement" or clearance produces loss of power and overheating. If the condition is not corrected, it will necessitate the early replacement of the clutch facing. See the operator's manual for instructions on the procedure for checking "free movement" between the release levers and the release bearing.

FIELD MACHINERY

Student Abilities to Be Developed

1. Ability to appreciate the importance of field machinery.
2. Ability to select suitable field machinery.
3. Ability to maintain field machinery.
4. Ability to adjust field machinery.
5. Ability to select suitable tools and equipment for adjusting and repairing field machinery.
6. Ability to perform field machinery repair jobs.

CHAPTER 27

Selecting Field Machinery

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What equipment is included in the term "farm machinery"?
2. How does modern farm machinery compare with the farm machinery of the past?
3. What factors should be considered in selecting machinery?

Equipment Included in Farm Machinery—A machine is a device that gives a mechanical advantage, facilitating the doing of work; thus the term "farm machinery" includes the mechanical equipment of field and farmstead, from water pumps to tractors. In general, "farm machinery" includes the main items of field machinery. As used in this section it refers to seeding, tillage, and harvesting equipment such as plows, harrows, drills, cultivators, and harvesters.

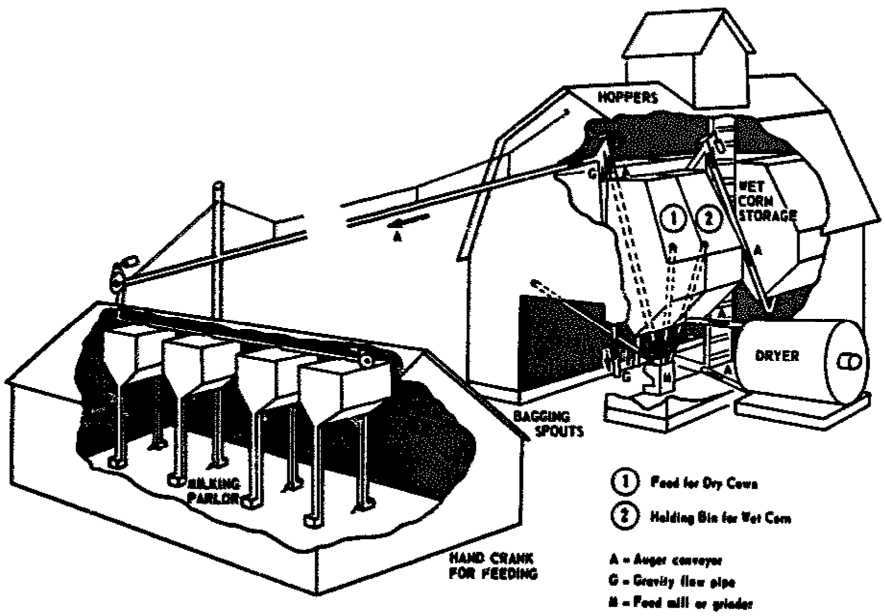
History of Agricultural Machinery—Agriculture, defined broadly and not limited to farming, involves the use of more machinery and power than any other enterprise. In recent years extensive use has been made of machinery to replace human labor. It was not until 1850 that the use of machinery in agriculture was of much consequence. Many machines were invented before this date, but their introduction was slow until their worth was proven.

About 1870 the adoption of agricultural machinery became more rapid. This was due mainly to the fact that machines were perfected so that they would work satisfactorily. In addition, mechanical power became available at this time, which widened the scope of usefulness of farm machinery. Also, the movement onto "western" farms increased the farming area.

In more recent years, farm machines have been improved in quality and usefulness, and their adoption by farmers has been rapid. The modern farmer seeks ways and means of lightening burdens and desires machines to lessen labor requirements.

Early and Present-Day Machinery—Some of the early types of machines were crude devices. Many of them have been improved, and so their appearance is entirely different at the present time. This is particularly true of tractors.

The general appearance of many machines, such as plows, for example, has



(Courtesy U.S.D.A.)

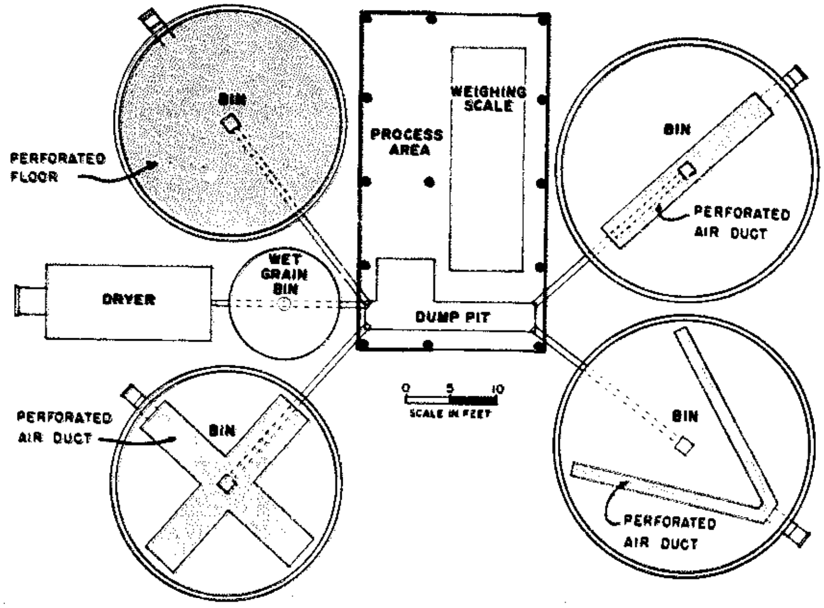
Fig. 27.1. Farm machinery includes feed-handling and automatic corn-drying equipment, as well as field machinery.

not changed much in the past 20 or 30 years except for size. However, the appearance or the quality of individual parts or mechanisms on these machines may have been changed considerably. For example, a modern plow beam may appear to have the same bends in it as the plow beam of an earlier implement, but the iron or steel used may be entirely different. Farm machinery, like all other commodities, has been improved in usefulness and quality.

Quality of Field Machinery—Designers of field machinery have tried to design machinery adaptable to a wide variety of situations, and the success of their efforts has resulted in a greater use of field machinery. The quality has also been improved as indicated by its having:

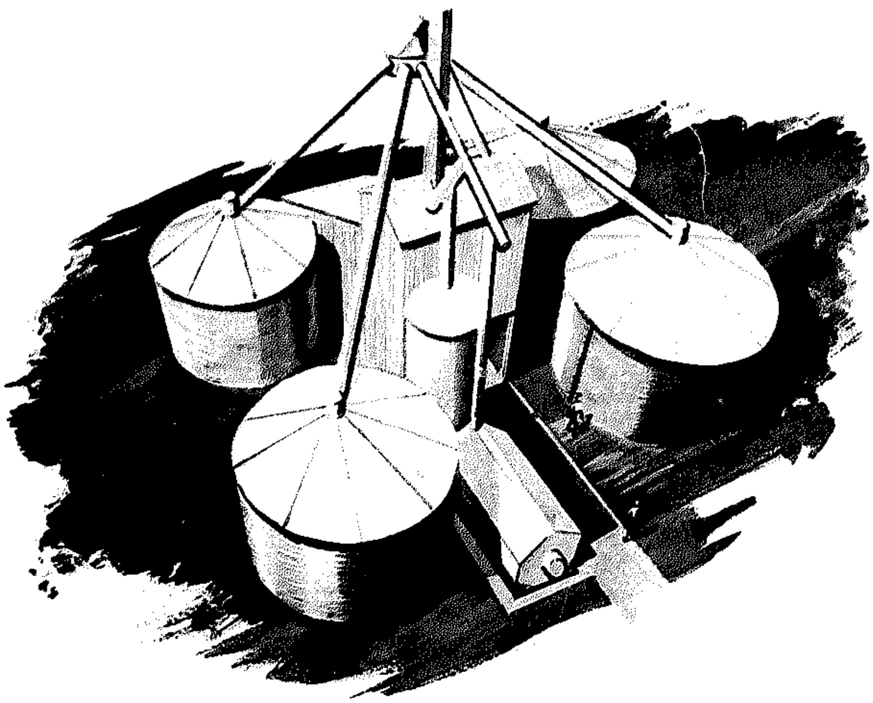
1. More durability measured in greater units of service.
2. Greater wear resistance resulting in reduced replacement, adjustment, and conditioning of parts.
3. More freedom from clogging, heating, breakage, and servicing.
4. Greater efficiency in power requirements and in the performance of duty; a greater degree of effectiveness and a larger capacity for each machine.
5. Greater safety, and more comfort and ease in operation.

Life of Farm Machinery—There is great variation in the service life of farm machinery. In determining the life of farm machinery, the owner must consider each situation. One owner may use a machine for 20 years, while a neighbor may use the same type of machine for only 3 years. The days used per year and the acres covered are often thought to directly influence machinery life, but studies



(Courtesy U.S.D.A.)

Fig. 27.2. A labeled drawing of a grain-feed handling system.



(Courtesy U.S.D.A.)

Fig. 27.3. A grain-feed handling system.

have shown that these are not always the most important factors. The care, repair, and adjustment of machinery, discussed in later chapters, contribute the most to long machinery life. In recent years, changing farming practices have caused certain machines to become obsolete before they are worn out. Obsolescence thus becomes an increasingly important factor in the life of farm machinery.

The following facts relate to the cost of service of farm machinery:

1. The average life of farm machines varies a great deal, depending on the type of machine.

Fig. 27.4. A combine.

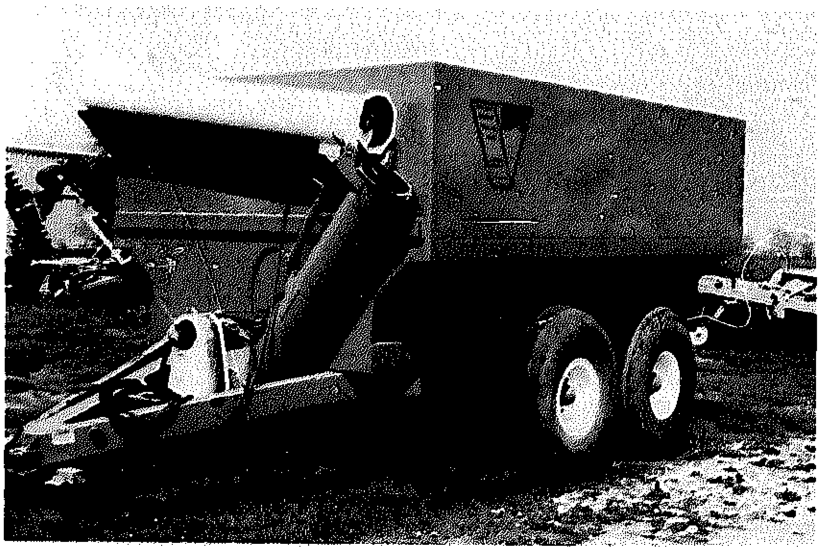


Fig. 27.5. A wagon.

2. The life of individual machines varies much from the average.
3. The average annual service of farm machines in days of use per year is surprisingly low.
4. The life of farm machines is not greatly influenced by the annual days of use.

Selecting Field Machinery—In the production of crops, labor, power, and machinery account approximately for two-thirds of the cost of production. It is, therefore, important that proper thought be given to the selection, operation, care, and repair of all machinery used in production.

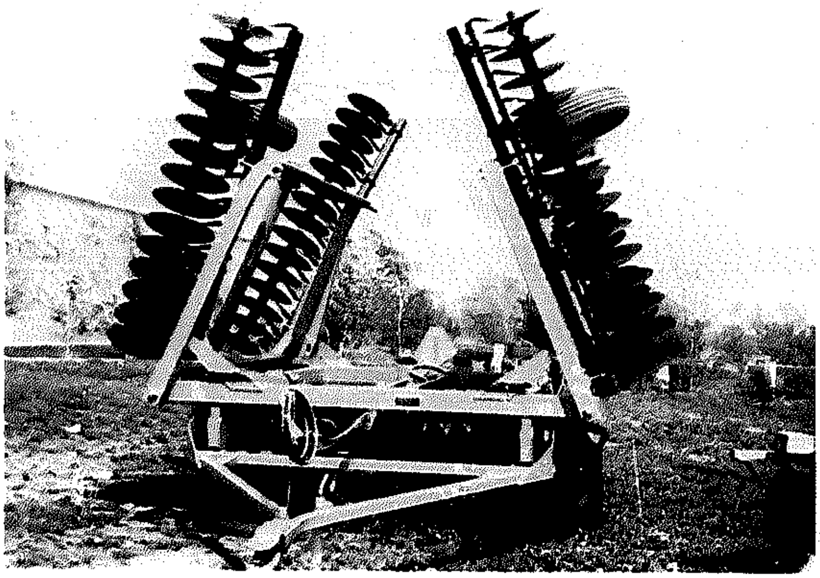


Fig. 27.6. A disk prepared for transport to another location.

Fig. 27.7. A tractor and corn planter.

In selecting field machinery, consider the following:

1. The availability of repairs is important because delays due to waiting for repairs are undesirable.
2. The general design of a machine is important. A machine should be simple, durable, and capable of performing its duty in optimum fashion. The work quality and the finish of a machine should be good.
3. The adaptability to the work must be considered in order to obtain machinery that will function in a certain locality.
4. Ease of operation is desirable. However, a machine which is easy to operate may not always do the best work.
5. Reliability of the manufacturer and the dealer in standing behind their product is a desirable feature and should be considered.
6. The cost of the machine should be considered, not so much from a comparative make standpoint as from a use standpoint. Standard machines of quality are usually very close in comparative price. The cost of a machine compared to what it will do is the important item to consider.

CHAPTER 28

Using and Maintaining Field Machinery

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Why is a study of field machinery important?
2. How should machinery be lubricated?
3. How should field machinery be operated?
4. At what time of year should repair work be done?
5. When should a new machine be purchased?
6. What tools and equipment are necessary for machinery repair?
7. How may machines be disassembled and inspected?
8. What system should be followed in repairing and replacing broken parts?
9. How should machinery be assembled and adjusted?
10. What precautions should be observed in painting machinery?
11. How should machinery be stored?

Importance of Care and Maintenance of Machinery—The expression, "Good equipment makes a good agricultural worker better," applies to used machinery as well as to new machinery. Good equipment does not stay good unless it is given proper care. Adequate and timely adjustment, repair, lubrication, and protection from the weather determine the life of a machine. Approximately 75 per cent of the breakdowns of machinery in the field are caused by neglecting these four items of proper care. Such breakdowns are costly in loss of time and loss of crop. The cost of production on farms is increased by improper machinery management. Practically all farm operations require the use of machinery, and it should be kept in shape for accomplishing the maximum for the time it is used.

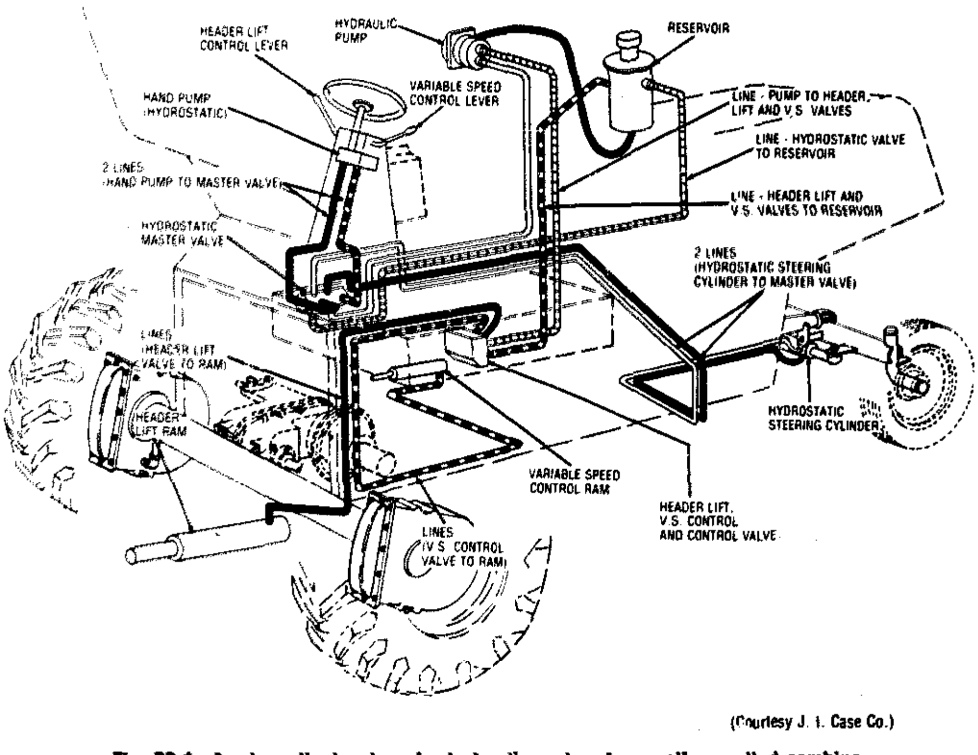
Preventive Maintenance should be given first consideration in the use of field machinery in order to reduce to a minimum the chances for breakage, costly repair bills, and loss of time. A farmer should keep machinery repaired, properly adjusted, and lubricated with the proper lubricants. All moving parts should be kept working freely, thus reducing the chances for wear or breakage.

Machinery Lubrication—It is important to select the proper lubricant for the different parts of machines. Consideration must be given the function each part has to perform.

Lubrication must be effective. Oil poured "at" a part does little good. Lubricants must contact the moving parts of machines.

1. Secure a lubrication chart, if possible, for the machine to be lubricated and follow its directions. A general rule is that all moving parts that move in contact with other parts require lubrication at the point of contact. A lubricant should not be placed on parts where it will collect dirt or grit, or the parts will wear faster than they will without lubrication.
2. Inspect the cylinder oil and transmission grease, and fill or change according to the directions of the manufacturer of the machine.
3. Use the proper equipment to lubricate the machines. If the machines have special fittings, lubrication equipment for these special fittings must be used.
4. Inspect but do not molest or destroy the seal of parts of machines operating in a "sealed for life" lubrication system.
5. Consult the operator's manual for lubrication instructions for the machine and for the location of the parts to be lubricated. Check whether or not the machine has a bank or central lubrication system.

The Operation of Field Machinery—The proper use of field machinery decreases operating costs. Operators of machinery should develop an attitude of preservation in their use of machinery, and not an attitude of seeing how much the machines can stand before breaking down. Often when machinery is misused,



(Courtesy J. I. Case Co.)

Fig. 28.1. A schematic drawing of a hydraulic system for a self-propelled combine.

breakage does not occur at the time, but serious strains are developed which directly cause breakdowns later. A tractor is often overloaded with no immediate notice of injury. When later it breaks, the operator instead of the tractor should be blamed.

Practically all machines will work smoothly when operated properly. For good performance it is necessary to see that machines are correctly adjusted for the work, that they are properly lubricated, and that they are in good mechanical condition.

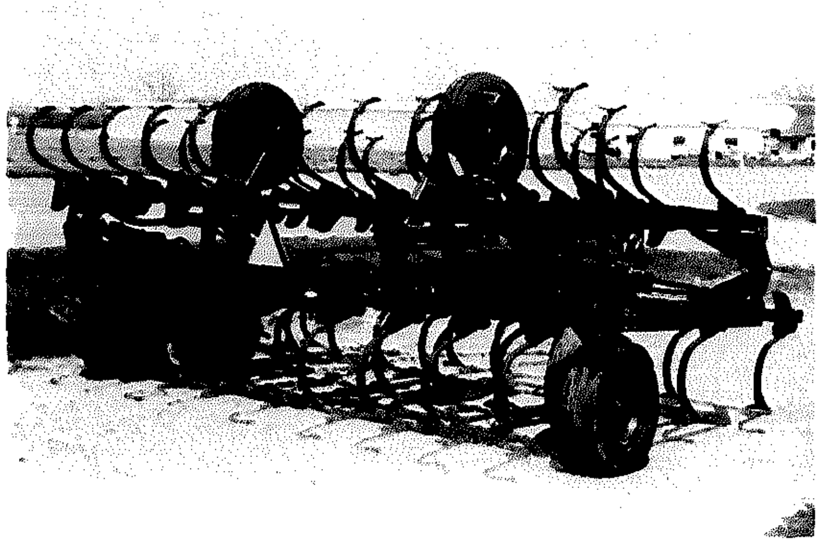
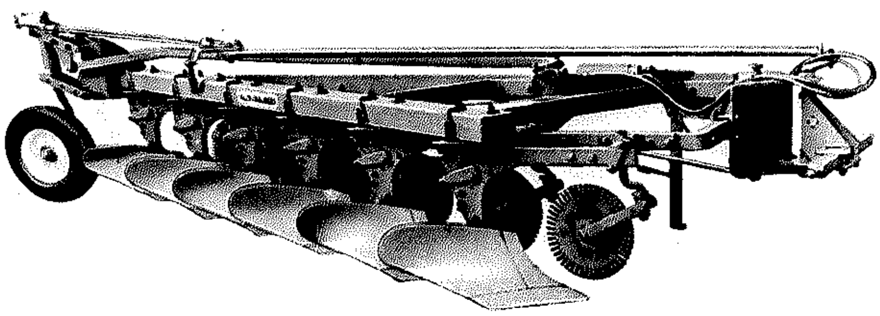


Fig. 28.2. A field cultivator prepared for transport to another location.

When Repairing Should Be Done—Most field breakdowns can be avoided by the systematic checking and repairing of field machinery during the slack seasons. Machinery inspection, repair, and adjustment should be considered necessary jobs to be performed in slack seasons. Systematic repair of machinery often reduces the cost of repairs.

When to Purchase New Machinery—The problem is usually whether to repair or replace a machine. If the machine under consideration is not obsolete, if the cost of repairs will be nominal, and if the machine can be expected to do first-class work, then it should be repaired. If the machine cannot be depended upon after repairing and if capital is available for a new one, a new machine should be obtained, especially if there is any danger of a breakdown at a critical time. If capital is not available, or if it can be made available only by paying excessive financing charges, or by unwisely mortgaging the future, then it is better to repair the old machine, even though other factors indicate that it would be better to obtain a new one.

Tools and Equipment—Good tools and equipment are necessary for repairing field machinery. The extent of repair jobs performed on a farm is governed by



(Courtesy Allis-Chalmers Mfg. Co.)

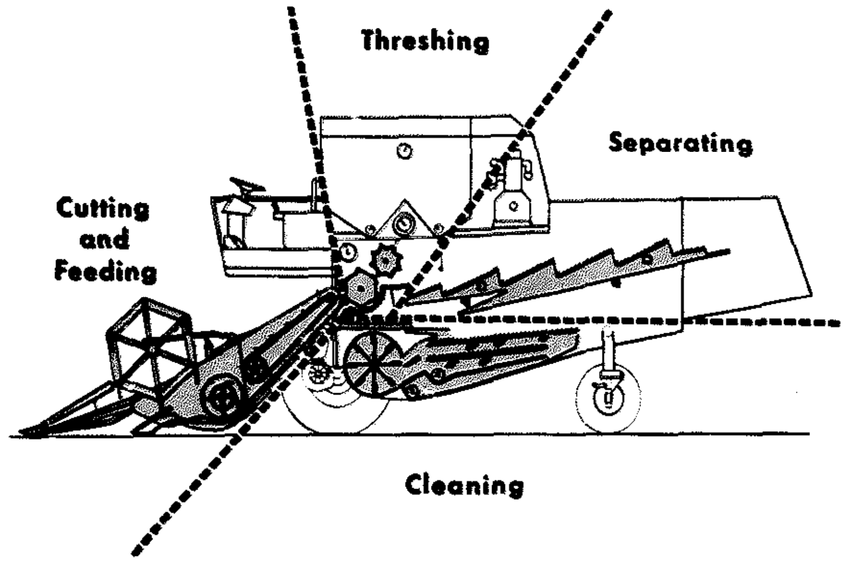
Fig. 28.3. A six-bottom semi-mounted plow.

the farmer's ability and the equipment available. The ability of a farmer and the employees should govern the tools that are acquired. A certain degree of skill in the use of tools is necessary. Good tools improperly handled will not result in a satisfactory repair job.

An assortment of tools and equipment such as wrenches, hammers, screwdrivers, pliers, drift punches, cold chisels, files, wire brushes, rags, oil, safe solvent, cans or small boxes, tags, instruction books, and parts lists will do much toward motivating the proper and intelligent adjustment and repair of the machinery on a farm. A welder, a portable power drill, a tool grinder, and other such tools enlarge the field of repair work that may be performed on a farm.

Identifying Machinery Parts—A machine is an assembly of various parts which will enable the finished mechanism to perform definite functions efficiently. Practically all machinery is composed of units, such as a cutting attachment, or a seeding attachment. These units may be composed of a multitude of small parts. All parts used have names; many have repair numbers. Some parts do not carry numbers, and it is necessary to identify them by their names. All parts are known by names that are descriptive in character. The cutting knife of a mower, for example, is known as a knife or a sickle.

Most repair catalogues group repair parts according to their use. Both the descriptive listing and the pictures of the parts are grouped in this way. Thus a listing might be main wheels, axles, and drive members. If parts do not carry numbers, their likeness can be found in the pictures. The description of parts in catalogues should be read to determine whether you have the right part. For example, you might have to replace a 14-tooth sprocket. The only picture in the catalogue of a sprocket of the type needed gives the number R256-M, but when looking through the descriptive matter, you see that R256-M has only 13 teeth. Thus you will have to seek further. Often a catalogue will give in parentheses numbers and brief descriptions of other parts that are slightly different. In the above example, the number of the 14-tooth sprocket and its brief description might be given in parentheses. The age and the model of machines should be known before parts are ordered. Too much care cannot be exercised when parts are ordered.



(Courtesy Ford Tractor and Implement Operations Training Department)

Fig. 28.4. How a conventional combine works.

The following procedures are important in the identification of machinery parts:

1. Clean the machine so that all numbers on parts can be seen readily.
2. Obtain parts catalogues and instruction books for the machine.
3. Remove temporarily any parts that cannot be identified otherwise. This procedure is rarely necessary.
4. Name the various main or unit parts of the machine. You will at least have to name approximately the parts before you can find them in a catalogue.

Disassembling and Inspecting Machines—The following procedure is suggested when you are disassembling and inspecting a machine:

1. Place the machine on a level and clean place, where small parts will not be lost if dropped.
2. Look over the assembly of the machine and observe the placement of parts so that it can be reassembled.
3. Remove nuts carefully. Use **wrenches** that **fit**. Badly rusted nuts should be loosened with a penetrating solvent, by tapping, or by using heat.
4. Clean all rusty parts with a wire brush and then oil the parts with a good machine oil. Wash greasy parts with a safe cleaning solvent. Clean the whole machine.
5. Inspect all parts for wear and breaks, and make notations of their condition.
6. Mark all parts that might be confused with other parts in assembling the machine. Tag, file, or punch parts as a means of identification. Parts stored for a time before replacing should be oiled and placed in boxes, or temporarily replaced on the machine.
7. List all necessary repairs and parts.

Repairing and Replacing Broken Parts on Machines—When repairing and replacing broken or worn parts on machinery, follow an orderly system:

1. Replace parts that are broken or worn beyond repair with new parts. If no number is found on the old part and it cannot be identified by the use of a parts catalogue, take it to a dealer for identification. Costs and a satisfactory job should govern whether or not repairs are made on the farm or at a machine shop. Only a perfect fit should be tolerated in replacements and adjustments.
2. Sharpen or replace cutting edges.
3. Replace worn gears.
4. Check chains for wear, rust, and cracks. Clean the chains with a safe cleaning solvent and then oil them.
5. Replace or reinforce wood parts that are defective.
6. Tighten nuts and set screws where they are required to be tight. Lock those that are used for making adjustments. Do not tighten any nuts enough to ruin the threads.
7. Replace or use cotter keys, pins, lock washers, and flat washers for a good job.
8. Oil bearings and moving parts when the machine is reassembled.

Assembly and Adjustment of Machinery—Much of the final success of a repair job depends upon the correct assembly and adjustment of the machine. Too much care cannot be exercised in performing this job, and the following suggestions are given:

1. Be sure that parts belong where you try to put them.
2. Do not force parts into place—something is undoubtedly wrong if force must be used.
3. Do not bend or "make over" parts, other than cleaning and polishing them, to make them fit.
4. Follow directions and use your head before your hands. Many parts of machinery cannot be properly assembled unless related parts are left loose. When the assembly is finished, tighten all nuts.
5. Test parts assembled to see that no mistakes have been made. Some pieces seem to work equally well in several places until the machine is finished; then trouble results.
6. Try the machine when assembled. Use care in this procedure, as parts are often broken due to improper placement or adjustment. Operate the machine by hand or run it without a load to test the assembly.

Painting Machinery—Painting machinery has the following values:

1. It protects certain parts of the machine from deterioration.
2. It improves the appearance of the machine and its value is often increased more than the cost of the painting job.
3. It finishes a repair job.
4. It increases your satisfaction.

The following procedure should be followed when painting machinery. For more detailed information on painting, refer to Chapter 11.

1. Select a clean, dry location.
2. Have parts clean and dry. Smooth any rough parts.
3. Clean metal parts with a safe cleaning solvent, and polish with a wire

brush, a file, or steel wool. Have parts dry. Use a metal rust-resistant paint such as red lead for the first coat. Enamel or implement paints thinned with turpentine are best for metals and may be applied with a paint gun or brush. Several coats of paint may be necessary on machinery that needs paint badly. One coat per year will keep machinery in good shape.

Storing Machinery—Machinery gives much better service when housed, because it does not become so rusted and small delicate parts stay in better working condition. Other industries properly care for their equipment, and agriculture must do likewise. Expensive shelters are not necessary; only protection from the weather is necessary. Before storing machinery, check it in an orderly way:

1. Examine all parts thoroughly. List those that need repair, adjustment, or replacement on a tag and fasten it to the machine to serve as a guide when the machine is overhauled. The best time to do this is when the machine finishes its work, as the operator is then aware of the parts needing attention.
2. Remove all parts that require special storage. Store them in a clean, dry place, free from vermin. Minor repairs should be made to determine whether or not a part can be fixed or needs replacement.
3. Grease carefully all parts that should be kept bright or free from rust, such as plow shares, moldboards, and chains.
4. Drain water from all containers to prevent freezing and rusting.
5. Use pieces of wood to block wheels up out of the dirt if the shed does not have a concrete or wood floor.
6. Place the machine in a clean, dry shed so that it will be protected from the weather, and from birds and animals.

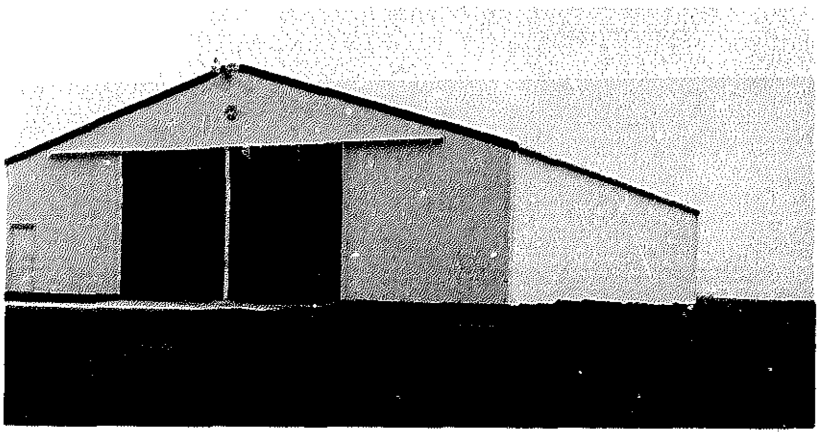


Fig. 28.5. A machinery storage building. The shop area is entered through the small door on the left.

CHAPTER 29

Adjusting and Repairing Field Machinery

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

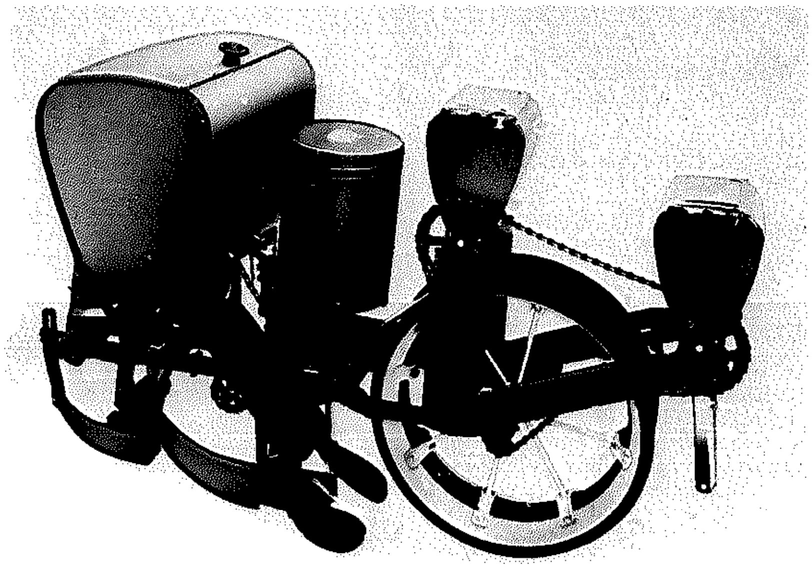
1. How should row planters be adjusted and repaired?
2. How should grain drills be adjusted and repaired?
3. How should plows be adjusted and repaired?
4. How should disk, spring-tooth, and spike-tooth harrows be adjusted and repaired?
5. How should cultivators be adjusted and repaired?
6. How should mowers be adjusted and repaired?
7. How should forage harvesters be adjusted and repaired?
8. How should balers be adjusted and repaired?
9. How should combines be adjusted and repaired?
10. How should corn heads be adjusted and repaired?
11. How should sprayers be adjusted and repaired?

INTRODUCTION

The adjustment and repair of only the more important field machines are discussed in this chapter. The suggestions given do not attempt to include all the minor details involved in the adjustment and repair of these machines. Insufficient space is available in a mechanics in agriculture book which covers the entire field of agricultural mechanics, as this book does, to include a detailed discussion of all machines used in production agriculture. The abilities developed in adjusting and repairing the more important and complex machines included should make it possible, however, for a person to learn, with the help of the operator's manuals, how to adjust and repair other machines used on farms and in nonfarm agricultural businesses.

ROW PLANTERS

Types—Row planters may be classified as (1) trailing, (2) rear-mounted, and (3) front-mounted. A classification can also be made on the way the planter places the seed. There are drill planters, hill-drop planters, and check-row planters. Hill-drop and check-row planters have been used much less in recent years.



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.1. Disk-type furrow openers for a row-crop planter.

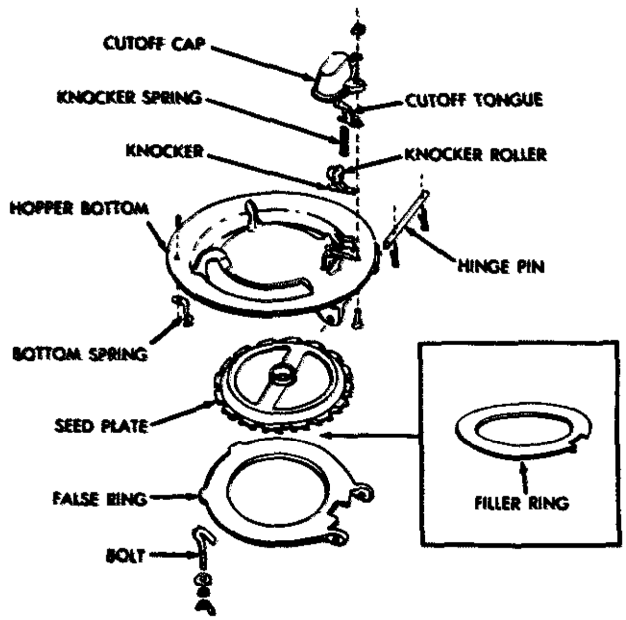
Drilling—A planter that is drilling seeds drops the seeds in a row a certain distance apart. This distance may be varied, for example, from 2.5 inches to 17.5 inches. With seeds 6.5 inches apart and with a row spacing of 40 inches, the planting rate would be 24,000 plants per acre. Consult the operator's manual for the planter for instructions on how to adjust it to obtain varying planting rates.

Hill-Dropping—A planter set to hill-drop will collect the seeds and drop two or more seeds at regular intervals. The number of seeds dropped per hill depends on how the planter is adjusted. Consult the operator's manual for instructions for changing the hill spacings and the number of seeds per hill.

Checking—A planter equipped to check will drop the seeds in squares, which permits cultivation with rows and across rows.

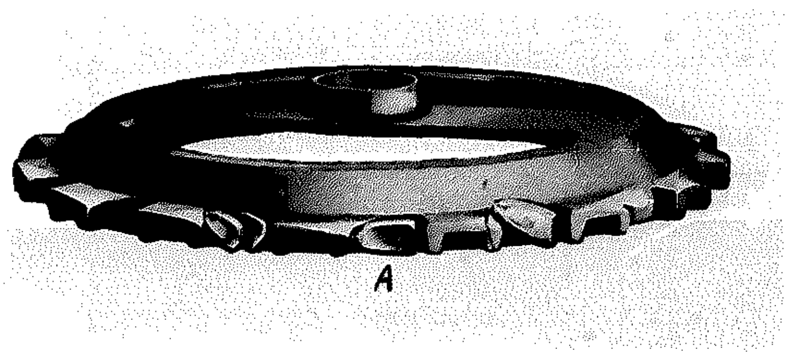
Parts of a Planter—Row-crop planters have the following parts:

1. Frame.
2. Drives. Trailing type planters are commonly driven by a wheel such as a carrying wheel, gauge wheel, or press wheel.
3. Openers for seed furrows. The furrows for the seed may be opened in various ways such as with runners, disks, shovels, or a combination of these devices.



(Courtesy Allis-Chalmers Mfg. Co.)

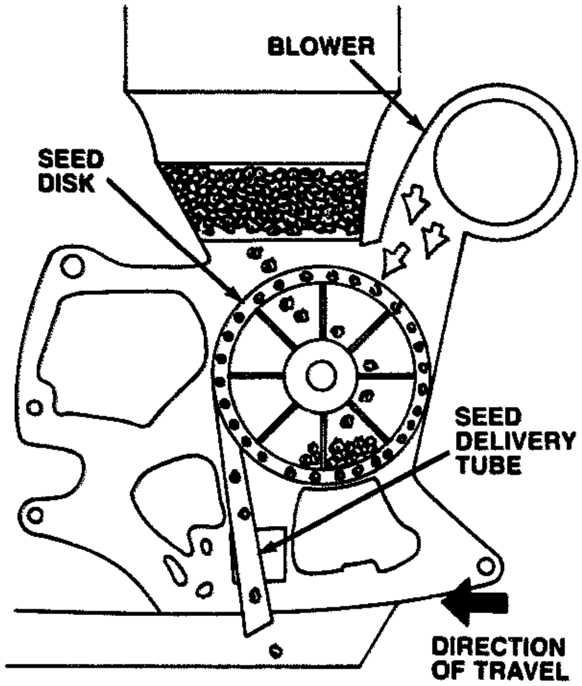
Fig. 29.2. An exploded view of the parts of a corn hopper for a planter with seed plates.



(Courtesy John Deere, Moline, Ill.)

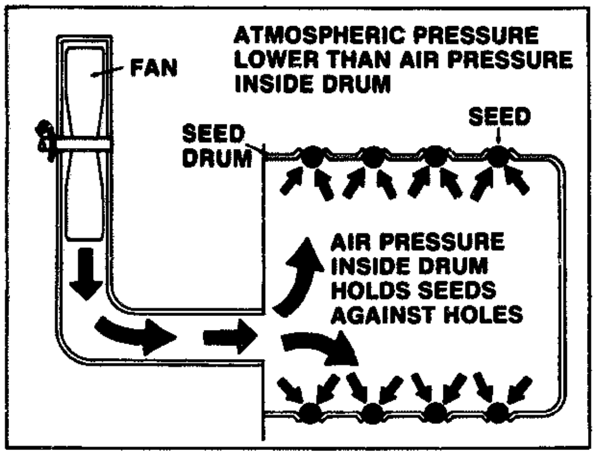
Fig. 29.3. Edge-drop seed plates should be selected so that the corn kernels, like the kernel marked "A," fit the cells.

4. Metering device for seed. The devices for metering the rate of seeding are of three primary types. They are seed plates, finger pickup devices, and air devices. See Figs. 29.2, 29.4, and 29.7 for illustrations of these devices.
5. Mechanism for placement of seed. Some planters have a gravity-drop mechanism. In order to obtain greater precision in seed placements, machinery companies have developed power-drop mechanisms such as seed conveyor belt drop, rotary valve drop, chain drop, and air drop. See Fig. 29.8 for illustration of a rotary valve mechanism and Fig. 29.9 for illustration of a chain-drop mechanism.



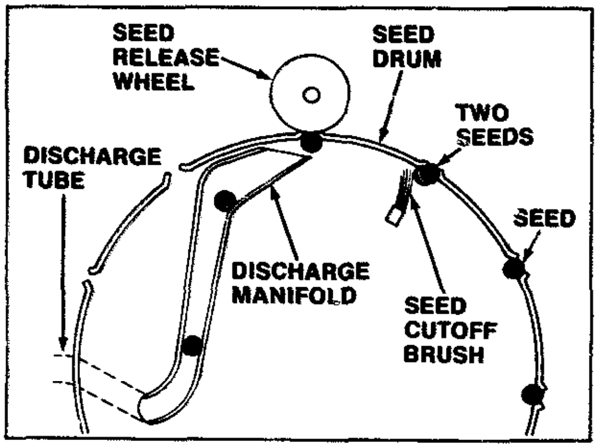
(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.4. A cutaway view of an air pressure seed metering device for a row-crop planter.



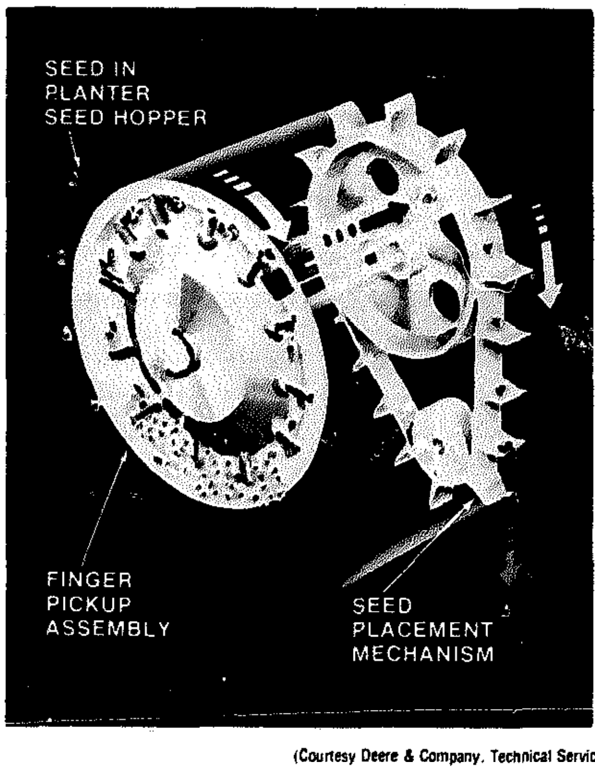
(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.5. A cutaway view of an air pressure seed metering device, showing how air pressure holds the seed in place inside the seed drum on a planter.



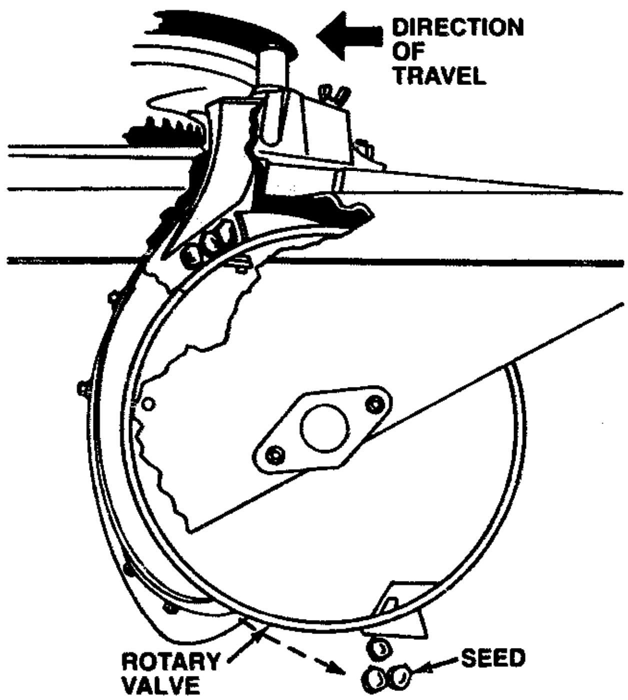
(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.6. A cutaway view of an air pressure seed metering device, showing the seed cutoff and release mechanism on a planter.



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.7. A seed metering mechanism, using a finger pickup device on a planter.



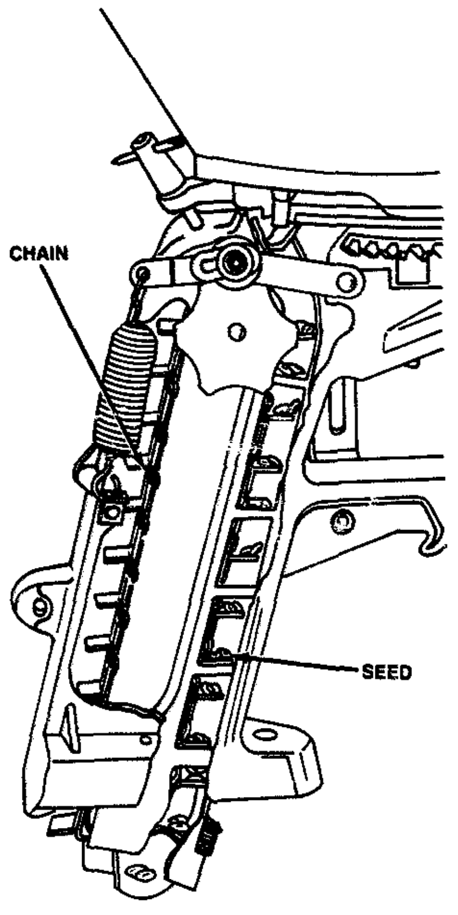
(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.8. A power-drop seed placement mechanism on a planter, using a rotary valve.

6. Covering devices for the seeds. Various mechanisms are used to cover the seeds. They include such devices as shovels, knives, and disks. The type of seedbed determines the best covering device.
7. Devices for pressing or packing the soil over the seeds. Some type of wheels are used such as press wheels, firming wheels, or packer wheels. The type of seedbed often determines the best type of wheel to use.
8. Hoppers for seed. Some planters are equipped with individual seed hoppers for each row, while other planters are equipped with a centralized seed hopper.
9. Attachments for tilling the soil directly in front of the furrow opener. In plowed ground, such mechanisms as a disk-furrow attachment, tine-tooth attachment, or V-wing attachment are used. For minimum tillage, such mechanisms as the fluter coulter or the ripple coulter are used.
10. Monitors. Monitors to determine whether or not a planter is planting properly are used on some planters. Monitors often utilize an electric eye.

Prefield Preparation—Several prefield adjustments may be made on a planter. The following are recommended:

1. Check the parts of the planter. Inspect for worn sprockets, gears, and chains. Inspect the hoppers. Check for weakened springs. The power train should be checked.
2. Attach the planter. See the operator's manual.
3. Level the planter. See the operator's manual for instructions regarding this procedure.



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.9. A power-drop seed placement mechanism on a planter, using a chain-drop.

4. Adjust the space of rows. The space between rows may be adjusted on many planters. Consult the operator's manual for procedures.
5. Adjust the length of the row marker.
6. Select the planting population and adjust the planter to obtain this rate. Consult the operator's manual for instructions on adjustments necessary to obtain a specified rate. The rate of planting may be influenced by speed of travel and by tire inflation.
7. Calibrate the planter on "trial runs."

In prefield adjustments, set the planter to plant at the desired rate, and then provide a trial run to determine whether or not the planter is adjusted correctly. In the trial run raise the planter and "plant" 100 feet on top of the ground. Then check the drops to determine whether or not the distance between seeds is correct, and whether or not the rate of seeding is correct. If the rate of seeding is incorrect, make adjustments. The scattering of the seed may be caused by excessive planting speeds. Consult the operator's manual for the best operating speed.

Field Adjustments—The speed of forward movement may affect the planting rate and the accuracy of seed drops. In calibrating a planter on "trial runs," the rate of travel should be the same as it will be in the field.

If chains break or climb, they may not be running straight, or they may be too tight or too loose. A chain may be tightened or loosened by adjusting the chain idler. If a chain is not running straight, realign the sprockets.

Check the seed hoppers to determine whether or not they are all using the same amount of seed. If not, the setting of the drive gears may be different, or the size of plates, if the planter has plates, may not be the same in the various hoppers.

The depth of planting needs to be checked. Depth of planting adjustments are often needed. Consult the operator's manual for procedures for adjustment of planting depth. Always calibrate the seeding rate in the field. Remember that travel speed may affect seeding rate. Therefore, it is essential to know travel speed. Travel speed is affected by:

1. Tire size.
2. Inflation of tires on drive wheels.
3. Soil conditions.

The formula for checking travel speed is to measure the distance (in feet) traveled in one minute and divide by 88. The result will be miles per hour.

Repairing—In repairing a planter before the planting season, check for the following and make the repairs indicated:

1. Twisted or bent frame. If the furrow openers are not an equal distance from the ground, a twisted or bent frame is indicated.
2. Worn wheel bearings. The wheel bearings should be cleaned and lubricated before the planting season each year. Replace worn bushings.
3. Loose bolts, rivets, and bearings.
4. Weak or broken springs.
5. Dull furrow openers.
6. Slippage of planter drive mechanisms, such as the drive wheel.
7. Condition of seed metering devices.

GRANULAR ROW APPLICATORS

Calibrating—Granular application of chemicals for weed and insect control may be made at any time. However, granular applicators often are attached to planters. These planter-attached applicators usually apply the chemicals in a band over the seed. Calibration of these applicators is important because inadequate application may not produce the results desired. Too heavy an application is costly, and it may damage the crop being produced.

The rate of application is determined by (1) metering orifices, (2) speed of the agitator, (3) ground speed of the applicator, (4) nature and size of the granules, (5) roughness of the field, and (6) humidity and temperature.

In setting applicators, read the chemical label to determine the percentage of active ingredients and the recommended rate of application of active ingredients, such as ½ pound of active ingredients per acre. Consult the operator's manual to determine the orifice setting required for applying the pounds of granules recommended. Check the width of row for which the orifice setting is based. Also check the ground speed recommended for the orifice setting suggested.

Place paper or cloth bags over the hopper dispenser chutes, and field test the amount of application for a round or two in the field. Weigh the granules collected and determine the acreage covered. The acreage covered may be determined by the following formula:

$$\frac{\text{Rows covered}}{\text{Rows per acre}} = \text{Acreage}$$

The application rate may be determined by this formula:

$$\frac{\text{Pounds applied}}{\text{Acreage covered}}$$

If the rate of application is not correct, make certain that the speed of travel of the applicator agrees with the recommended speed of travel. Varying the speed of travel can make tremendous differences in the rate of application. Most applicators use a rotating agitator. The action of the agitator varies with the ground speed of the applicator. An increase of ground speed of the applicator of 1 mile per hour may double the rate of application.

To check ground speed, determine the seconds it takes to travel 176 feet. If it takes 60 seconds, the ground speed is 2 miles per hour. If it takes 30 seconds, the ground speed is 4 miles per hour, and so forth. If the amount of application is incorrect when the ground speed is correct, change the orifice setting proportional to the increase or decrease in rate desired, and continue to field test until the desired amount is being applied.

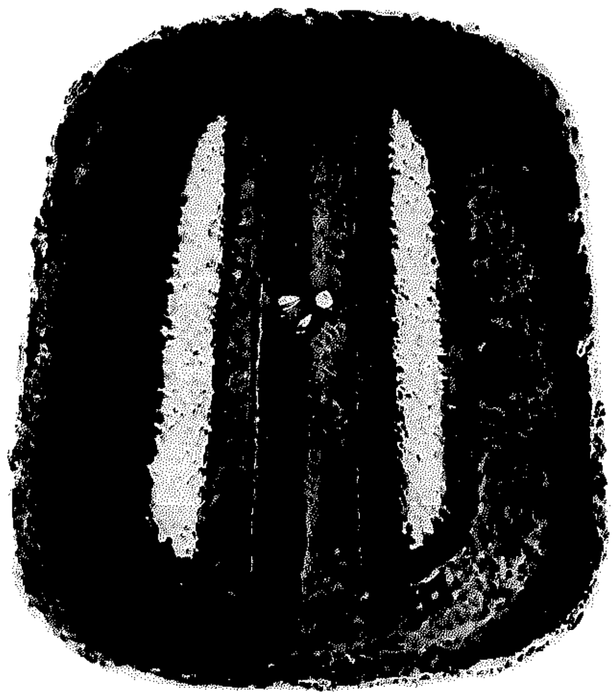
Frequent checks of the amount of application are desired so that the applicator is motivated to drive at the speed recommended, and so that minor adjustments can be made to compensate for the degree of roughness of the field and for humidity and temperature changes.

GRAIN DRILLS

A grain drill is made to seed successfully many different seeds of various sizes, shapes, and weights. It therefore has various adjustments which make it possible to plant these different seeds accurately. Grain drills have two types of drill feed mechanisms:

1. Internal double-run type.
2. Fluted force feed type.

Adjusting the Internal Double-Run Drill—The mechanism for regulating the rate of seeding of an internal double-run drill consists of a feed wheel and a feed gate. (See Fig. 29.11.) The feed wheel has a deep side and a shallow side. On the deep side of the feed wheel, the serrations are of greater depth than they are



(Courtesy J. I. Case Co.)

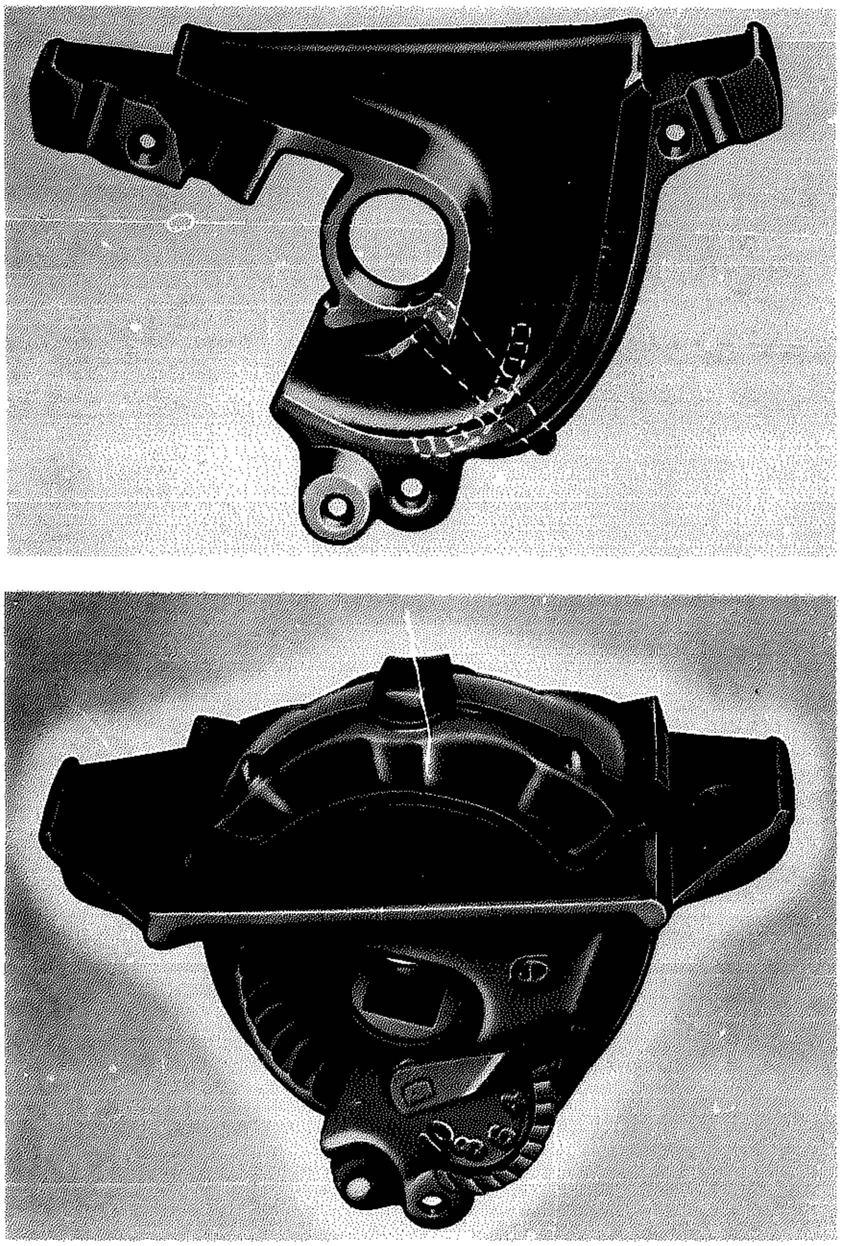
Fig. 29.10. This illustration shows how fertilizer is distributed in relation to the seed.

on the shallow side. The wheel can be adjusted so that either side may be used to regulate the flow of the seed. The wheel is adjusted for the use of the deep side when large or bulky seeds such as oats are being drilled. It is also used when large quantities of seed are to be sown. The shallow side is used for such seeds as wheat or alfalfa.

The side of the feed wheel used is an adjustment that can be made to regulate the amount seeded, but two more important ways of regulating the amount of seed sown are the adjustment of the speed of the feed wheel and the adjustment of the seed gates.

The speed of the feed wheel is adjusted by changing the gear ratio in the gear box. Most gear boxes have 7 to 10 gear ratios. The size of the driving sprockets may also be changed. When this is done, a new set of feed wheel speeds is provided.

The position of the seed gates in the feed wheel is as important as the speed of the wheel in determining the amount of seed sown. There are two to four possible positions for the seed gate on the shallow side of the feed wheel, and two to four possible positions for the seed gate on the deep side of the feed wheel, the number depending on the make of the drill. The seed gates are located at the bottom of the seed cup. (See Fig. 29.11.) For uniform seeding all gear boxes and seed gates must be set the same. The manufacturer's instructions should be consulted for the recommended setting for the various rates of seeding of the different kinds of seed sown with a drill.



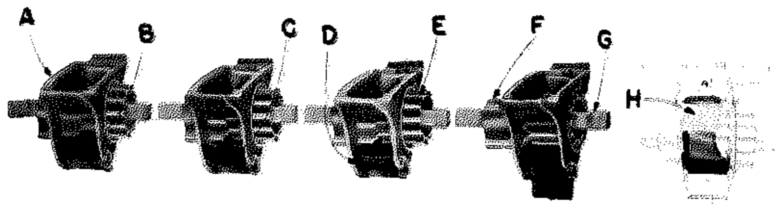
(Courtesy John Deere, Moline, Ill.)

Fig. 29.11. A detailed view of a double-run feed mechanism showing (top) an adjustable gate inside the feed cup for regulating the size of the feed opening, and (bottom) a lock lever on the small side of the feed mechanism for regulating the quantity feed gate.

Adjusting Fluted Force Feed Drills—The fluted force feed mechanism for regulating the rate of seeding consists of a seed cup containing a fluted roll, a feed cutoff, and a feed gate. When the feed roll turns, it forces the seed over the feed gate and into the seed tube which delivers the seed to the soil.

The amount of seed sown is regulated by the feed roll in the seed cup. A lever is provided for adjusting the feed roll. A dial is provided beneath the lever which indicates the rate of seeding. For example, if the lever is set at 20, the corresponding number may be found on the sowing chart, usually on the inside of the lid of the hopper. The sowing chart will indicate the rate of seeding for this setting.

Many factors may influence the rate of seeding, such as the moisture content of the seed and the quality of the seed. Therefore, all settings are approximate. The quantity of seed being sown should be checked after one or two acres have been drilled, and adjustments made to compensate for the differences that influence the rate of seeding. The rate of seeding may also be calibrated before going to the field. The method of calibrating a grain drill is described in the following section of this chapter.



(Courtesy John Deere, Moline, Ill.)

Fig. 29.12. The detail of fluted grain drill feed cups, showing the different settings for the various seed sizes. The quantity is regulated by shifting the feed roll and feed cutoff to permit more or less of the feed roll to turn within the feed cup.

Position 1—(A) Feed cup, (B) latch in upper left-hand notch. Fasten all gates with latches in top notch on left side to sow all grains, small seeds, kaffir corn, and beets.

Position 2—(C) Latch in right-hand notch. Fasten all latches at right side to sow peas, common beans, soybeans, corn, and extra-large quantities of trashy oats.

Position 3—(D) Latch in lower left-hand notch, (E) Feed roll. Fasten all latches in lower notch on left side to sow soybeans or kidney beans.

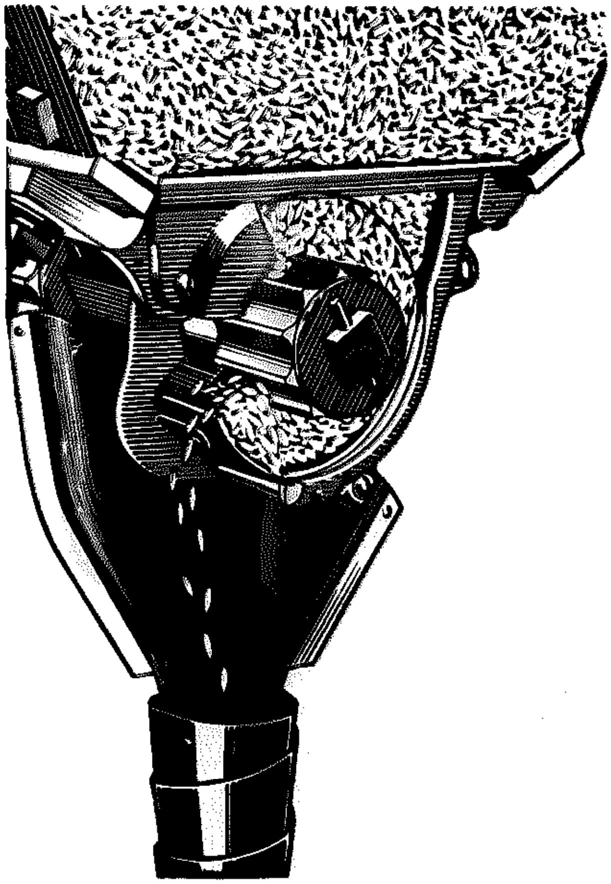
Position 4—(F) Feed cutoff, (G) feed shaft. Drop the gates to clean.

Position 5—(H) Soybean gate special attachment. Can be furnished for planting soybeans and rice in quantities up to 80 pounds per acre.

In addition to the adjustment on the fluted feed roll, some drills can also be adjusted by changing the speed of the feed roll, which is done by changing the speed of its drive shaft. The gate in the seed cup is the adjustment provided for handling the various sizes and shapes of seeds sown. The gates can be set in several positions. The closed or uppermost settings of the gates are used for small, heavy seeds such as wheat. The lower or more open positions are used for bulky, light seeds such as oats. For uniform seeding all seed gates must be set the same.

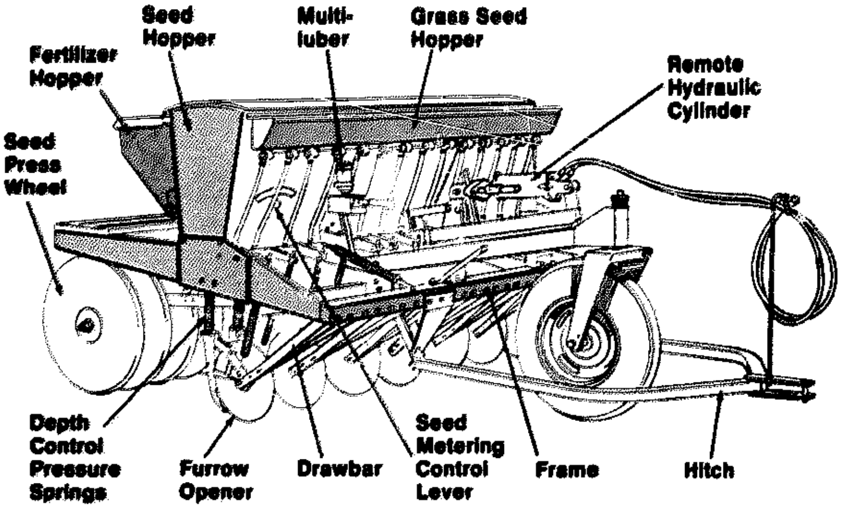
Calibrating the Seeding Mechanism—To begin the calibration of a grain drill, first partially close each seed gate; then pour some grain into the seed box. Block up the drill and place a canvas under the drill to catch the grain. Be sure that the canvas is under all the seed tubes. Lay a board under the drill to protect the canvas when the furrow openers are lowered to their operating position.

If, for example, oats are to be sown at 12 pecks per acre, to check the calibration, set the drill according to the manufacturer's directions to seed this amount.



(Courtesy J I Case Co.)

Fig. 29.13. An illustration showing how the seed is forced into the tube leading to the ground.



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.14. A partial view of a grain drill, with the principal parts named.

Then measure the width of the drill. The next step is to measure the circumference of the drive wheel. This information is used in the computation required for checking the seeding rate.

There are 43,560 square feet in one acre. The 43,560 should be divided by the width of the drill (in feet). The number obtained equals the distance, in feet, the drill must travel to cover one acre. The distance the drill must travel for one acre should be divided by the circumference of the drive wheel (in feet). The number obtained equals the turns the drive wheel must make to cover one acre.

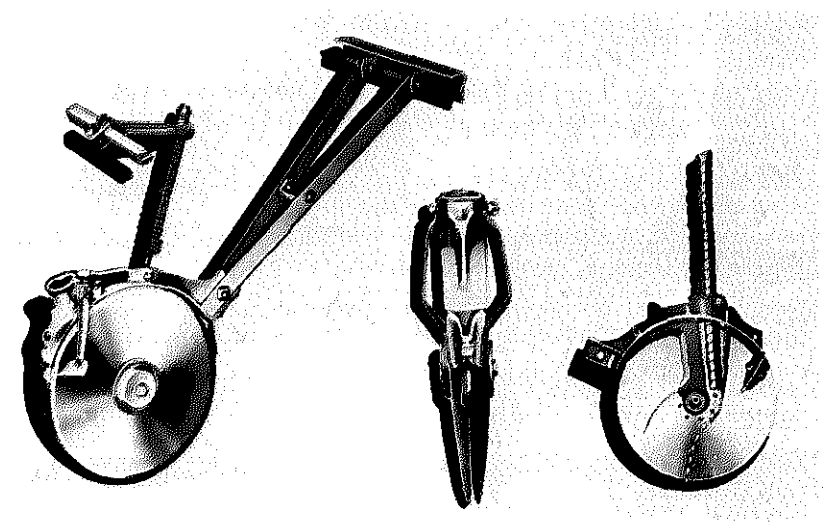
Turn the drive wheel to force the grain out of the seeding mechanism. In order to keep track of the turns more easily, tie a rag around the rim of the drive wheel. The piles of grain should be approximately equal in size to insure a uniform seeding rate.

After the wheel has been turned the desired number of times, raise the furrow openers, remove the board, carefully gather up the grain, and put it in a sack for weighing or measuring. With this information, the computation can be completed.

Adjusting Furrow Openers and Covering Devices—A single disk is the most common type of furrow opener used. Double-disk, hoe, and shoe furrow openers are used on some drills, however.

If a single-disk furrow opener is used, it should be adjusted to operate at a slight angle. If this angle is too much or too little, the seed will not be covered properly. The operator's manual gives instructions regarding the angle at which to set the disks. Examination of the work of the drill will also indicate whether the correct angle is being used.

The disks should penetrate the ground to the same depth. The depth of the disks is controlled by springs. These springs are adjustable.



(Courtesy John Deere, Moline, Ill.)

Fig. 29.15. Views of double-disk furrow openers. The cutaway view on the right shows how seed is delivered to the opened trench.

The two types of covering devices in most common use are press wheels and drag chains. Examination of the work of a drill will indicate whether the covering device used is performing its function.

Adjusting Hitches, Drives, and Wheels—A swinging drawbar should not be used with a drill, because it may permit the drill to swing from side to side. Use a fixed drawbar and hitch at a height that will permit the top of the seed box to be level. If the box tips backward, the seed will be covered too deeply. If the box tips forward, the placement of the seed will be too shallow.

The drive chains should be adjusted to remove the slack, but excessive tension should be avoided.

The tires on a drill should be inflated properly, because the degree of inflation influences the rate of seeding. The operator's manual gives the proper inflation for the tires. The wheels of a drill should be adjusted so that the distance between the top sides of the wheels is 1 inch further than the distance between the bottoms of the wheels. This is known as camber. The front of each wheel should have a "toe-in" of ½ inch.

Checking and Repairing—If a grain drill does not operate properly, the difficulty may be caused by:

1. The feed mechanism. Turn the feed mechanism drive shaft with a wrench. If it does not turn easily, check for obstructions in the feed wheel or feed cups. Check for broken feed gears. Examine the feed shaft to determine whether or not it is twisted. Check for frozen or broken parts in the fertilizer feed box.
2. Worn or improperly adjusted clutch.
3. Failure of driving gears to mesh.
4. Worn pawls in drive wheels.
5. Leaks in seed or fertilizer box.
6. Sprung frame.

The drive chains should be checked for wear. The furrow opener bearings should also be checked frequently for wear. Replace them when they become worn.

The following is a list of the parts which should be checked before a grain drill is stored:

1. Hopper
2. Agitator
3. Feeding device
4. Seed shaft
5. Furrow openers
6. Seed tubes
7. Drag bars
8. Scrapers
9. Wheel bearings
10. Frame
11. Wheels
12. Levers
13. Fertilizer and grass seed attachments

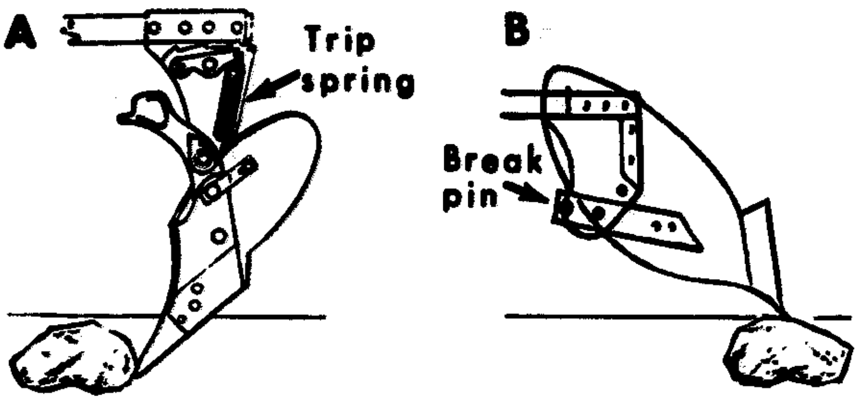
The following procedure is suggested for cleaning the seeding mechanism:

1. Remove grain from seed box hoppers. All grain should be removed to prevent the molding or germinating of the grain, which may cause the mechanism to clog.
2. Place the drill on sawhorses.
3. Open the feed regulator and open each feed gate.
4. Lower the furrow openers and put the drill in gear.
5. Turn a drive wheel to run the seed through the feed mechanism.
6. Brush any remaining seed or foreign material into the seed mechanism to remove it from the seed box.
7. Clean the feed gates and surrounding surfaces thoroughly by brushing with a cleaning solvent.
8. Clean the fertilizer attachment to eliminate the hardening of old fertilizer and to help prevent the corrosion of the mechanism.

MOLDBOARD PLOWS

The moldboard plow is one of the most common farm implements, and with proper care and maintenance it will last for many years. Like other implements, it should be kept properly lubricated and adjusted for efficient use. At the close of a day's work, the plow moldboards and shares, the coulters, and the jointers should have a light coat of oil applied to them to protect their surfaces from rust. At the close of the season they should be covered with a thin coat of grease. The plow should then be placed in a suitable shed and housed until needed.

Plowing difficulties are usually caused by the improper adjustment of the plow. Most operators can do an excellent job of plowing if their plows are adjusted properly.

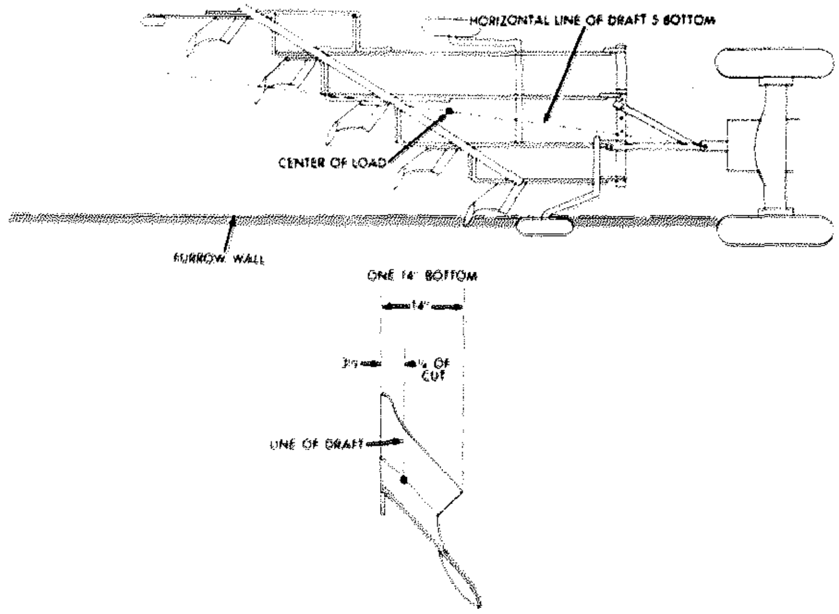


(Courtesy U.S.D.A.)

Fig. 29.16. A trip spring and a break pin hitch release mounted on beams to protect plows when objects are hit while you are plowing.

Adjusting Hitches—Plows will work best if they are hitched as nearly as possible to their center of draft. The method of locating the line of draft of a plow is illustrated in Fig. 29.17. When plows are hitched so that they are pulled, to the extent possible, straight ahead from their line of draft, difficulties such as the following will be prevented:

1. Failure of the front bottom to cover
2. Failure of the front bottom to take a full cut
3. Side draft
4. Excessive load
5. Ridging of the ground



(Courtesy Allis-Chalmers Mfg. Co.)

Fig. 29.17. Finding the center of draft on any size plow is simple. First find the total cut of the plow for one or more bottoms. Half of the total cut is the center of the cut. Measure to the left of the center of the cut one-fourth of the distance of the cut of one bottom to obtain the center of draft. The horizontal line of draft is the line of pull from the center of the load of the plow to the tractor hitch, as shown.

Remember in hitching a tractor that the center of pull is midway between the rear wheels.

In adjusting the hitch of a tractor plow, do the following:

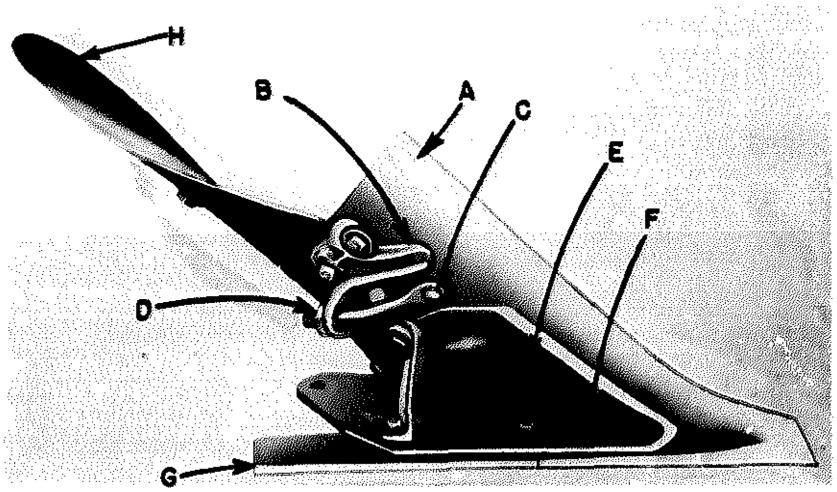
1. Locate the plow so that the front bottom will be cutting a full furrow.
2. Lower the plow into plowing position.
3. Block up the land wheel to a distance equal to the depth at which the plow is to be operated.
4. Adjust the plow so that weight of the plow is on the points of the plowshares.
5. Determine the center of cr· and line of draft of the plow. (See Fig. 29.17.) The center of draft is a point approximately on the line where the moldboard and share jcin.
6. Determine the center of pull of the tractor.
7. Stretch a cord from the center of the draft of the plow to the center of pull of the tractor. With a fixed drawbar, the plow should be hitched to

the hole nearest the string. With a swinging drawbar, the drawbar should be locked in position parallel to the string.

8. Set the hinge bolt of the plow hitch to correspond to the height of the string stretched between the center of draft of the plow and the tractor hitch.
9. Adjust the brace bar on the hitch so that the front bottom will take a full cut.

If the plow goes too deep as hitched, the difficulty may be that the vertical adjustment of the hitch is incorrect; see step 8 in the procedure for adjusting the hitch. Another indication of an incorrect vertical hitch is the front end of the plow riding high. An incorrect hitch may cause a tractor to steer hard, or it may cause the rear wheels of the tractor to slip because of a lack of traction.

Adjusting the Furrow Wheel—A furrow wheel is designed to support the weight of the rear part of a plow. After the hitch is adjusted and while the plow and tractor are blocked up on the floor, adjust the furrow wheel so that the heel or landside of the plow bottoms is ½ to ¾ inch from the floor. The furrow wheel should also be adjusted against the furrow wall so that the heel or landside of the plow bottoms is ½ to ¾ inch from the furrow wall. The tire on the furrow wheel must be kept inflated properly to maintain this adjustment.



(Courtesy John Deere, Moline, Ill.)

Fig. 29.18. A plow bottom with the parts named. (A) Share, (B) share brace, malleable, (C) stud for holding quick-detaching bolt, (D) quick-detaching bolt, (E) frog for supporting share, (F) slot in frog for lug in share, (G) landside, and (H) moldboard.

Adjusting Coulters and Jointers—Adjust coulters so that the hubs of the coulters are directly above the points of the plowshares. If the plow does not penetrate properly in hard ground, setting the hubs of the coulters approximately 3 inches back of the points of the plowshares may help.

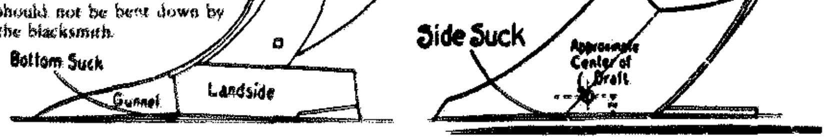
The coulters should also be set high enough so that the plowshares are cutting about 2 inches deeper than the coulters, but the coulters should never be set to penetrate deeper than 4 inches. The coulters should be set ½ to ¾ inch away from the landside of the plow bottoms.

Set jointers as near as possible to the coulters. Allow about $^{1}/_{16}$-inch clearance between a jointer and a coulter. Adjust the jointer so that it will penetrate the soil about 2 inches.

If the furrow wall crumbles, the coulter may be set too close to the plow bottom. If the coverage of trash is not adequate, the coulters and jointers may be set too high.

Coulters on plows should be kept sharp. Coulters may be sharpened with a bench grinder. Remove each coulter from the plow and adjust the bearing so that the coulter will turn easily. When grinding a coulter, hold it against the grinding wheel so that the coulter will turn as it is sharpened. The turning of the coulter avoids the overheating of the cutting edge and makes the sharpening process easier.

Adjusting Mounted Plows—To get a mounted plow to plow at the correct depth, the lifting connections must be adjusted so that they are loose while plowing. The side draft may be decreased by narrowing the width of the wheels of the tractor as much as possible while maintaining a safe width. The heel of the landside of the bottom should run to the bottom of the furrow. This may be accomplished by adjusting the vertical hitch. It should also be adjusted so that the plow runs level. Remember, the depth of plowing is controlled by the hitch.



(Courtesy M. T. Gowder, University of Tennessee)

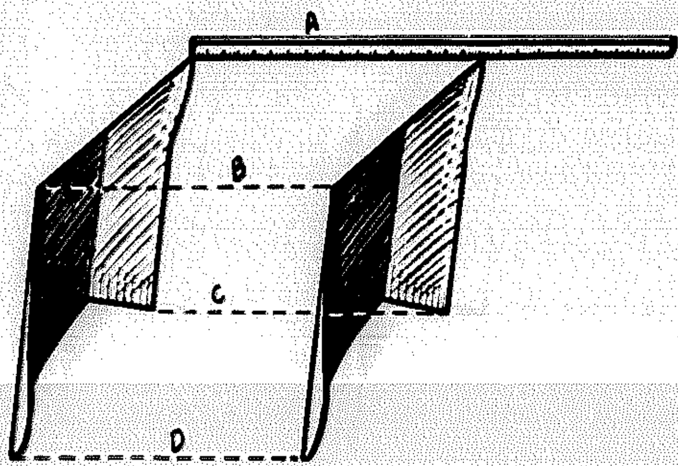
Fig. 29.19. Plows must have down suction to give penetration. The amount of clearance at the point indicated in the illustration should be about ¼ inch. Side suction enables a plow to cut an even, full-width furrow. The clearance at the point indicated in the illustration should also be about ¼ inch.

Mounted plows have an adjustment for tilting the plow. Locate this adjustment by consulting the operator's manual, and adjust so that the wing of the share is about ½ inch higher than the landside of the bottom. This tilting decreases side draft and helps to keep the plow in the ground.

Repairing—Some of the parts of a plow to be checked for wear and breakage before storing are:

1. Share
2. Landside
3. Frog
4. Moldboard

Fig. 29.20. Before using a plow, check the bolts for tightness.



(Courtesy H. D. Bruhn, O. I. Berge, and the Extension Service, University of Wisconsin)

Fig. 29.21. When checking a plow, make sure the distances of A, B, C, and D are all equal.

5. Beam
6. Jointer
7. Coulter
8. Wheel bearings
9. Bails and collars
10. Frame
11. Lifting clutch
12. Lifting springs
13. Levers
14. All bolts

At the time of storing or early in the spring, the plow may need to be thoroughly cleaned and painted.

Coulter bearings can usually be tightened with the bolt on the coulter fork. The cones may have to be ground to permit this tightening. The axle shaft of a plow may become worn. If it does, it can be repaired by padding with a weld, or the axle may be replaced. Wheel bushings in wheel hubs may have to be replaced.

If the beam is sprung, it usually requires (1) special equipment to correct the difficulty, or (2) the replacement of the beam.

The plowshares should be sharpened or replaced with new ones before the beginning of the plowing season.

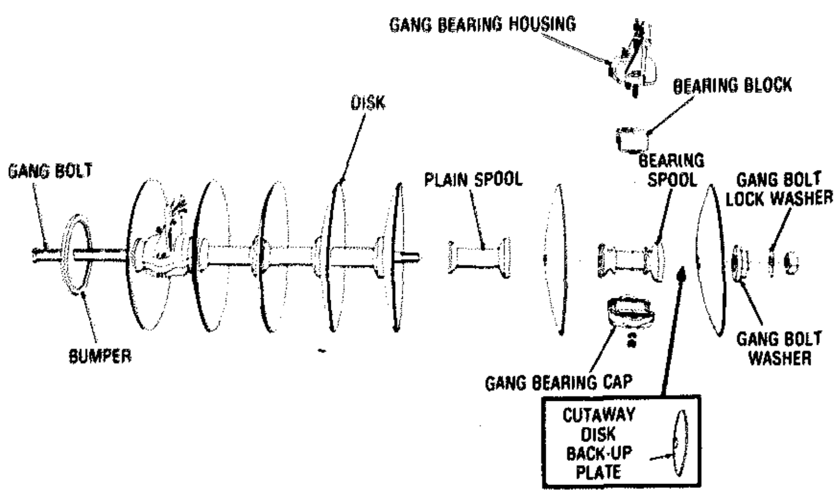
HARROWS

Harrows are used to prepare seedbeds. There are three principal types:

1. The disk harrow
2. The spring-tooth harrow
3. The spike-tooth harrow

Disk Harrow—It is important to keep a disk harrow sharp. A disk harrow may be sharpened without being taken apart if special disk-sharpening equipment is available, such as a flexible shaft grinder. If only a stationary power grinder is available, the individual disks must be removed. Do this by unscrewing the nut from the end of the arbor bolt and then removing in succession the disks and spools. The disks should be ground on the convex or outer side. Be careful not to overheat the disks while grinding them, or their temper will be destroyed. After they are sharpened, the disks and spools should be put back in the order in which they came off. The arbor bolt should be tightened and locked in place. If the arbor bolt is bent, you may straighten it on an anvil without heating it.

The bearings should be cleaned and tested for wear. Test excessive wear by



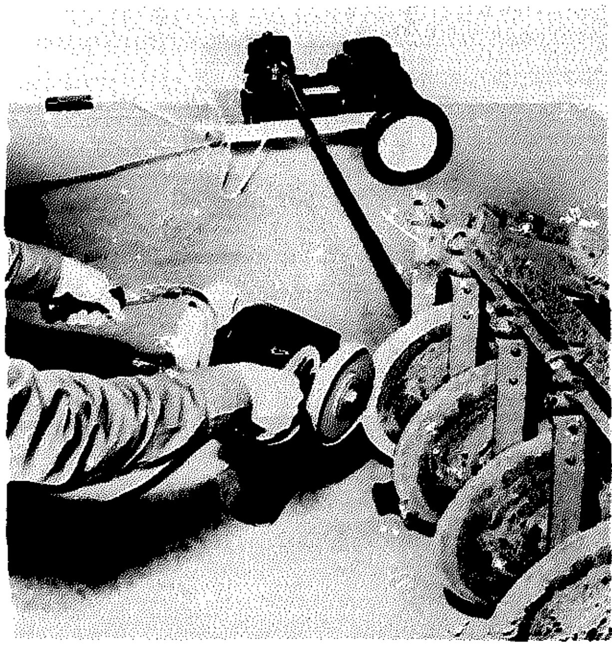
(Courtesy Allis-Chalmers Mfg. Co.)

Fig. 29.22. Detailed drawing of part of a gang of a disk harrow.

placing a disk, adjacent to a bearing, on a two-by-four and checking for movement in the bearing. If excessive wear is suspected, turn the disk over on its back and remove bearing caps to inspect the wear. Replace the bearings if worn excessively or if broken. Spools do not wear as rapidly as bearings, but they do need to be replaced occasionally. All bearings and spools should be cleaned thoroughly before the disk is reassembled.

Scrapers frequently need to be adjusted and repaired. Worn scrapers may need to be replaced, but bent scrapers can often be straightened. After the scrapers are repaired, they should be adjusted so that they are about 1 inch from the outer edges of the disks.

All bolts in a disk should be checked to determine whether or not they are tight. Levers, hitches, and braces should also be checked to determine whether or not they are in good working condition. All lubricating devices should be checked to determine whether or not they are working properly.

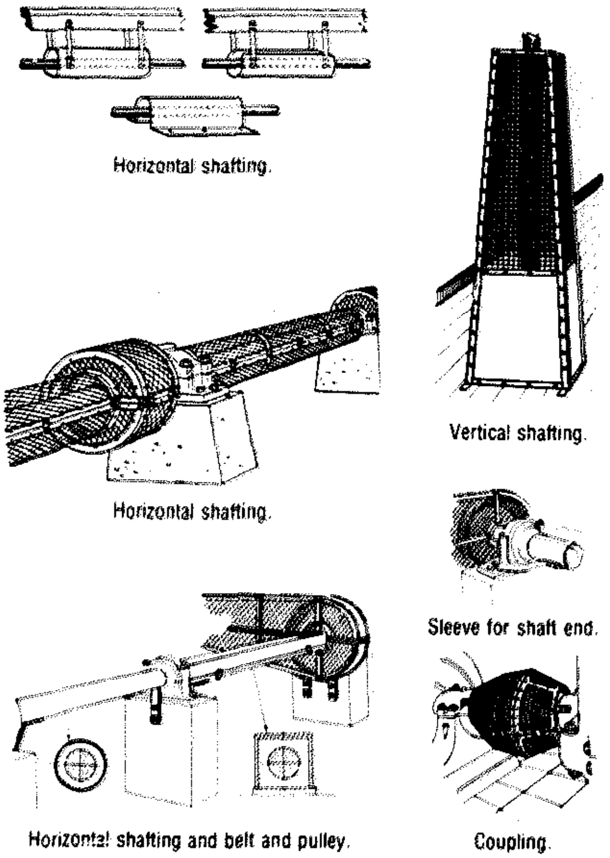


(Courtesy Foley Manufacturing Co.)

Fig. 29.23. A disk should be kept sharp.

Spring-Tooth Harrow—A spring-tooth harrow is a simple tool. It is often used to control weeds with a widespreading root system. The teeth need to be kept sharp. They should be ground on their back side. The points not only will become dull but will wear round. Points may be restored by grinding. In grinding do not allow the teeth to heat above a cherry red color. Plunge the teeth in water to prevent overheating. Some teeth may need to be restored to their original shape by a blacksmith.

After the teeth have been repaired and sharpened, they should be adjusted.



(Courtesy U S. Department of Labor, Occupational Safety and Health Administration)

Fig. 29.24. Examples of techniques of guarding rotating motion on agricultural machines.

Place the harrow on a level area and set it so that the teeth touch the floor. Those that do not should be adjusted. The teeth may also need to be adjusted so that no tooth will follow immediately behind another tooth. Check to see that all clamps holding teeth are tight.

A spring-tooth harrow is subjected to considerable strain and vibration. The frame of the harrow should be checked to determine whether or not it is bent. The frame and draft bars may be straightened on an anvil. Examine the bolt holes and the runners for wear. Worn bolt holes should be reamed and larger bolts inserted. A worn runner may be repaired by welding a new piece to it. Breaks in the frame may also be repaired by welding.

Spike-Tooth Harrow—Tooth bars and frames of spike-tooth harrows may be straightened on an anvil. The front of the spiked teeth should be sharp. They may often be turned so that a sharp edge will be forward. If it is not possible to turn a sharp edge forward, the tooth should be removed and ground or forged sharp.

When a tooth is worn so short that it cannot be set so that it will run as deep as the other teeth, it should be replaced. All teeth should be adjusted so that they will penetrate the soil equally. Adjust their placement so that no tooth follows directly behind another tooth.

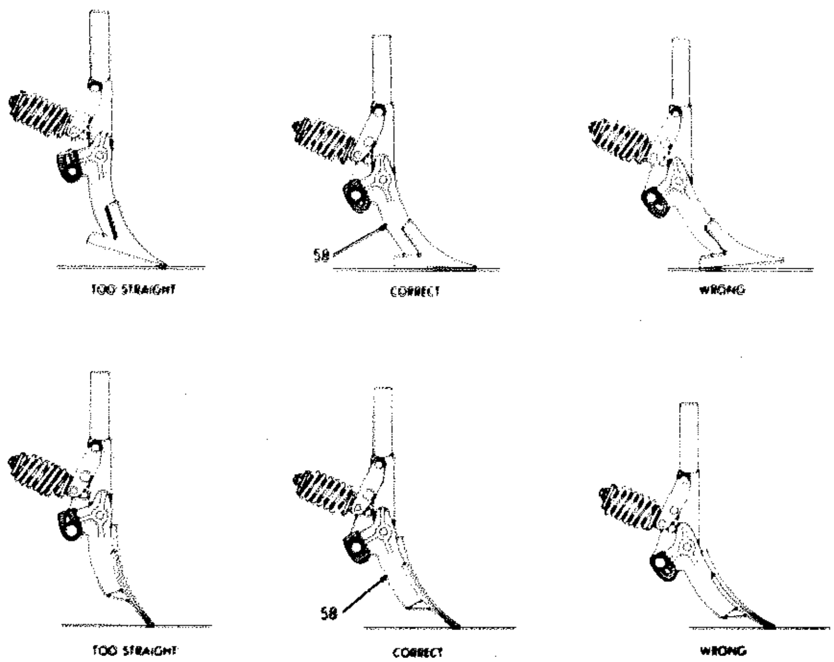
Tighten all teeth, bolts, and nuts. Check to determine whether or not all control mechanisms are operating correctly.

ROW-CROP CULTIVATORS

Tractor-mounted row-crop cultivators are in common use on the vast acreage of row crops in the United States. The most common type of soil-engaging part used on a cultivator is some kind of shovel.

Adjusting Shovels—All shovels should enter the soil easily and to the same depth. They should be set to run straight ahead and not crowd toward or away from the row. If a shovel does not enter the soil easily, it may need sharpening or a reshaping of the point. Penetration of a shovel is determined by the degree of pitch of the shovel. If a shovel is set too flat, it will not penetrate. If set too straight, it will not penetrate and will tend to "jump." A shovel should usually be set at a 135-degree angle. A T-bevel may be set at a 135-degree angle with a combination square. The T-bevel can then be used to set the correct pitch of the shovels. When shovel pitch is being set, be sure the gangs are level. Each shovel shank should be raised or lowered so that all the shovel points are level.

Prefield adjustments can be made by drawing lines on a floor at a width equal



(Courtesy Allis-Chalmers Mfg. Co.)

Fig. 29.25. Correct and incorrect shovel and sweep settings. To adjust, loosen the adjusting bolt in the shovel or sweep sleeve (58).

to the width of the rows to be cultivated. The tractor wheels should be set apart twice the distance of the width of the rows. The tractor can then be driven over the lines drawn on the floor.

The tractor should be blocked to a height equal to the operating depth of the cultivator when leveling the shovels, setting the pitch of the shovels, and setting the distance of the shovels from the row. When this is done, the shovels can be set in the exact position in which they will be working.

After the inside shovels are set at the proper distance from the row, the remaining shovels should be adjusted so that they will cultivate the rest of the soil between the rows.

When the inside shovels are angled toward the row to hill the soil around the row, crowding can be prevented by angling the back shovels in the opposite direction. When the inside shovels are angled away from the row to prevent the covering of young plants, the back shovels are angled toward the row.

Adjusting Lifting Mechanism—Most row-crop cultivators are equipped with hydraulic lifts for raising and lowering the gangs. The lifting mechanism should work freely. If springs help in lifting the gangs, they may need to be adjusted. The valves of the hydraulic lift should be checked to determine whether they are operating correctly. Checks should also be made for leaks in the hydraulic mechanism.

Repairing—The first step in repairing all machines, including a cultivator, is to clean all parts of dirt and grease. All moving parts should be checked for wear. Loose parts and bolts should be tightened. The hydraulic mechanism should be carefully checked for wear, for leaks, and for valves that are operating improperly.

Broken parts should be repaired or replaced. The shovels should be examined for wear and dullness. If the shovels are dull but the correct shape, they may be sharpened by grinding. The under edge of a shovel should be ground with a 45-degree bevel when it is sharpened. If the point is worn out of shape, it should be heated and repointed. If worn severely, the shovel may have to be replaced.

Lubricate all working parts at regular intervals. The shovels should be covered with a thin coat of oil at the close of the day and with a thick coat of grease before being stored at the end of the season. *Remember, preventive maintenance may save many costly repair bills.*

MOWERS

A mower presents most of the problems found in general machinery overhauling. It is one of the most important implements on nearly every farm, and being a machine with fast-moving parts, it is subject to rapid wear. A mower appears to be a simple machine, but there are many adjustments that are not understood and consequently never made. The parts of a mower are accessible, and, almost without exception, every part subject to wear can be replaced. When properly repaired and adjusted, a mower can be kept as long as the major framework is sound. Much of the cost of a mower is in the cutter bar and sickle, which are readily accessible for repairing. Many mowers that have been discarded can be repaired and made serviceable for a relatively small sum of money.

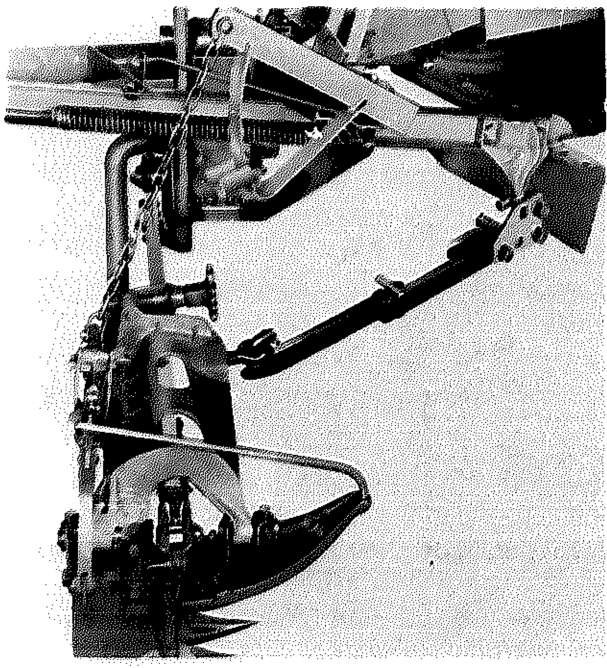
MOWER DIFFICULTIES

Common mower difficulties are heavy draft, side draft, broken guards, broken knives, unmowed streaks, and uneven cutting. The causes of these difficulties are many, such as lag of cutter bar, lack of register of knives, worn ledger or wear plates, guards not being aligned, dull knives, sprung knife bar, worn knife bar head, and worn pitman.

MOWER CUTTER BAR ADJUSTMENTS AND REPAIR

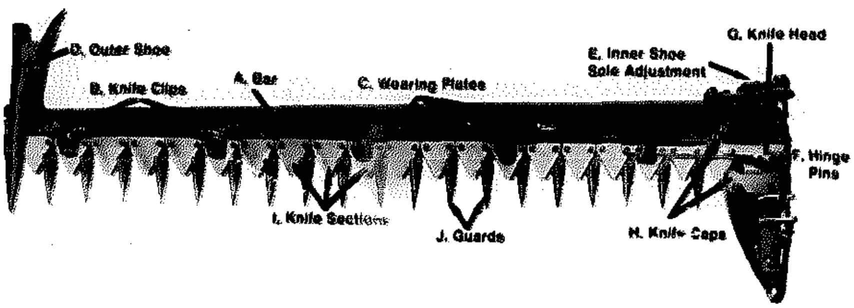
Lead—Improper lead in the cutter bar is the cause of many mower difficulties. The outer end of a cutter bar should *lead* or be set ahead of the inner end of the cutter bar.

In determining the amount of lead a cutter bar has, place the hitch in its operating position. The outer end of the cutter bar is then pulled back as far as it will go. A cord may then be fastened to the flywheel end of the pitman and placed along the pitman to the outer shoe. Be sure to keep the string parallel to the pitman. The amount of lead is the distance the cord is from the back edge of the knife at the outer end of the cutter bar.



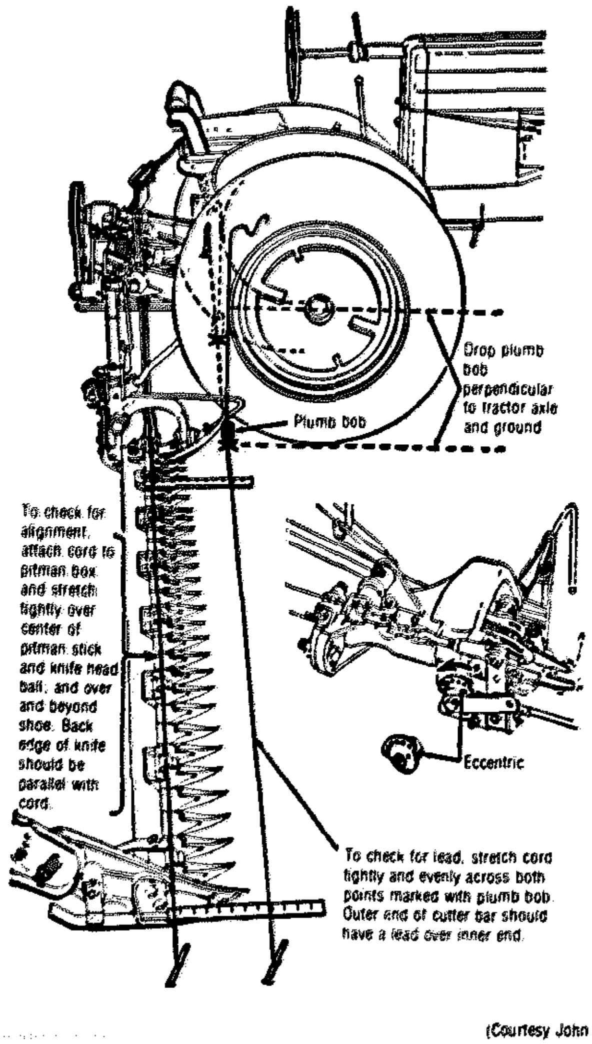
(Courtesy International Harvester Co.)

Fig. 29.26. A mower showing an automatic safety release in the tripped position.



(Courtesy International Harvester Co.)

Fig. 29.27. A mower cutter bar with the important parts named.

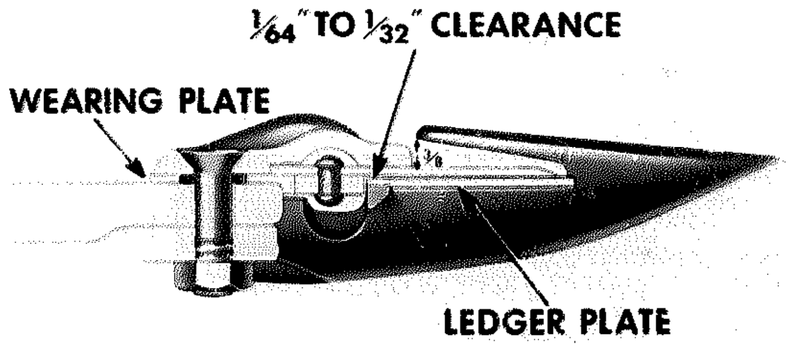


(Courtesy John Deere, Moline, Ill.)

Fig. 29.28. How to determine the lag or lead in a cutter bar.

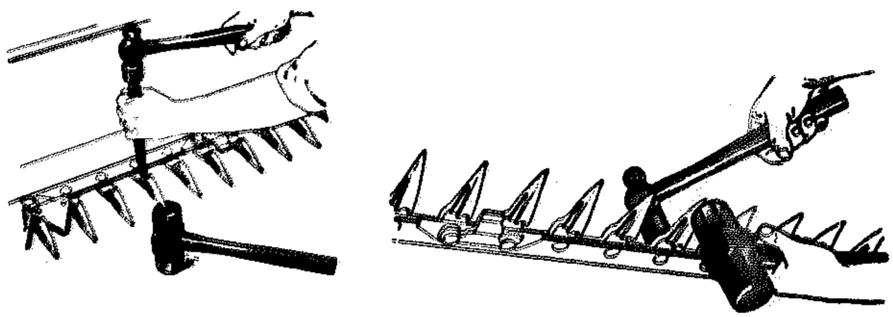
A lead of 1/4 inch per foot of length of cutter bar should be provided. Some of the newer mowers are provided with a device for making this adjustment. However, the operator's manual for the mower being adjusted should be consulted. It will provide instructions regarding the method of making lead adjustments.

Guards—The guards on a cutter bar must be in alignment, and the ledger plates on the guards must be periodically replaced and adjusted to obtain a good job of mowing. See Fig. 29.29 for an identification of the parts of a guard.



(Courtesy International Harvester Co.)

Fig. 29.29. A cutaway view of a guard and knife showing the correct adjustments for the guard lips and the ledger plates.



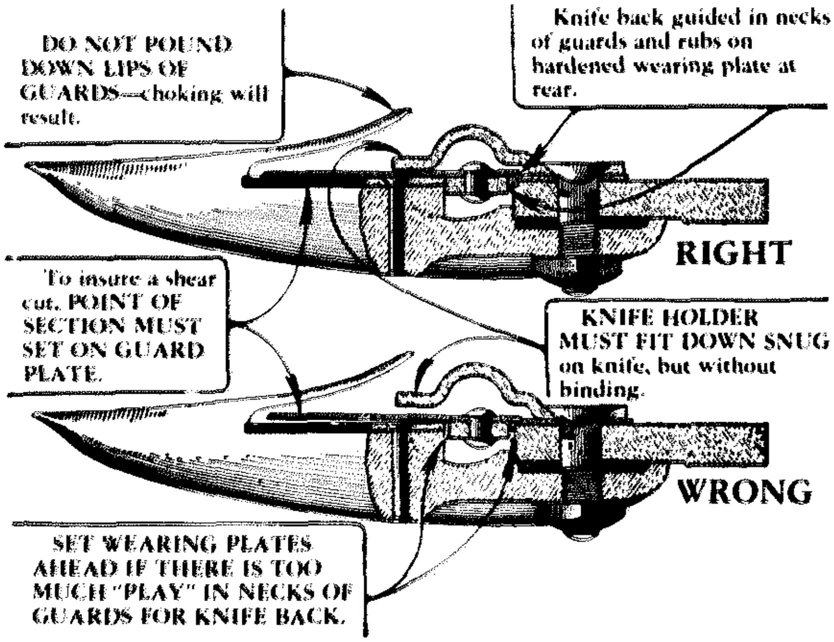
(Courtesy Massey-Ferguson, Inc.)

Fig. 29.30. To align the ledger plates in a mower cutter bar, remove the knife assembly. If it is necessary to lower the heel of the ledger plate, follow the procedure illustrated on the left. If it is necessary to raise the heel of the ledger plate, follow the procedure illustrated on the right.

Cutting depends upon a shear cut between the knife section and the ledger plate. To obtain this shear cut, it may be necessary to move the guards up or down. The knife holders may have to be raised so that the knife will not bind while the alignment of the guards is being checked. Before the guards are moved up or down by hammering, tighten the guard bolts. The guards are then struck with a hammer at their thickest part in front of the ledger plate. A good procedure is to pound all the high guards down first and then pound up all the low guards. Remove the knife and sight across the ledger plates to determine whether or not they are in line. When the ledger plates are in line, align the guard wings. The alignment of the guards on a cutter bar should be checked periodically.

The back of a mower knife rubs against *wearing plates*. (See Fig. 29.31.) These wearing plates must be adjusted, by moving them forward, or replaced as they and the back of the knife are worn away. When worn, they allow excessive play in the knife and they allow the rear of the knife to drop, which lifts the front of the section from the ledger plate. Poor cutting results. When wearing plates are moved forward, align the front edges of the plates.

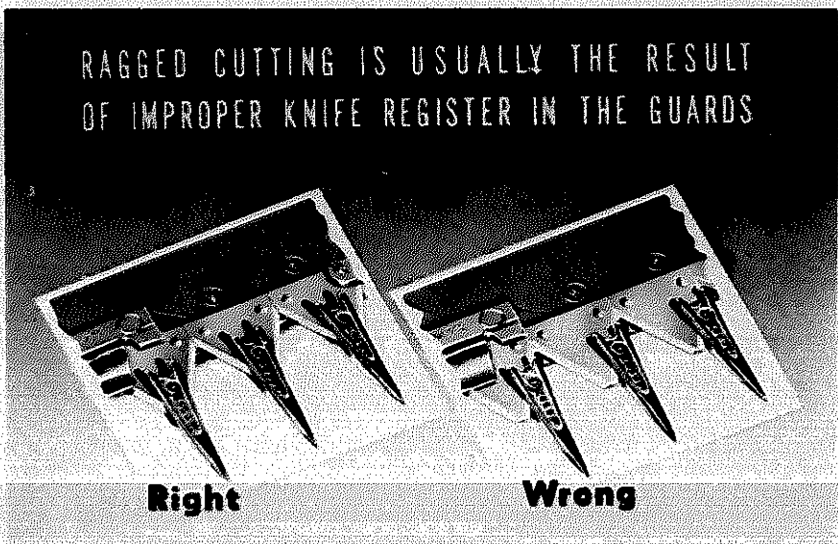
Knife holders (see Fig. 29.31) should be adjusted so that they hold the knife in place, but they should allow the knife to work freely. A knife should have about $^1/_{100}$-inch clearance between the ledger plates and the knife holders. To tighten a knife holder, strike it on the tip. To draw it away from the knife, strike it, with a peen hammer, between the bolt heads holding it to the cutter bar.



(Courtesy John Deere, Moline, Ill.)

Fig. 29.31. The correct and the incorrect way for mower knives to fit and operate in the guards.

The *ledger plates* in the guards form one of the cutting edges. (See Fig. 29.29.) They are riveted to the guards. When the serrated edges become worn, they should be replaced. Remove the guard and place it in a mower block or anvil available from machinery companies. (See Fig. 29.35.) Punch out the rivet holding the ledger plate. Insert a new ledger plate and tap it forward into position. Insert the rivet and place over the rivet post of the mower anvil (see Fig. 29.35) and rivet the plate in place. Then tighten the plate with a few blows to a punch placed over the head of the rivet.



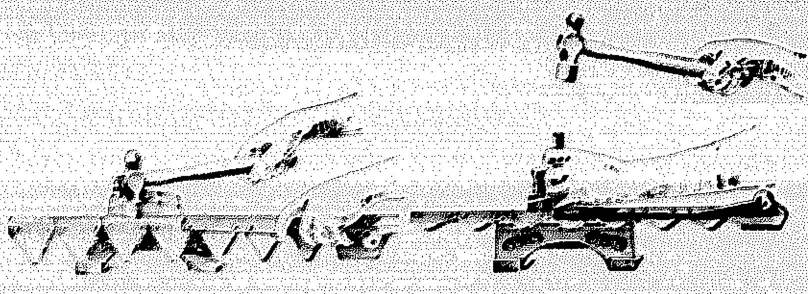
(Courtesy John Deere, Moline, Ill.)

Fig. 29.32. Correct and incorrect knife register.

Register—A cutter bar is in register when the knife sections travel from the center of one guard to the center of the next guard with each stroke. If this does not happen, the mower will not cut clean. To adjust a mower with a pitman so that the knives will register, use the following procedure:

1. Move hitch to operating position.
2. Remove play in cutter bar by pulling it back as far as it will go.
3. Rotate pitman until it is at the end of its stroke.
4. Check to determine whether or not the knife sections are centered in the guards.
5. Rotate pitman until it is at the other end of its stroke.
6. Check again to determine the position of the knife sections.
7. Consult the operator's manual for the method of correcting the trouble if the register is incorrect. Different methods are used on various mowers to correct the register.

See Fig. 29.36 for information on checking lead on a mower without a pitman.

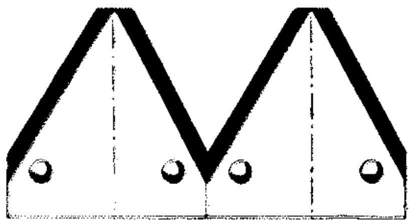


(Courtesy John Deere, Moline, Ill.)

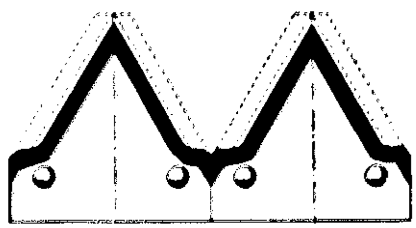
Fig. 29.33. When knife sections are being removed or replaced, use a solid base to prevent the back of the knife from being bent or broken.

Knife Bar—One-half of the cutting mechanism of a cutter bar is the knife bar. (See Fig. 29.27.) For a mower to work properly, however, the knife bar must be straight and the knife sections must be sharp.

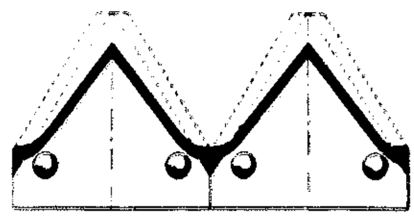
The knife sections may be sharpened. (See Fig. 29.34.) After they are so worn that they can no longer be sharpened successfully, they should be replaced. To replace knife sections, use a mower anvil (see Fig. 29.35) or put the bar in a vise with points of the sections down. Strike the back of the sections over the rivets. This will shear the rivets without bending or breaking the back of the knife. (See



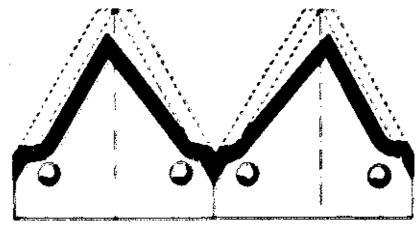
New sections—proper bevel and angle for good work.



Sections properly ground. Even after repeated grinding, proper bevel and angle are retained.



Improperly ground sections—narrow bevel and wrong angle which changes the angle of shear.



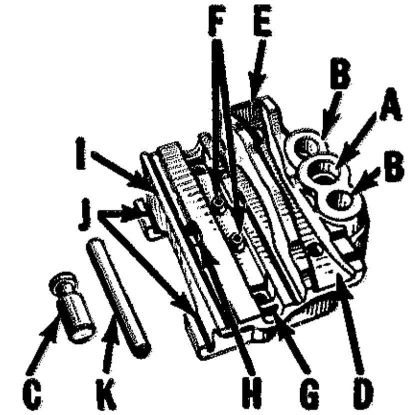
Sections ground off center, destroying the register of blade in guard.

(Courtesy John Deere, Moline, Ill.)

Fig. 29.34. The correct and incorrect methods of grinding mower knives. Dotted lines show the outline of new sections. A knife that is dull or improperly ground reduces the effectiveness and the efficiency of a mower. It causes heavy draft, excessive wear, and ragged cutting. It may increase draft 30 per cent.

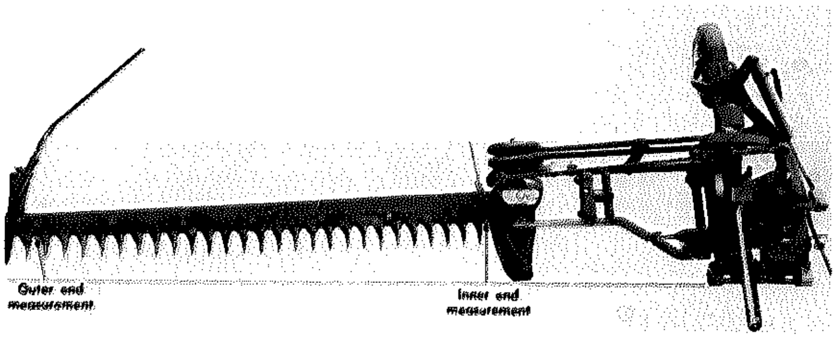
Fig. 29.33.) Insert the new sections and rivet them securely. The rivet heads should be formed with a rivet set.

If a knife bar becomes bent, it may be straightened in a vise. Check to determine whether or not the knife bar is straight, both up and down and edgewise.



(Courtesy John Deere, Moline, Ill.)

Fig. 29.35. A mower repair block. Hole "A" is used for riveting the wrist pin to the flywheel. "B" indicates the holes for the guard plate riveting post "C." "D" is the anvil for the mower guard. "E" is the anvil for a combine or binder guard. "F" indicates the removable hardened riveting posts. "G" is a groove for the knife back. "H" indicates the hole through which sheared rivets are driven. When sections are sheared, the knife back rests on edge "I." The grooves "J" steady the knife. "K" is the rivet set used in completing the job of riveting.



(Courtesy International Harvester Co.)

Fig. 29.36. To check the lead of the cutter bar of a rear-mounted pitmanless mower, stretch a cord across the front edge of the mower to the outer end of the cutter bar. Then measure distances from the cord to the back of the knife at the inner end and at the outer end. The difference between the two is the lead of the cutter bar.

MOWER PITMAN REPAIR

Pitman Rod—Excessive end play at the knife end or pitman box end of a pitman rod causes a cutter bar to cut poorly. Some mowers have a self-adjusting pitman rod which automatically eliminates this end play. If the mower does not have a self-adjusting rod, shims or adjusting bolts are provided for removing the end play. If a pitman rod must be replaced, check for register and lead of the cutter bar after the replacement.

Pitman Pin—Examine the pin for wear. To replace it, remove the flywheel and crankshaft from the machine. Place the flywheel on an anvil and strike the pin with a heavy hammer or sledge to break the pin. The stub in the flywheel can then be driven out and a new pin riveted in place.

Pitmanless Drive—Some front- and rear-mounted mowers use counterbalance wheels in a gear box to drive the knife in the cutter bar. The counterbalance wheels in the gear box change rotary motion to reciprocating motion the same as the pitman does.

The cutter bar of pitmanless drive mowers may be operated above or below a horizontal position. Pitmanless drive mowers operate with less vibration and at much higher speeds than pitman mowers. See Fig. 29.36 for directions for determining the lead of a pitmanless drive mower. Consult the operator's manual for instructions on maintaining the gear box containing counterbalance wheels.

FORAGE HARVESTERS

A forage harvester simplifies the harvesting of forage. It is used to cut or pick up, chop, and blow hay or grass silage into a wagon. With a row-crop attachment, it is used to cut and chop corn and other row crops.

The cutting head attachment on a forage harvester operates in a manner similar to the cutter bar and reel on a combine. The pickup attachment operates in the same manner as a combine's pickup attachment for windrowed grain. The row-crop attachment operates in a manner similar to a combine corn head.

The chopping mechanism of a forage harvester has revolving blades that work against stationary blades or bars.

Maintaining and Adjusting—The revolving knives and the stationary bars in a forage harvester need to be kept sharp. Some forage harvesters have sharpening attachments that may be purchased which permit the sharpening of the blades without removing them from the machine. If a sharpening attachment is not available, remove the revolving blades and sharpen them on a grinder. The stationary bars may also be removed and reshaped on a grinder, or the blades may be turned over and reversed so that a new, sharp edge is presented for the revolving blades to work against.

The clearance between the revolving blades and the stationary bars should be checked frequently. Consult the operator's manual for the machine for the correct clearance between the revolving blades and the stationary bars and for the method of adjusting for clearance.

Most of the drives for cutting, pickup, feeding, and chopping on a forage harvester are protected with slip clutches. These slip clutches should be checked occasionally to determine whether or not they are working correctly. Check the operator's manual for the location of these slip clutches. A slip clutch is adjusted by loosening the springs on the clutch until it slips under a normal load. The springs are then tightened just enough to prevent the slipping of the clutch.

In maintaining a forage harvester do the following:

1. Use the operator's manual for instructions regarding lubrication.
2. Check the machine for loose nuts and parts, and for worn and missing parts.
3. Check the oil level of the main gear box, and if low, fill with the correct grade of oil. Use the operator's manual for specific instructions.
4. Check belts and chains for wear and for proper tension.
5. Check air pressure in tires.
6. Check whether safety shields are in place.
7. Check the blower for bent and broken fan blades and for burnt-out bearings.

Handling Operation Difficulties—If difficulties are encountered in cutting or pickup mechanism, see the mower and combine sections in this chapter for information regarding these problems.

If difficulties are encountered in the chopping mechanism, do the following:

1. Check the knives and shear bars for sharpness, clearance, and lubrication if the chopping mechanism pulls hard.
2. Check whether the fan blades are bent, broken, or out of balance if the blower becomes noisy. Also check the bearings in the blower.
3. Check the speed of the blower and the number of paddles on the wheel if the blower clogs.

BALERS

Baling hay makes it easier to handle, and the storage space needed is reduced. Baled hay weighs 12 to 14 pounds per cubic foot, while loose hay weighs only 4 to 5 pounds per cubic foot.

Several different types of balers are used on farms. Some balers make a round bale, while others make a rectangular bale. Some rectangular balers tie the bales with wire, while other balers use twine.

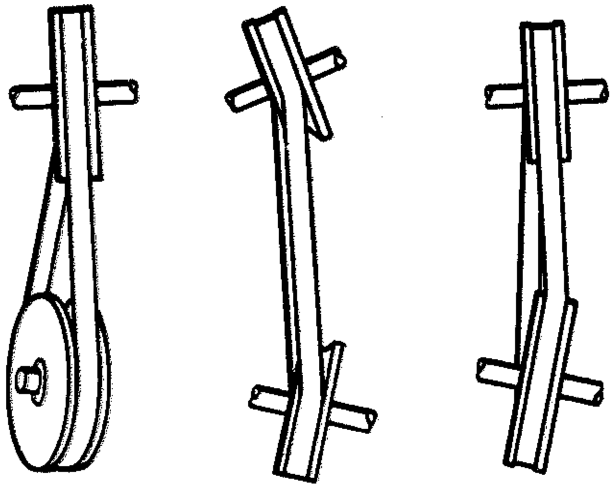
Different kinds and makes of balers vary in the way they are adjusted and maintained. The operator's manual for a baler should be consulted for information regarding adjustments. The following paragraphs will indicate the adjustment and maintenance procedures that are common for many balers.

Adjusting the Pickup and Feeder Mechanism—Belts and chains are used to power the pickup and feeder mechanism of a baler. In adjusting and maintaining the pickup and feeder mechanism of a baler, do the following:

1. Check all belts to determine whether or not they have the correct tension. A belt should not slip, but care must be taken to avoid getting it too tight. A belt that is too tight may damage the bearings on the shafts. If too loose, it will slip and "burn" or wear out too rapidly. A V-belt should have ¾ inch to 1 inch of slack on the slack side of the belt.

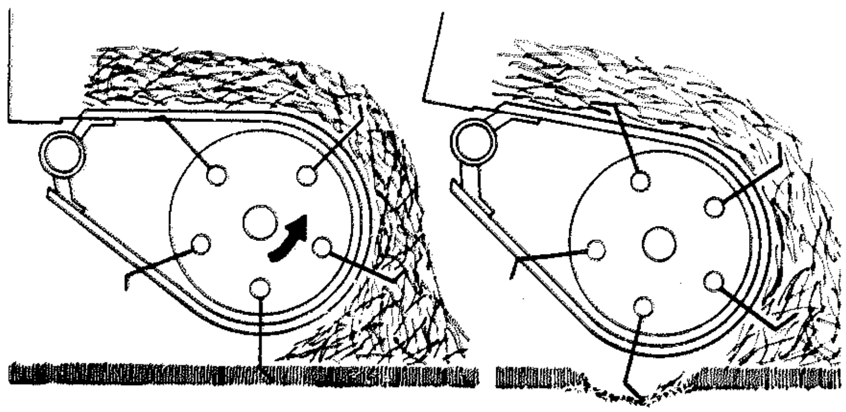
   A belt may be tightened by adjusting the belt tightener provided on the machine. See the operator's manual for detailed instructions on tightening the belts on your baler.

2. Inspect belts to determine whether or not the sheaves, or grooved pulleys, are in alignment. If the sheaves for a belt are not aligned, the belt will roll or twist. If any belts are twisted, check the alignment of the sheaves. If the alignment of the sheaves is correct, the twisting is probably the result of insufficient belt tension.
3. Remove grease from belts by wiping the belts with a cloth dampened with a safe solvent.
4. Clean all belts at the end of the season by washing them with soap and water. When removing belts, loosen the belt tightener. Do not pry the belts off the sheaves.
5. Inspect chains for tension. If the chains, sprockets, and bearings are showing excessive wear, the chains are probably too tight and should be loosened by the method provided by the manufacturer. See your



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.37. Examples of belt-sheave nonalignment. Sheaves should be in alignment.



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.38. The pickup mechanism on a baler needs to be adjusted properly. On the left, the pickup height is correct. On the right, the pickup height is incorrect.

operator's manual. If a chain is riding in the sprocket teeth or jumping off the sprocket, the chain may be too tight.
6. Check the alignment of the sprockets.
7. Clean chains at the end of the season by removing and washing them in a safe solvent.
8. Check the pickup and feeder mechanism for broken parts.
9. Inspect grease fittings to determine whether or not they are working.

Adjusting and Maintaining the Baling Unit—Most balers that produce a rectangular bale compress the hay with a plunger, a block which travels back and forth in the bale chamber and compresses the hay. Knives are used to slice the bale into sections. Different makes of balers use various mechanisms to assist in the packing operation. Consult the operator's manual for instructions on the adjustment of the packing mechanism on your machine. If your baler is not forming good bales, the packing mechanism may need adjustment.

In adjusting and maintaining the baling unit of a baler, do the following:

1. Check the shape and the weight of the bales being produced.
2. Check the speed of the plunger. Consult the operator's manual to determine the correct speed of the plunger.

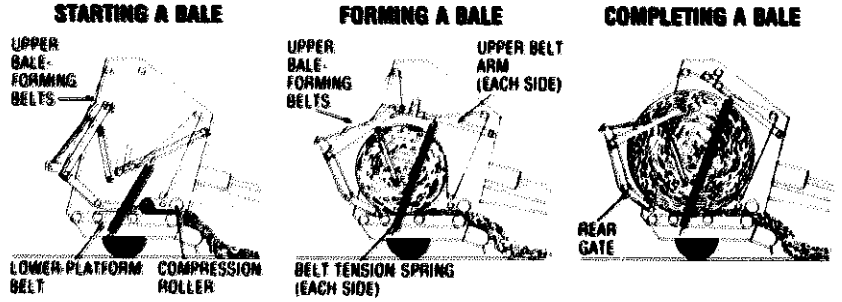
   If the plunger exceeds the strokes recommended by the manufacturer, its wear will be excessive. If the plunger is not operating fast enough, the capacity of the baler will be decreased.

   The first step in adjusting the speed of the plunger is the inspection of the drive belts to determine whether or not there is slippage. If the drive belts are slipping, tighten them. If the drive belts are operating properly, adjust the governor to change the speed of the engine.
3. Inspect the slide blocks on which the plunger travels to determine whether or not the clearance is correct. Consult the operator's manual for the clearance recommended. Wear will increase the clearance, making the reduction of clearance necessary. The clearance may be reduced by adjusting the slide blocks. When these become badly worn, they should be replaced. After adjusting the slide blocks, check the path of the needle on automatic balers with needles.
4. Adjust and sharpen the slicing knives so that a clean cut is obtained. The proper adjustment of the slicing knives requires the correct adjustment of the clearance between the plunger and the sliding blocks. This is true because the stationary blade is mounted on the bale chamber and the other knife is mounted on the plunger.

   Operator's manuals give detailed directions for adjusting the clearance of the slicing knives. Consult your operator's manual. If the knives are dull, they may be removed for grinding, or they may be sharpened on the machine with a file or with a built-in grinder.
5. Break bales apart and check the uniformity of density. Also check the weight of the bales. If the density of the bales is not uniform, or if the weight of the bales is less than it should be, the difficulty may be caused by the improper operation of the retaining plates in the bale chamber. These plates are supposed to (1) hold the hay as it moves through the bale chamber and (2) prevent it from falling forward. On some balers, the retaining plates also help determine the density of the bales.
6. Examine the bales to determine whether or not the desired density is being obtained. If not, adjust the tension springs provided on the bale chamber. Some balers use other devices to control the density of the bales. Consult your operator's manual for instructions regarding the adjustment of these devices.

In adjusting and maintaining the bale-forming mechanism of a baler producing round bales, do the following:

1. Check the tension of the bale-forming bands. The tension of these bands is controlled by springs that are adjustable. See the operator's manual for correct adjustment of these springs.
2. Examine bales to determine their density. The density of round bales is often controlled by a brake mechanism on a tension roller. See the operator's manual for instructions on adjusting the brake mechanism.
3. Check the diameter of the bales being produced. The diameter is changed by adjusting the trip mechanism. See your operator's manual for information on adjusting the diameter of the bales.
4. Inspect the mesh of the gears. Improper meshing may cause several difficulties. The operator's manual provides instructions for adjusting the meshing of gears.



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.39. Starting, forming, and completing a round bale.

Adjusting the Tying Mechanism—Some balers use twine to tie the bales, while others use wire. The adjustment and maintenance of wire-tying and twine-tying balers will be presented separately.

In adjusting and maintaining the wire-tying mechanism of a baler, do the following:

1. Check the timing of the twister pinions. Consult your operator's manual for information on the timing of the twister pinions.
2. Check the timing of the ejector shaft.
3. Inspect the wire-tying mechanism for wear. The wire-tying mechanism cannot be adjusted properly if the parts are worn out.
4. Inspect the alignment of the twister pinions, twister guards, and gripper yoke.
5. Determine whether or not wire-guide rollers are rotating freely. If not, they may need to be replaced because of excessive wear. If they are not worn out, use a safe solvent to free them.
6. Check needle clearance.
7. Inspect the wire-shear plungers to determine whether or not they are functioning properly. If not, the difficulty may often be corrected by flushing them with a safe solvent. If this does not eliminate the difficulty, it may be necessary to replace the springs, the shear plungers, or both.
8. Examine the plate behind the twister pinions for grooves cut by the wire. These grooves may be removed with a file.

Detailed instructions for the adjustment and maintenance of the tying mechanism of a baler should be obtained from the operator's manual for the baler being adjusted.

In adjusting and maintaining the twine-tying mechanism of a baler, do the following:

1. Examine the tying mechanism for wear and for broken and bent parts. Check gears for wear.
2. Determine whether or not the pin in the twine-disk pinion has been sheared or worn.
3. Check the bill hook. If not smooth, use a file for smoothing. If the twine hangs to the bill hook, loosen the tension.
4. Examine the shear bolts on the knotter.
5. Check needle clearance.
6. Inspect the twine-tension spring. If the spring is too tight, insufficient twine will be provided for a knot. If it is too loose, the twine may slip out of the disk.
7. Examine the disk and twine holder for sharp or rough edges. If sharp or rough edges are found, they may be removed with an emery cloth.
8. Inspect sharpness of the twine knife.
9. Check clearance between the knife arm and the bill hook.

Use the operator's manual to locate the parts mentioned in the preceding steps. Also, use the operator's manual for detailed instructions for making the adjustments needed.

COMBINES

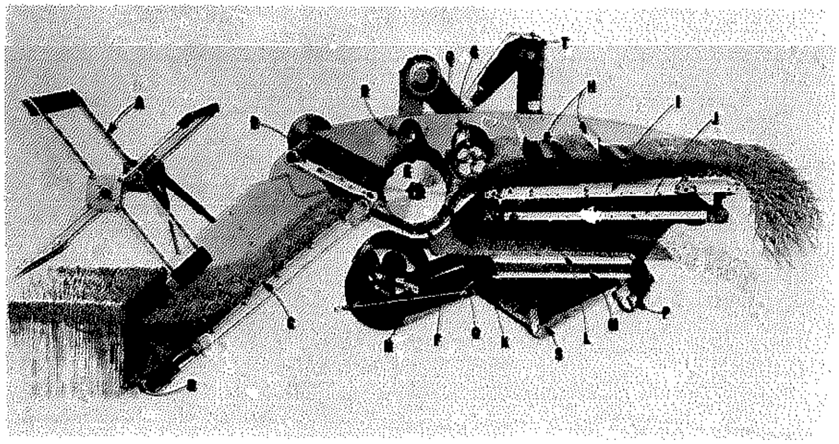
A combine is a machine which cuts a crop, removes the seed from the head or pod, separates the seed from the stalk, and cleans the seed. The improper adjustment or lack of repair of a combine may cost a farmer great losses of seed. The loss of 18 to 20 wheat seeds, 10 to 12 oat kernels, or 4 to 5 soybeans per square foot represents a loss of 1 bushel an acre. Loss of seed can result from failure of the cutting mechanism to cut all the grain, failure of the threshing mechanism to remove the seed from the head or pod, and failure of the separating mechanism to separate the seed. Seed may also be lost by cracking in the threshing process or by blowing away in the cleaning process.

Adjusting the Cutting and Feeding Mechanism—Losses of grain may be caused by the cutter bar's being set too high. A cutter bar should cut no more of the stem than necessary, but it should be low enough to obtain all the seed kernels.

Losses may be the result of the shattering of the seed kernels from the pod or head. Shattering is often caused by a rapidly moving reel. The speed of a reel may be reduced by changing the size of the sprockets operating the reel.

A cutter bar may also shatter grain. If it does, it needs to be repaired. There are probably broken sections or guards.

Cutter bar losses may result from the grain's not being placed on the platform so that it can be conveyed to the threshing mechanism. This difficulty may often be eliminated by moving the reel back from the cutter bar and closer to it. Leather



(Courtesy John Deere, Moline, Ill.)

Fig. 29.40. A cross section view of a conventional combine, showing how grain passes through the machine.

The reel "A" divides the grain, holds it to the cutter bar "B," and assists in tipping it onto the platform "C," which, together with feeder "D," delivers the grain evenly to threshing cylinder "E."

As the grain travels between cylinder "E" and concave and grate "F" and on back against beater "G," the grain is removed from the head, and the greater part of the separation of the grain takes place. The grain falls through perforated grate "F" to shoe pan "K" and is moved back to shoe chaffer "L."

Beater "G" deflects grain down through the front end of the straw rack and also taps straw to get kernels out, then passes the straw onto the straw rack "I." Retarders "H" assist the beater in retarding the straw on the straw rack and prevent the grain from being thrown out by the cylinder. Grain mixed in the straw is shaken out as the straw travels outward and the grain falls through onto grain sieve or conveyor "J" and is delivered back to shoe pan "K" and thus onto shoe chaffer "L" for further separation.

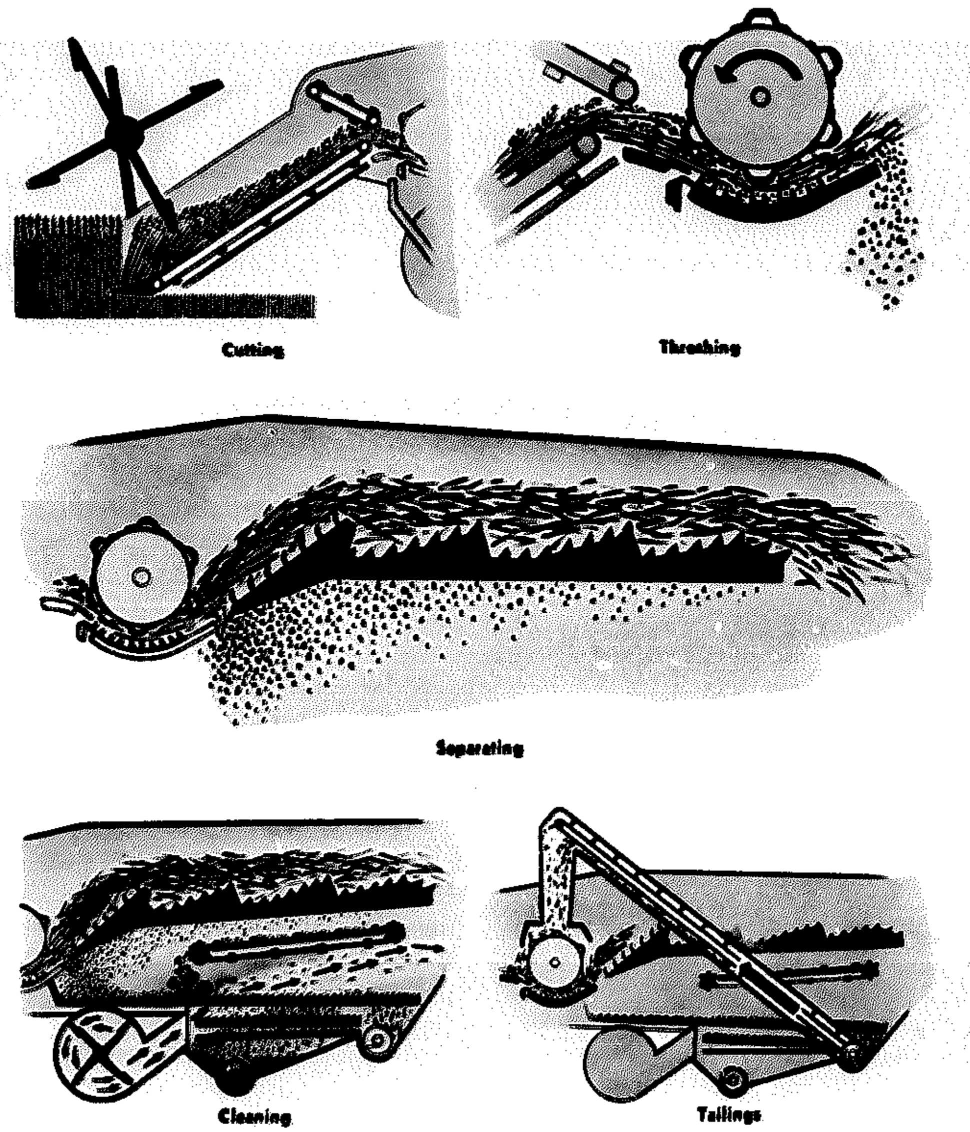
Fan "N" delivers a blast of air, directed by deflector "O," against shoe chaffer "L" and shoe sieve "M." This blast of air, regulated in quantity by gates in the ends of the fan housing, blows chaff out of the grain, and with the aid of the chaffer sieve agitation, moves the unthreshed heads to tailings auger "P." This auger conveys the tailings to tailings elevator "Q," which conveys them to auger "R" where they are delivered to the threshing cylinder for rethreshing.

Clean grain, after dropping through shoe chaffer "L" and shoe sieve "M," is carried by clean grain auger "S" to elevator "T" and delivered through the spout into the grain tank.

pieces may be attached to the reel to brush the cutter bar. The speed of the cutter bar may also have to be increased.

Adjusting the Threshing Mechanism—The cylinder of a conventional combine removes the seed kernels. (See Fig. 29.41.) A cylinder can cause losses by failing to remove the grain or by cracking the grain. Cylinder losses may be measured by catching the material that leaves the back of the machine. If the loss in unthreshed heads is about 1 per cent of the yield, adjustments are needed. The operator's manual should be consulted to determine the recommended R.P.M. for the machine. A tachometer is used to measure the R.P.M. The operator's manual will indicate the points where the R.P.M. of the machine should be measured.

The distance between the cylinder and the concaves (see Fig. 29.43) may have to be decreased. If the clearance is decreased too much, the straw will be broken excessively and the rack and chaffer loss will be increased. See the operator's man-



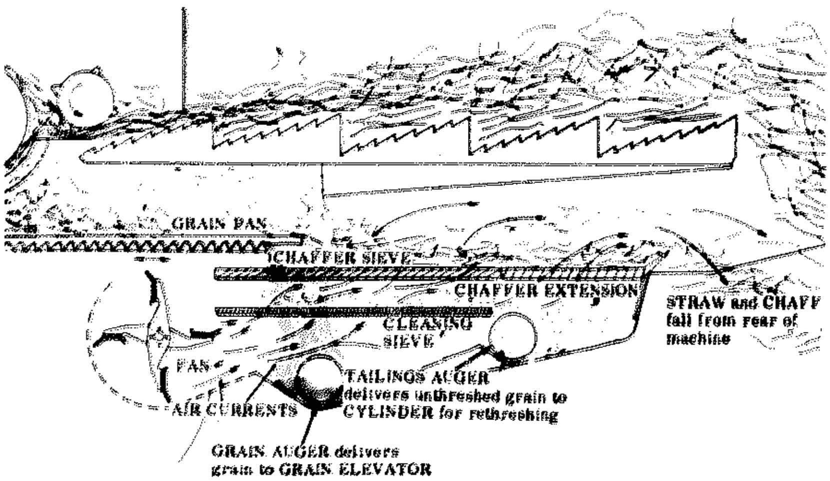
(Courtesy Tractor and Implement Division, Ford Motor Company)

Fig. 29.41. How a conventional combine works.

ual for a combine for instructions on increasing the speed of the cylinder or decreasing the distance between the cylinder and the concaves.

Adjusting the Separating Mechanism—Grain is separated from the straw at the concaves and the straw rack. The rack loss may be measured by catching the straw as it leaves the straw rack and measuring the kernels of grain found in the straw. The rack loss should not be over 0.4 per cent. If the loss is excessive, it may be caused by the rack speed's being too high or too low. The power take-off speed should be checked to determine whether or not it is operating at the speed recommended in the operator's manual. Overloading may cause rack losses. The raising of the cutter bar and the reducing of the speed of travel will decrease overloading. Overloading may also be caused by not enough clearance between the cylinder and the concaves. Insufficient clearance causes the straw to be broken excessively. This may also be caused by the speed of the cylinder being too great. The racks should be checked to determine whether or not they are open. Plugged racks can cause excessive rack loss.

Adjusting the Cleaning Mechanism—Grain is cleaned by a chaffer and shoe sieves. A fan sends air through the sieves and the chaffer, blowing the chaff and dirt out of the rear of the combine. The grain falls through the chaffer and sieves to the grain auger. (See Fig. 29.42.) Loss of grain from the cleaning mechanism may be measured by counting the threshed or free kernels of grain in the material that leaves the back of the machine. If the loss is greater than 0.4 per cent, the need for adjustments is indicated. The chaffer and shoe sieves should be checked for overloading. If overloading is evident, it may be decreased by reducing the rate of travel, increasing cylinder-concave clearance, decreasing cylinder speed, and raising the cutter bar. Another cause may be the incorrect speed of the chaffer. The speed of the power take-off which controls the speed of the chaffer should be checked.



(Courtesy J. I. Case Co.)

Fig. 29.42. A schematic drawing of the cleaning system of a combine.

Loss of grain may be caused by the direction of the wind blast or the power of the wind supplied. The speed of the fan should be adjusted to obtain the correct amount of wind. Loss of grain may sometimes be decreased by enlarging the chaffer openings or by cleaning the openings.

Cracked grain is caused by too small a clearance between the cylinder and the concaves, by an excessive cylinder speed and by too much return of tailings to the cylinder. The adjustments to make for cracked grain are the increasing of the clearance between the cylinder and concaves, the reducing of cylinder speed, and the opening of the lower sieves. See the operator's manual for instructions for making these adjustments, because they will vary with different types of combines.

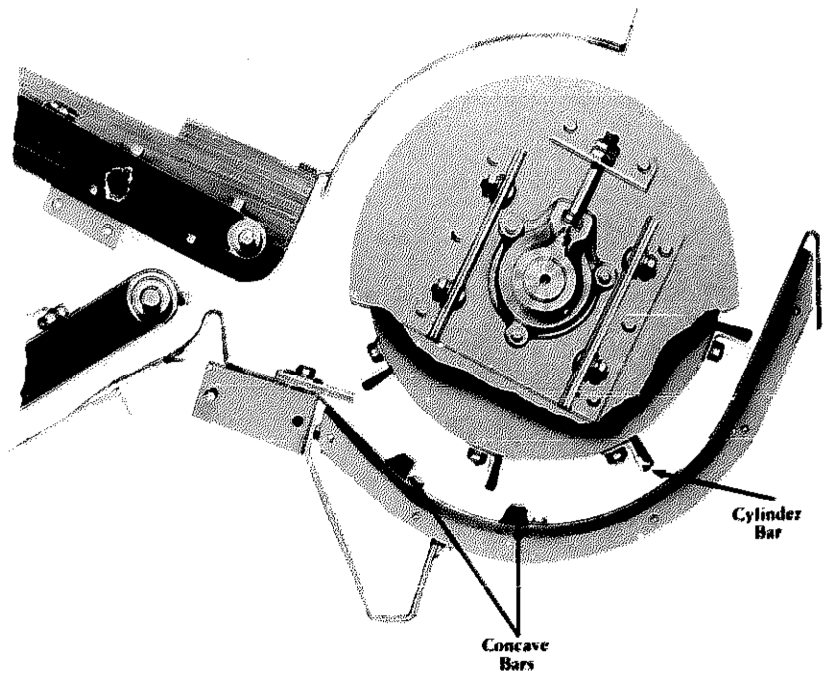
Repairing the Cutting and Feeding Mechanism—The procedures for repairing the cutter bar on a combine are similar to the procedures for repairing a mower cutter bar. The instructions in this section should therefore be consulted.

In repairing the feeding mechanism, check for the following:

1. Worn chains. It is better to replace a worn chain before the season than it is to have a breakdown while combining.
2. Worn sprocket. Sprockets with teeth that are pointed or "hooked" should be replaced.
3. Torn canvas and broken or loose slats.
4. Loose bearings.
5. Bent or broken auger. Sometimes a bent auger can be straightened.

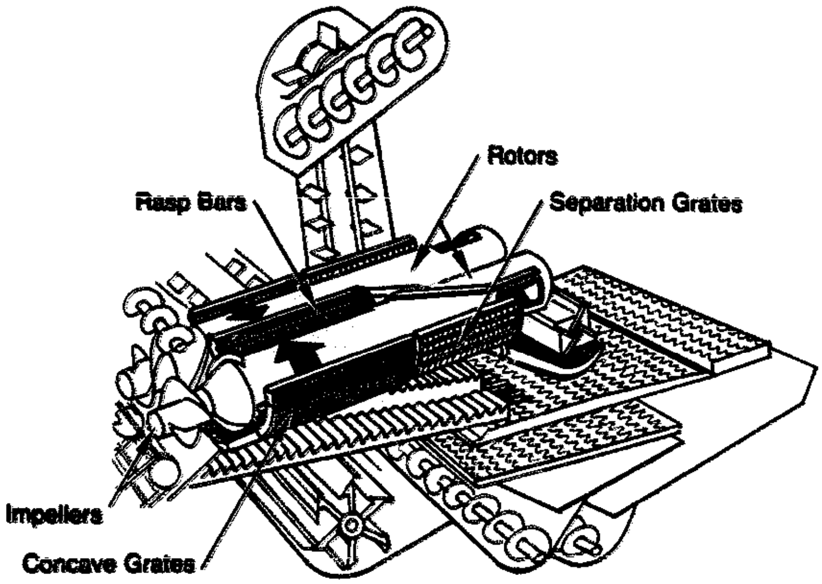
Repairing the Threshing Mechanism—Check the following for needed repairs and make the repairs indicated:

1. Check for wear on a cylinder having rub-bars. If the grooves are not apparent, replace the rub-bars. All rub-bars must be replaced at once or the cylinder will be out of balance. The cylinder will also be out of adjustment if all bars are not replaced at once. Tighten rub-bars frequently and straighten bent bars by striking them with a hammer.
2. Check for broken, bent, and worn teeth on a spike-tooth cylinder. Replace teeth worn thin or pointed and teeth that are broken. Straighten bent teeth. A bar is usually provided for this purpose.



(Courtesy Allis-Chalmers Mfg. Co.)

Fig. 29.43. The threshing assembly of a conventional combine, showing the concave and cylinder bars.



(Courtesy Agriculture Education Division and Vocational Agriculture Service, University of Illinois)

Fig. 29.44. A cutaway view of a twin axial flow, rotor-type combine.

3. Determine whether chains, sprockets, or belts driving the cylinder are worn or broken. Replace if they are.
4. Determine whether or not concave teeth are straight. If they are bent, they can usually be straightened. If they are worn thin or to a point, replace them. If loose, tighten. Examine the concave bars for breaks.
5. Check space between cylinder teeth and concave teeth. The operator's manual should be consulted for the correct spacing. An adjustment mechanism of some type is usually provided for adjusting the space between the concaves.
6. Examine bearings for wear. Check for end play in the cylinder shaft. If present, follow manufacturer's instructions for removing the play.
7. Remove the roller chain and clean it with a safe solvent. A roller chain has a removable link which makes the removal of the chain an easy task.
8. Check open link chains to be sure they are traveling in the correct direction.

When the cylinder teeth are replaced, the balance of the cylinder may be disturbed because the new teeth are heavier than the worn teeth. A scattering of new teeth will not usually throw a cylinder out of balance.

Repairing the Separating Mechanism—Examine the separating mechanism for the following:

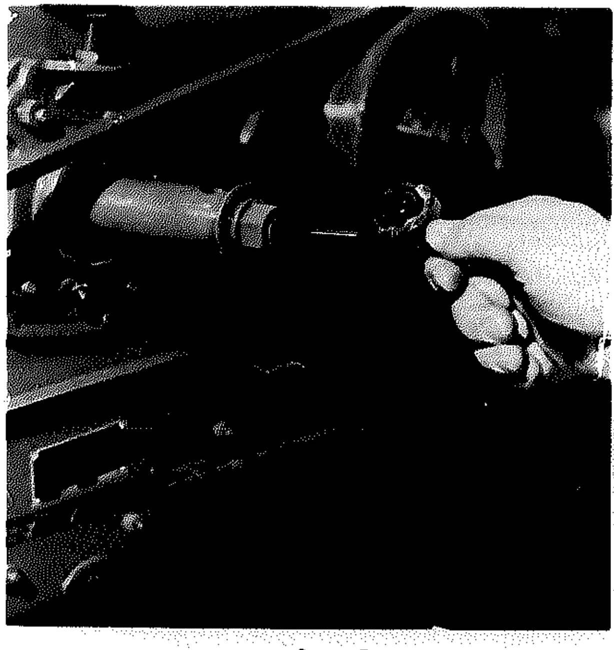
1. Broken and worn racks. Remove racks to repair them.
2. Worn check flaps.
3. Loose rivets and nuts. A periodic check is needed because rivets and nuts on a rack work loose due to the movement and vibration of this part of the machine.

Repairing the Cleaning Mechanism—The cleaning mechanism should be examined for the following evidences of need for repairs:

1. Holes in the grain pan. If the grain pan has holes in it, it should be replaced to prevent the loss of grain through the holes.
2. Loose and worn bearings. Bearings are adjustable.
3. Bent fingers on the chaffer. Bent fingers can usually be pried back into place.
4. Broken slats. Broken slats should be replaced.
5. Dents in sieves. If a sieve is dented, remove it and hammer out the dents.
6. Bent air fan valves. If the air valves are bent, remove and straighten them.

Repairing Elevators, Sheet Metal Parts, Clutch, and Gears—Examine the other parts of the machine for the following:

1. Holes or cracks in the sheet metal. Cracks and holes can often be repaired by patching, riveting, or welding. Examine the elevator and augers for holes and cracks.
2. Loose nuts, rivets, bearings, and screws.
3. Worn gears, chains, and clutch.

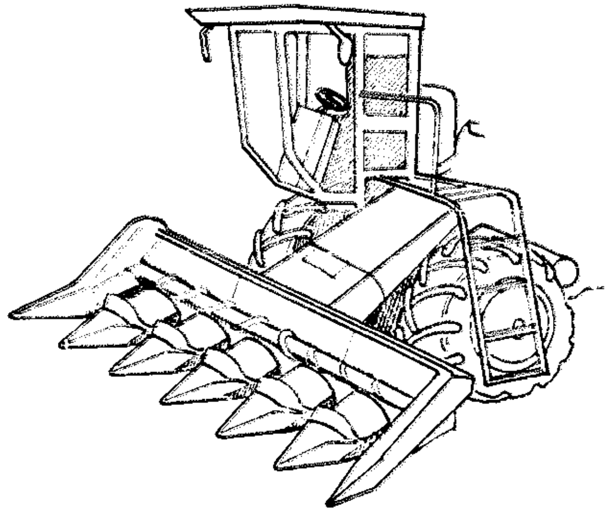


(Courtesy Tractor and Implement Division, Ford Motor Company)

Fig. 29.45. Checking the R.P.M. of the cylinder of a combine.

CORN HEADS FOR COMBINES

The improper adjustment, repair, and operation of a corn head can result in a considerable loss of corn. A combine, with a corn head, in good repair and adjustment should leave less than 5 per cent of the yield of corn in the field. For example, if the yield of corn is 100 bushels an acre, the loss of corn should not be more than 5 bushels per acre. However, the average loss is 10 per cent, or 10 bushels of corn per acre if the yield is 100 bushels per acre.



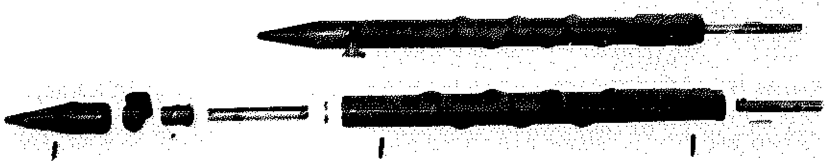
(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 29.46. A combine with a corn head.

The amount of corn being left in the field can be estimated by measuring the ears and shelled corn left on the ground. An estimate of the ear corn left in a field may be made by collecting and weighing the corn on $\frac{1}{100}$ acre, a row of corn 145 feet long, for example, if the rows are 36 inches apart. The loss in shelled corn may be estimated by counting the kernels of corn in a measuring frame of 10 square feet. The accuracy of an estimate may be increased by taking several samples and averaging the results. Twenty kernels per 10 square feet equals one bushel per acre.

Another difficulty encountered because of the improper operation, adjustment, and repair of corn heads is the clogging of snapping rolls and husking rolls.

Gathering and Snapping—If there is an excessive loss of corn, check the gathering chains. They should be tightened so that they will have 1 or 2 inches of slack, depending on their length. The fingers on the gathering chains should be adjusted so that the fingers on one chain are midway between the fingers on the opposite chain when the machine is in operation. The speed of the gathering chains may be increased to assist in picking up down corn. Consult the operator's manual for instructions on changing the speed of the gathering chains. The space



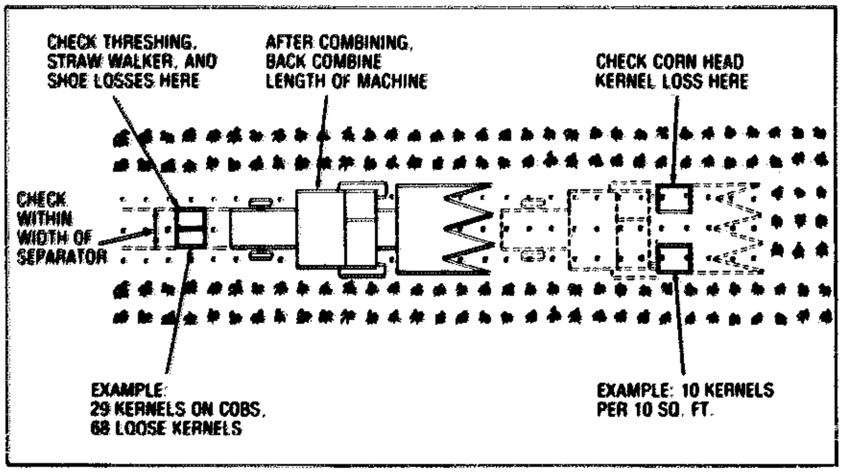
(Courtesy Tractor and Implement Division, Ford Motor Company)

Fig. 29.47. An exploded view of a snapping roll for a corn head.

between *snapping rolls* is adjustable, and the correct distance between the rolls varies with the condition of the crop such as dryness, size of stalk, and toughness of stalk. If the stalks are dry, frozen, or large, the spacing will have to be wider than when the stalks are tough or small. The correct setting is a trial-and-error field adjustment. The adjustment mechanism for snapping rolls on some machines is located at the lower end of the rollers. Usually the rollers should be spaced ¼ to ½ inch apart. If the snapping rolls become clogged easily, there may be several causes. Clogging may be caused by the crushing of stalks, and the pulling of stalks from the ground. It may also be caused by worn snapping rolls, the high speed of the rolls, or the dryness of the corn.

If the stalks are being crushed, widen the distance between the snapping rolls. If the stalks are being pulled from the ground, increase the speed of the snapping rolls. If the snapping rolls are worn smooth, weld beads on the rolls or replace the rolls. If the corn is very dry, add lugs to the rolls. If none of these adjustments is needed, the speed of the rolls may be too great and may need to be reduced.

Excessive shelled corn may be left on the ground because of the improper adjustment of the snapping rolls. Excessive speed of snapping rolls or an excessive number of lugs on the rolls may cause shelled corn to be left on the ground. Improper adjustment of the rolls may also cause a clogging of the husking rolls. The speed of snapping rolls may be changed on some machines without changing the speed of the other parts of the machine. Consult the operator's manual for instructions on how to change the speed of the rolls.



(Courtesy Deere & Company, Technical Services, Moline, Ill.)

Fig. 29.48. Kernel losses of a combine with a corn head should be checked.

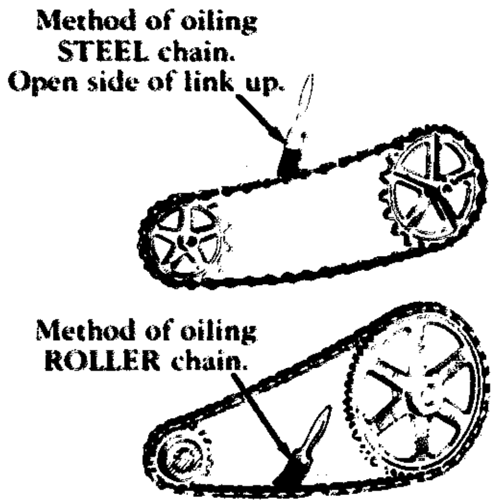
Ear Corn Loss—Ear corn loss is caused by careless driving and by not tilting the corn head forward enough. Keep the snouts of a corn head to the ground to get under the stalks that are down.

Repairing a Corn Head—When gathering chains become worn so that they are loose and when the take-up in the adjustable sprocket has been used, the chains should be replaced. They may be shortened by removing links only when it is possible to remove the same number of links from the chains operating opposite each other; otherwise the chains will be thrown out of time. Smooth-snapping rolls may be roughened by welding beads on them.

Chains and sprockets on the corn head should be examined for wear. A chain should operate with the open side of the hook to the outside and with the hook ends of the links toward the direction the chain is moving.

Sprockets that are not in line should be aligned.

Examine bearings, and tighten or replace loose bearings. Repair sheet metal parts by riveting, patching, or welding.



(Courtesy International Harvester Co.)

Fig. 29.49. Recommended methods of lubricating open-link and roller chains.

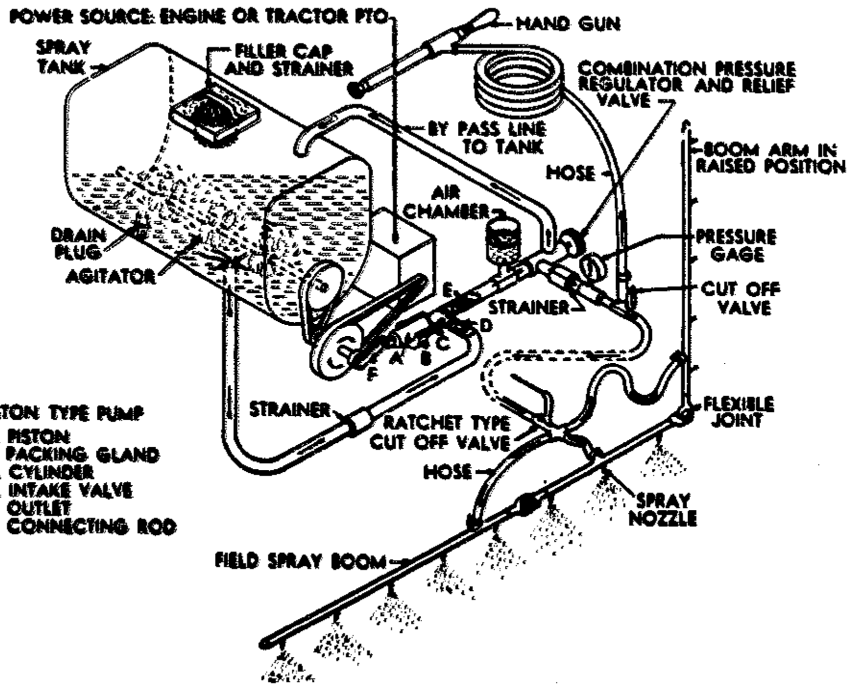
SPRAYERS

A sprayer consists of:

1. A pump
2. A tank
3. A pressure regulator
4. Hoses and nozzles

Two types of sprayers are found on farms and in nonfarm agricultural businesses: high-pressure sprayers and low-pressure sprayers. The high-pressure sprayers are used for specialized jobs and are often found on large commercial farms.

The low-pressure sprayers have a more universal use and may be obtained at a reasonable cost. Low-pressure sprayers are used for (1) insect control, (2) chemical weed and brush control, (3) disease control, and (4) home orchard and vegetable spraying.

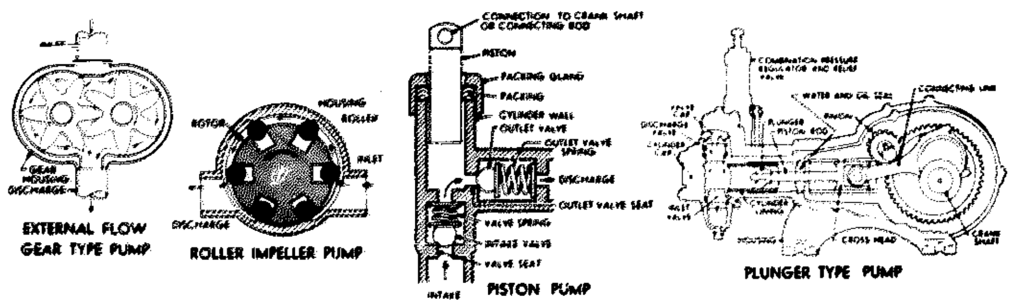


(Courtesy National Sprayer and Duster Association)

Fig. 29.50. A schematic drawing of a typical power sprayer.

Selecting a Pump—The pump is the most important part of a sprayer. There are four main types of pumps in use. They are gear, centrifugal, piston, and plunger. A gear pump is preferred by many sprayer operators because it needs no priming and develops higher pressures at lower speeds. When a gear pump is used, a pressure regulator and by-pass hose are necessary to prevent pressure damage when nozzles are cut off while the pump is operating.

Selecting a Tank—The type of tank needed depends on the type of spray materials that will be used. If corrosive chemicals are to be used, a noncorrosive tank is required. A special copper-bearing steel tank is often used for corrosive chemicals. A stainless steel tank is required for applying liquid fertilizers.



(Courtesy National Sprayer and Duster Association)

Fig. 29.51. Types of pumps used on power sprayers.

A tank should be equipped with screens to keep out of the nozzles materials that might clog them. A screen is needed at the opening where the tank is filled. Another screen is needed at the opening that leads from the tank to the pump. Additional screens are also needed in the nozzles and elsewhere in the system.

A tank should be equipped so that the material in the tank is agitated while the sprayer is in operation. This is essential when suspension-type sprays are being used. A mechanical agitator is needed for some sprays. Most spray materials are agitated sufficiently when a gear pump and a by-pass hose are used. The by-pass hose returns the unused spray material to the tank and thus provides sufficient agitation.

Selecting Hoses and Fittings—Neoprene hose is needed for sprays containing oil. Rubber hose may be used if the spray material does not contain oil. Oil deteriorates rubber rapidly. The hose needs to be of adequate size. For row sprayers the hose should be ¾ inch.

Brass fittings are best because they are corrosion-resistant and gaskets are not necessary.

Selecting a Pressure Regulator—A pressure regulator is needed because different spray jobs require varying pressures. A pressure regulator consists of a pressure gauge, pressure control valves, and cutoff valves.

Selecting a Boom and Nozzles—A boom is needed that is strong enough to withstand its being regulated as to height. It should be hinged to facilitate transporting, if it is made for spraying more than two rows. It should also be equipped with safety hinges to prevent damage if the end of the boom hits an object.

The tips of most nozzles are replaceable so that different orifices may be obtained by changing the tips of the nozzles. Nozzles are available that produce a cone spray pattern or a fan-shaped pattern.

The cone-type nozzle is usually preferred for controlling insects, and the fan-type nozzle is usually preferred for weed control.

Adjusting the Nozzles and Boom—The boom may be adjusted in height to control "wind drift" of the spray material. The closer the boom is to the ground, the less opportunity for "wind drift." The nozzle spacing on a boom should permit the locating of a nozzle over the center of each row. Also, openings should be provided so that nozzle drops may be attached for spraying the sides of row plants. The amount of spray applied is adjusted by the size of nozzle used and by the pressure used.

Calibrating a Sprayer—It is important to know the amount of spray material being applied. The application of too much chemical for weed control not only may waste spray material but may damage the crop.

In calibrating a sprayer, follow these steps:

1. Measure the usable width of the spray boom.
2. Divide the number of square feet in an acre (43,560) by the usable width of the boom. The figure obtained will be the number of feet the sprayer must travel to spray an acre.

3. Check the operation of the sprayer to determine whether or not all nozzles are operating properly.
4. Fill the tank with water.
5. Mark the water level in the tank.
6. Set the tractor's throttle for the speed recommended by the nozzle manufacturer.
7. Set the sprayer for the recommended pressure.
8. Operate the sprayer the distance required to spray a half acre (half the distance found in step 2).
9. Measure the amount of water necessary to fill the tank to the level it was when the test started.
10. Figure the amount of spray being used per acre. For example, if 1 gallon was used to spray ½ acre, the spray rate is 2 gallons an acre.
11. Adjust the rate of spray by increasing or decreasing the speed of the tractor, by changing the size of the nozzle tips, or by changing the pressure.
12. Continue the tests and adjustments until the correct rate of application is obtained.

Maintaining a Sprayer—Nozzles must be kept clean. A small piece of wood may be used to unclog a nozzle. It is not advisable to use a wire for this job, because the wire may enlarge the opening, which would increase the rate of application.

Before calibrating a sprayer, check the nozzles to determine whether or not all of them are discharging the same amount of spray material. Measure the discharge from all the nozzles for a period of two or three minutes. The discharge of all the nozzles should be approximately equal. If a difference is found, some of the nozzles tips may have to be replaced. Nozzle tips wear with use, and it is usually necessary to replace the tips every two or three spraying seasons.

When a spraying job is finished, clean the sprayer. This is important because the chemicals used in spraying often are corrosive. The residues may also be injurious to the next crop sprayed, and it is easier to remove residues immediately after a spraying job than it is after the residues have dried. A sprayer should be taken apart for a thorough cleaning. The nozzles and brass fittings should be stored in oil to prevent corrosion when they are not in use.

PART IV

Agricultural Buildings and Conveniences

AGRICULTURAL BUILDINGS

Student Abilities to Be Developed

1. Ability to make suitable working drawings or sketches before starting to construct or repair a building.
2. Ability to select suitable materials.
3. Ability to evaluate different parts of construction and choose the one that will best meet individual needs.
4. Ability to recognize desirable construction practices and to select the ones which will best meet a particular situation.
5. Ability to lay out a foundation.
6. Ability to do the ordinary construction jobs in agriculture.
7. Ability to do the ordinary agricultural building repair jobs.

CHAPTER 30

Constructing and Repairing Agricultural Buildings

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What planning should be done before construction or repair work is begun?
2. What are some building materials often used in agricultural buildings on farms and in nonfarm agricultural businesses?
3. What are some of the desirable types of floors to use in agricultural buildings?
4. What are some desirable practices in the construction of buildings?
5. How may rafters be cut?
6. What principles of construction should be followed in the erection of pole frame buildings? Clear-span buildings?
7. What procedure should be followed in the laying out of a foundation for a building?
8. When should plywood be used?
9. How may broken or rotted timbers in a building be replaced?
10. How may buildings be made rat-proof?
11. What principles should be observed in the roofing of agricultural buildings?
12. How should foundations be repaired?
13. Why should paint and preservatives be used?

PLANNING

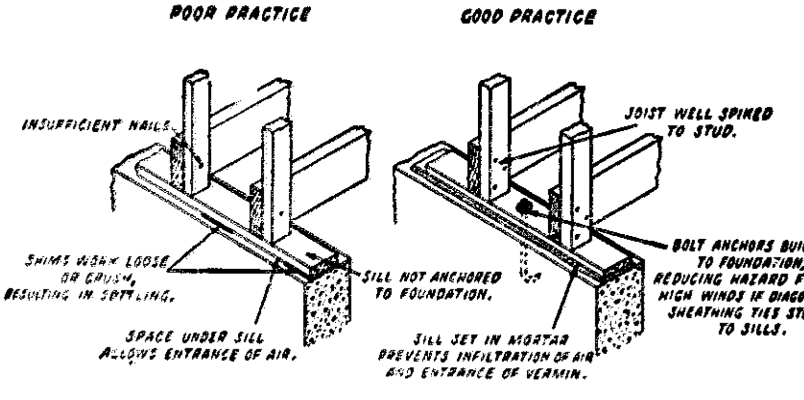
Preliminary Planning Essential—Before the construction of a building is begun, considerable planning should be done. The following steps in planning are suggested:

1. Decide the use to be made of the building.
2. Decide where to locate the building.

3. Decide the size of building needed.
4. Decide on the type of building needed. Keep in mind the appearance of the building in relationship to the other buildings on the farm or on the site of the nonfarm agricultural business.
5. Decide on the kind of materials to use.
6. Review plans and sketches of similar structures. Observe buildings similar to the kind needed. Look for good and poor construction practices in these buildings, such as conveniences provided.
7. Visit lumber yards, hardware stores, and other places handling building materials to discover the kinds of materials and equipment available. Also determine their cost and possible use in your building.
8. Consult persons experienced in building and in using agricultural buildings.
9. Determine whether it would be advisable to construct the building or purchase a building from a commercial building concern.
10. If the decision is made to construct the building instead of purchasing one from a commercial manufacturer, make the necessary sketches, drawn to scale, on graph paper. If a large building such as a house or barn is to be built, take the sketches to an architect and have the architect make the necessary blueprints.
11. Figure bills of materials and the total cost of the building. The supplier of the materials will usually assist in figuring the cost of the building. If a contractor is used, bids from several contractors should be secured.

Building Materials—Various kinds of building materials may be used such as lumber, poles, concrete, brick, and concrete blocks. The kind of material to use will depend on such factors as cost, availability, suitability, materials used in adjacent buildings, and the ability of the builder. For inexperienced builders a frame building is the easiest type to construct. Regardless of the kind of materials used, only good-quality materials should be selected. It is false economy to use poor materials. It requires just as much or more time to construct a building with poor materials as it does to construct a building with materials of good quality.

Desirable Practices in Construction—Before building, familiarize yourself with good and poor practices in the construction of buildings, and be able to recognize such practices when you see them. Several of these are illustrated in this chapter. They should be studied carefully.



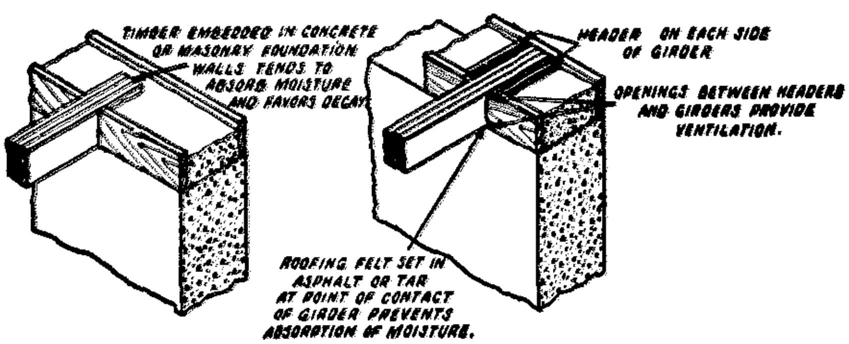
(Courtesy U.S.D.A.)

Fig. 30.1. Foundation sills, showing good and poor practices.

CONSTRUCTING

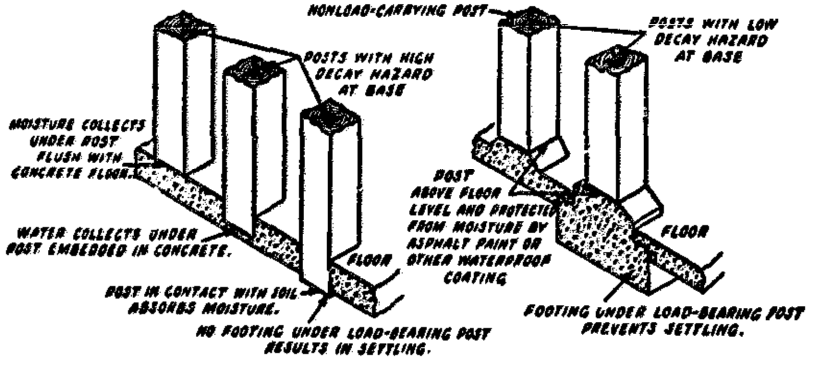
Laying Out a Foundation—The easiest and best way of laying out the foundation of a building is with a surveying level. If a surveying level is not available, the right triangle or 6, 8, 10 triangle method may be used. For large buildings it is best, however, to employ someone with surveying instruments, who is an expert in laying out buildings, to do the job.

In using the 6, 8, 10 triangle method mark out one side or one end of the building's foundation as a base line. In Fig. 30.4 these stakes are labeled A and B. Stakes A and B locate the two corners of the foundation of the building. The distance between stakes A and B is the length of the side or the length of the end of the building. The next step is to measure 6 feet from stake A on the line from stake A to stake B. Drive a stake at this point. Drive a nail in the center of the top of this stake. This stake will be labeled stake G. Drive a nail in the center of the



(Courtesy U.S.D.A.)

Fig. 30.2. Good and poor practices in embedding girders in concrete or masonry.



(Courtesy U.S.D.A.)

Fig. 30.3. Good and poor practices in using posts.

top of stake A. Make certain that the distance from the nail in stake A to the nail in stake G is exactly 6 feet.

The next step is to measure 8 feet from stake A toward corner C. (See Fig. 30.4.) Move this point back and forth until it is exactly 10 feet from stake G. When it is, drive a stake at this point. Put a nail in the center of the top of the stake, which may be labeled stake H. Remeasure to make certain that the distance from stake A to stake G is 6 feet, the distance from stake A to stake H is 8 feet, and the distance from stake G to stake H is exactly 10 feet. You have a right triangle. Line A to H may be extended the length or the width of the building. Drive a stake at this point. It is the third corner of the building. Repeat the process at the third corner to locate the fourth corner, or corner D on Fig. 30.4. Repeat the process at the second and the fourth corners as a means of checking for accuracy. The process may be facilitated by the construction of a right triangle, as shown in Fig. 30.4. The job may be checked by measuring the length of the diagonals, as shown in Fig. 30.5. The lengths of the two diagonal lines should be equal. See Fig. 32.20 in Chapter 32 for information on the use of batter boards to assist in digging foundation trenches.

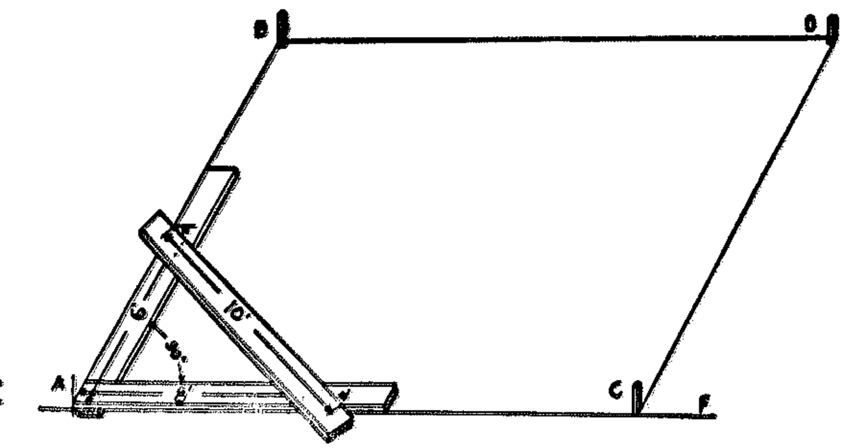
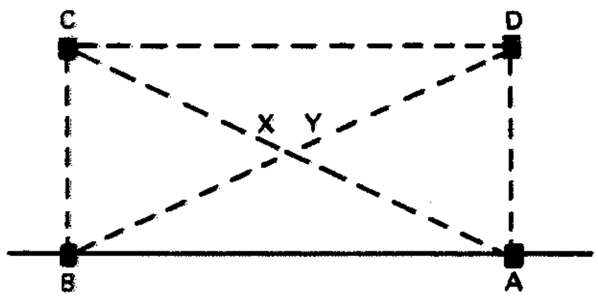


Fig. 30.4. The 6, 8, 10 triangle method of laying out a foundation.



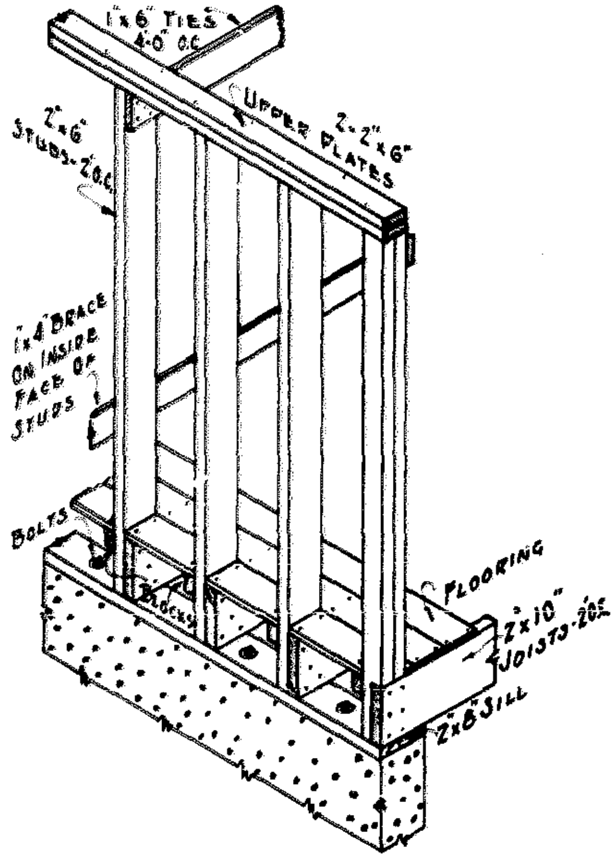
(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 30.5. In laying out the foundation of a building, make sure the diagonal lines X and Y are of equal length.

The size, the type of construction, and the type of soil on which a building is constructed should influence the size and depth of the foundation footing provided.

Floors—Some of the common kinds of floors used in farm buildings are concrete, wood, crushed rock, and earth. The kind to use will depend on the money available, the use to be made of the building, and the wishes of the owner. Concrete makes a desirable type of floor for many farm buildings. In constructing concrete floors, use a well tamped fill of 8 to 10 inches of crushed stone, gravel, or sand.

Wall Framing—In sidewalls the studs and joists should be spaced equally, as shown in Fig. 30.6. Greater strength at the floor line will be provided if the studs extend to the sill and are side-spiked to the joists. The sill should be fastened securely to the foundation with bolts. Diagonal braces placed on the inside of the studs increase strength. Cut-in type of bracing may be used, as shown in Fig. 30.7. Joists and studs should be of adequate size, as shown in Fig. 30.6.



(Courtesy College of Agriculture, University of Nebraska)

Fig. 30.6. Framing detail for new storage structures.

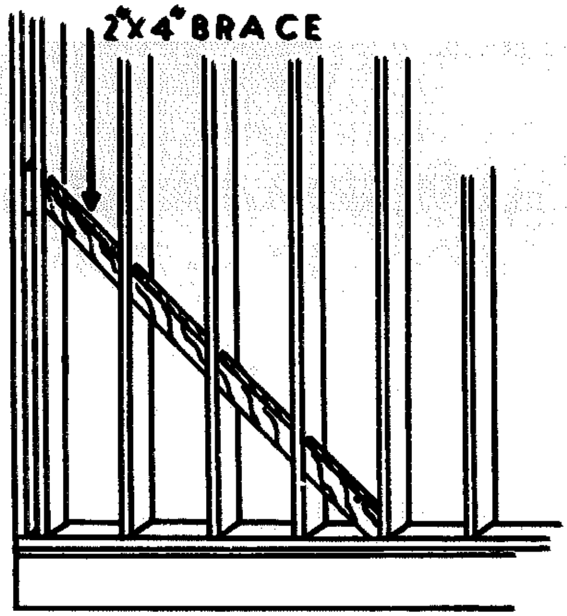
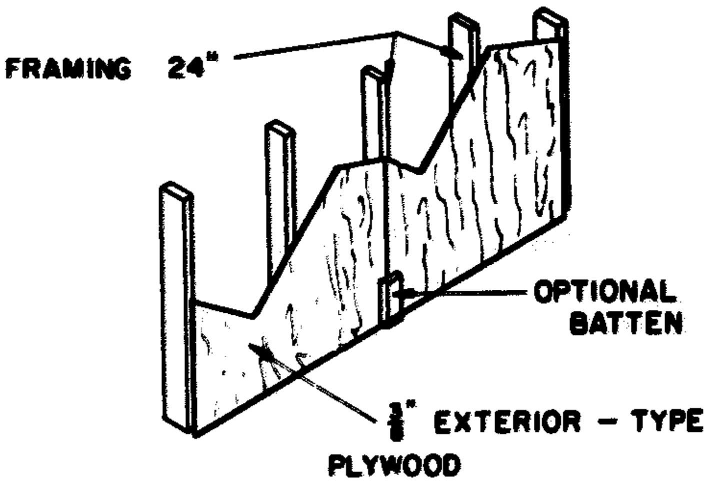


Fig. 30.7. Cut-in bracing, a desirable type of bracing.



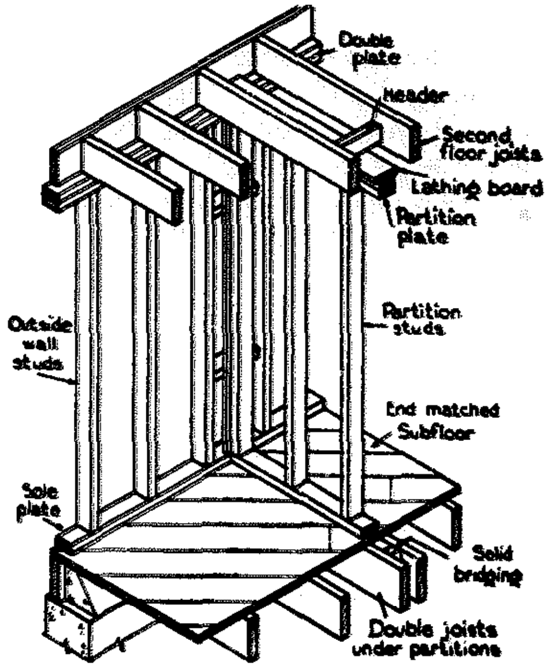
(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 30.8. Plywood sheathing helps to brace a building.

Figure 30.9 illustrates a desirable type of framing for nonbearing partitions. Figure 30.10 illustrates a desirable method of framing doors and windows.

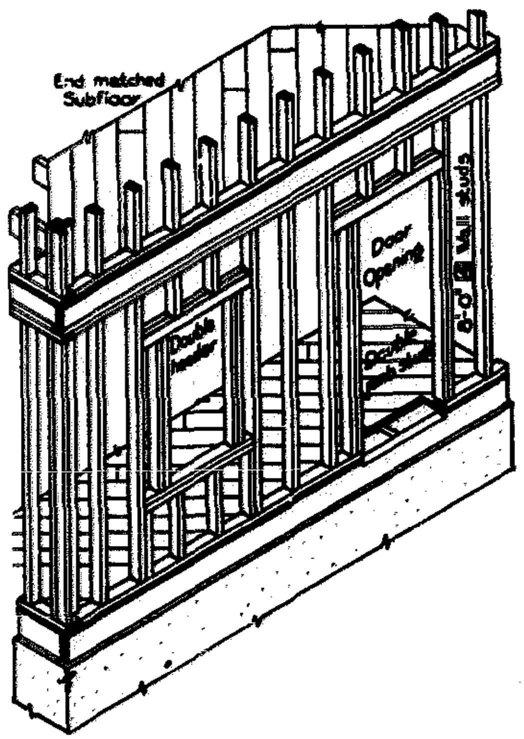
Rafters—It is important that roofs have the proper pitch. Rafters should also fit properly. The first pair of rafters should be cut and put in place to see whether or not they fit before the other rafters are cut. Rafter cutting is discussed in Chapter 10.

Rafters must be strong enough to support the roof, the weight of snow, and



(Courtesy Weyerhaeuser Sales Company)

Fig. 30.9. A desirable type of framing for nonbearing partitions.



(Courtesy Weyerhaeuser Sales Company)

Fig. 30.10. A desirable method of framing doors and windows.

the pressure of the wind. Rafters should not usually be placed farther apart than 24 inches. The sheathing may sag if a wider spacing is used.

The correct size of rafters depends on their spacing, their length, and the kind of wood used. The width of a rafter does not influence the rafter's strength as much as its depth does. If the weight comes from the top down, a 4 by 4, for example, is twice as strong as a 2 by 4, while a 2 by 8 is four times as strong as a 2 by 4 and twice as strong as a 4 by 4. If you figured the board feet in a 4 by 4 and a 2 by 8 of the same length, you would find that the board feet are equal.

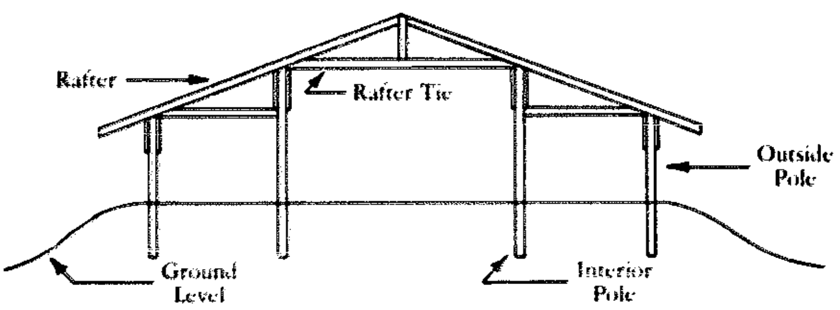
Table 30.1 gives, for New York conditions and for native New York–grown lumber, the sizes of rafters needed for various *runs* of rafters. The run of a rafter is equal to one-half of the span. The span is the distance from the outside ledge of one wall plate to the outside edge of the opposite wall plate.

Pole Frame Buildings—Pole frame buildings are gaining in popularity because of the progress being made in treating poles with preservatives to prolong their life. Pole frame buildings are easy to construct and relatively cheap to build. Such buildings eliminate the necessity of foundations and ground leveling. The amount of reinforcing and bracing is decreased, and the time required to build a pole frame building is less than the time required for other types of construction. Pole frame buildings are usually limited to one story, however.

Many plans for pole frame buildings are available. A good plan suited to your needs should be obtained before construction is started. In constructing a pole frame building, observe the following building principles:

1. Select the straightest poles for the four corners of the building.
2. Set poles a minimum depth of 5 feet. Use level to plumb holes.
3. Nail rafters to poles. Do not notch poles.
4. Locate poles lengthwise of the building not over 14 feet apart or less than 10 feet apart.
5. Use interior poles or wood-trussed rafters when the width of the building is more than 24 feet.

Study Figs. 30.11 through 30.14 for information regarding the methods used in constructing pole frame buildings. Examine some well constructed pole frame buildings for construction ideas.



(Drawn by Ronald Ipsen)

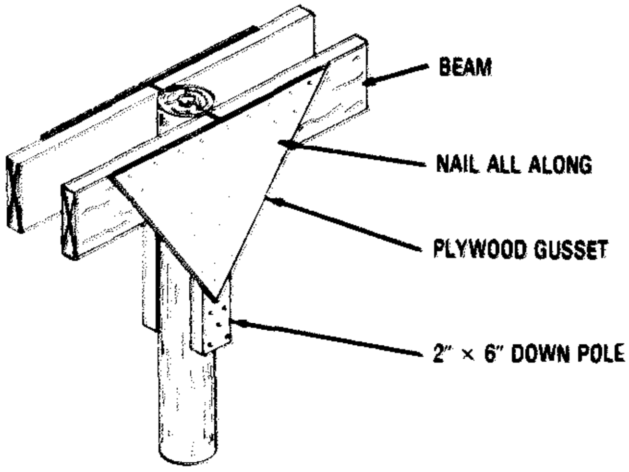
Fig. 30.11. A cross section view of a pole-type building with a gable roof.

Table 30.1—Allowable Clear Span (Horizontal Distance) for Rafters, Variously Spaced and Made of Different Kinds of Wood, Based on No. 2 Common Standard Grades of Lumber (Job Sorted)[1]

Suitable for Flat, Shed, Gable, and the Upper Slope of Gambrel Roofs[2] with Sheathing and with Any of the Usual Roof Covering Except Slate or Gravel-Covered Built-Up Roofing[3]

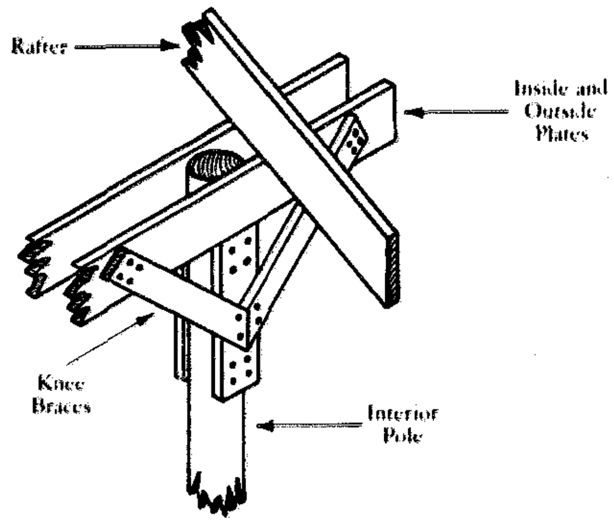
Kind of Wood[4]	Spacing (O.C.)[5]	Size: 2 × 4-inch, Full-sized		2 × 4-inch, Standard-dressed		2 × 6-inch, Full-sized		2 × 6-inch, Standard-dressed		2 × 8-inch, Full-sized		2 × 8-inch, Standard-dressed		2 × 10-inch, Full-sized		2 × 10-inch, Standard-dressed	
	In.	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
Group I: White Ash; Beech; Black and Yellow Birch; Rock Elm; Douglas Fir (West Coast); Hickory; Hard Maple; White and Red Oak; Short-Leafed, Yellow, and Southern Hard Pine	12	13	2	10	11	19	5	16	7	25	5	21	11	31	4	27	3
	16	11	5	9	6	17	3	14	6	22	5	19	2	27	8	24	0
	18	10	10	9	0	16	1	13	9	21	3	18	2	26	3	22	9
	24	9	5	7	10	14	1	12	0	18	7	15	11	23	0	19	11
Group II: Southern Cypress; American and Slippery Elm; Douglas Fir (Mountain Region); Eastern and Western Hemlock; Redwood; White and Red Spruce; Sycamore; Eastern Tamarack	12	11	4	9	5	16	8	14	4	21	11	18	10	26	11	23	6
	16	9	11	8	2	14	7	12	6	19	3	16	6	23	10	20	8
	18	9	4	7	9	13	10	11	10	18	3	15	8	22	7	19	7
	24	8	1	6	8	12	1	10	4	16	1	13	8	19	10	17	2
Group III: Black Ash; Paper Birch; Western Red Cedar; Soft Maple; Northern White Pine; Yellow Poplar	12	10	5	8	8	15	5	13	2	20	2	17	4	24	10	21	8
	16	9	1	7	7	13	6	11	6	17	9	15	3	21	11	19	0
	18	8	7	7	2	12	9	10	11	16	10	14	5	20	10	18	0
	24	7	6	6	2	11	2	9	6	14	9	12	7	18	4	15	10
Group IV: Basswood; Eastern Cottonwood	12	9	7	7	11	14	2	12	1	18	7	16	0	22	10	19	11
	16	8	4	6	11	12	5	10	8	16	4	14	0	20	3	17	6
	18	7	11	6	7	11	9	10	0	15	6	13	3	19	2	16	7
	24	6	11	5	9	10	4	8	9	13	7	11	7	16	10	14	6

[1]Pieces with knots within the middle one-third of the length should be discarded.
[2]The lower rafters of gambrel roofs should be the same size and have the same spacing as the upper rafters of such roofs.
[3]A. M. Goodman, "Roofs and Foundations," Cornell Extension Bulletin 741, New York, p. 19.
[4]Native New York-grown.
[5]O.C., on centers or from center to center.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 30.12. Triangular plywood gussets may be used for bracing needed at poles.

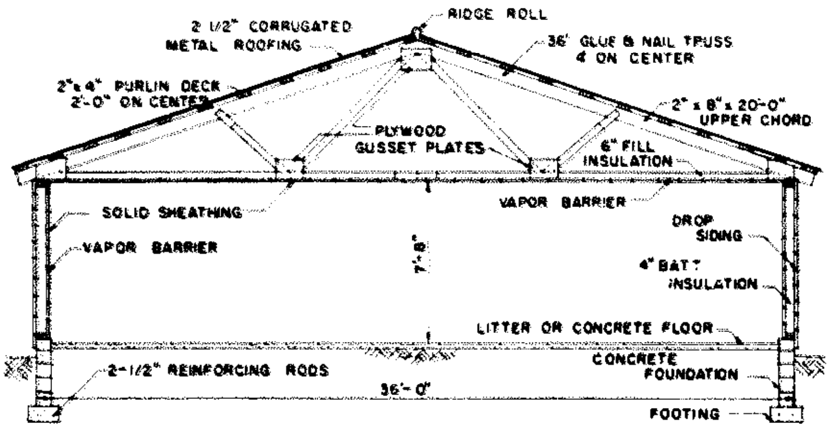


(Drawn by Ronald Ipsen)

Fig. 30.13. A drawing showing the use of knee braces on the interior poles of pole-type buildings. Notice also how the inside and the outside plates are attached to the interior plates.

Clear-Span Buildings—A clear-span building without inside posts or beams has many advantages over a building with interior beams or posts. The use of wood-trussed rafters makes clear-span buildings possible without increasing the costs excessively. Wood-trussed rafters with a spacing of 4 feet may be used for buildings with a clear span of 24 to 40 feet. See Fig. 30.14 for an illustration of a wood-trussed rafter for a building with a 36-foot width.

Before building a clear-span building with wood-trussed rafters, secure a good set of plans. In constructing the wood-trussed rafters, bolt or gusset plate the



(Courtesy Michigan State University)

Fig. 30.14. A drawing of a clear-span building with a glue-nail truss.

trusses and use both glue and nails for added strength. A jig may be used for constructing the trusses.

Using Plywood

Plywood is being widely used in agricultural construction. It is used in farm buildings such as machinery sheds, livestock buildings, and crop storage buildings. Plywood has two-way strength, and it has high impact strength. It has good resistance against splitting and cracking. It is also a building material with high rigidity, which is why it is often used as a bracing material in agricultural construction.

Plywood is durable. Plywood for exterior use is bonded with a waterproof glue that is resistant to acids that result from manure and urine. Plywood is economical because it can be installed at low cost. The skill required in installing plywood is minimal. Plywood has good insulation properties. It is effective in keeping agricultural buildings warm in the winter and cool in the summer, if used for exterior or interior paneling.

Plywood is readily available from lumber dealers in sheets 4 feet by 8 feet. These sheets are true and square. They stack and store easily. They are easily used for framing.

Plywood is easy to work. It is easy to saw, plane, drill, chisel, and nail. Plywood does not split easily when nailed, and it holds nails well. It may be painted or stained easily. Cracking and weathering of the surface of plywood may be retarded by the application of paint on the edges as well as on the surface. Plywood is cross-laminated. This cross-lamination reduces contraction and expansion, due to changes in weather conditions, to a minimum amount.

Types—There are various types and grades of plywood. Make certain that the type and grade being purchased is suitable for its intended use. Plywood is made from many different types of wood. The type of wood desired should also be considered when plywood is purchased.

There are two primary types of plywood. They are exterior plywood and interior plywood. If the plywood is to be exposed to the weather, use only exterior plywood. Interior plywood is not suitable for use in exposed situations. It will soon deteriorate if used for outside construction.

Uses—In agricultural buildings, plywood is often used as an exterior siding. When used as siding, the edges of the plywood panels must be located over framing pieces. Plywood panel edges should be spaced $^1/_{16}$ inch apart to allow for expansion. If the humidity conditions will be very high, space the edges and ends of the panels $^1/_8$ inch apart. Use six-penny common nails for nailing plywood panels up to $^1/_2$ inch thick. If the plywood is over $^1/_2$ inch thick, use eight-penny nails. Battens should be used over vertical joints. Galvanized or aluminum metal flashing is often used for the horizontal joints. This flashing may be purchased.

Plywood is often used for gussets on trusses. Plywood is also often used as an inside wall lining and for ceilings in agricultural buildings. Plywood is widely used as a sheathing material in the construction of roofs. Doors in agricultural buildings are often made of plywood.

When agricultural storage buildings require floors, plywood is often a suitable material. If plywood is used as a flooring material, the face grain of the plywood should go across the supports. This increases the strength of the floor. Use a plywood thickness adequate to support the weight it must carry. If the floor is to support grain, remember that grain is heavy.

ROOFING

Farm buildings are usually roofed with galvanized steel sheets or with asphalt composition shingles. The roofing material selected should be of a type that will last a relatively long period of time.

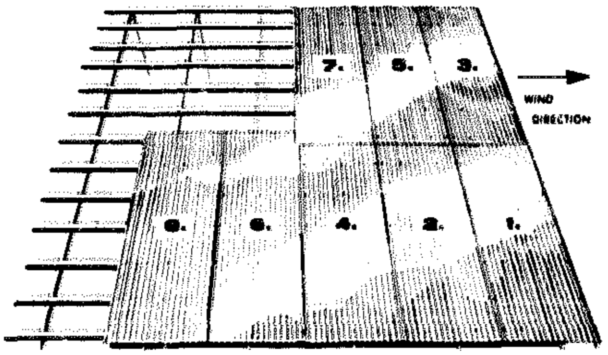
Galvanized Steel Sheets—Galvanized steel sheets are frequently used as a roofing material for agricultural buildings. They last a long time and are easy to install.

The weight and thickness of steel sheet used most frequently is 28-gauge. Some farmers and nonfarm agricultural businesspersons prefer 26-gauge sheets. Sheets heavier than 26-gauge are too thick to nail, and sheets lighter than 28-gauge are flimsy. Some people believe that the thickness and weight of the sheets determine how long they will last. This may not be correct because rust is a major enemy of galvanized roofing, and the thickness of the zinc coating and not the thickness of the sheet determines the rust-free life of the sheets.

In buying galvanized roofing, check the thickness of the zinc coating. Steel sheets with a 2-ounce coating of zinc are usually the best buy, even though the original cost is higher than the cost of sheets with a thinner coating of zinc.

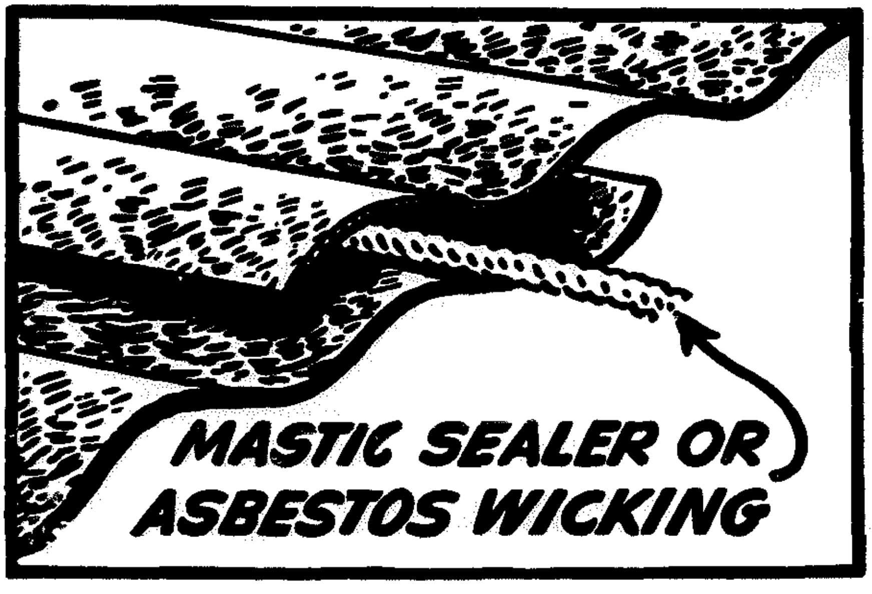
When installing galvanized sheets, first install the nailing girts, 1- by 6-inch strips nailed across the rafters. The galvanized sheets are nailed to these girts. One- by 2-inch filler strips nailed to the rafters between the girts are also advisable. Galvanized roofing may be installed over wooden shingles without the use of girts, but a better roof is obtained when girts and filler strips are first installed over the old roof. When girts are used over an old roof, seal the space between the galvanized sheets and the old roof at the gable ends of the building. Trim material may be purchased for this purpose.

The expansion and contraction of galvanized sheets make necessary the use of nails with special seals, such as lead, on the heads and with screw-type shanks. When installing sheeting, first determine the direction of the prevailing winds. If it is from the southwest toward the northeast, start installing the sheets on a north-south building on the south end of the building. The wind will then blow over the laps instead of under them.



(Courtesy United States Steel Corporation)

Fig. 30.15. The first steel roofing sheet should be placed on the end of the building opposite the direction of the prevailing winds.

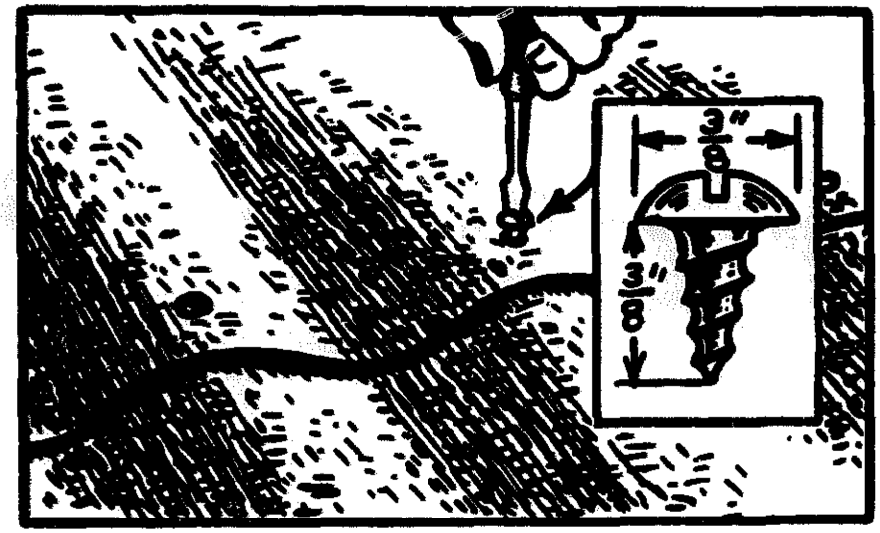


(Courtesy American Zinc Institute)

Fig. 30.16. The use of strips of asbestos wicking or sealing compound between the steel sheets will prevent leakage at the laps.

Nail the sheets just off the crown of the corrugations. Galvanized nails should be used. The nails are usually spaced 5 inches apart on the end laps, and 6 to 8 inches apart on the side laps. Before installing galvanized roofing, read the installation directions provided by the manufacturer of the galvanized sheets.

Galvanized roofs need to be kept in good repair or they will deteriorate rapidly. Galvanized sheets may need to be renailed. If a nail is rusty or loose, pull it out and use a new nail. The new nail should be driven at a new angle so that it will hold. When the sheeting becomes rusty, it should be repainted with a rust-inhibiting paint. See Chapter 11 for information on painting.

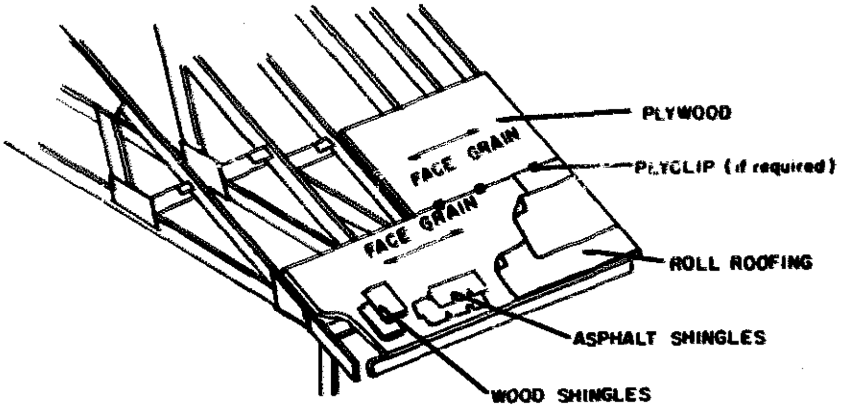


(Courtesy American Zinc Institute)

Fig. 30.17. When a good hold for nails is not available, self-tapping sheet metal screws may be used at the end laps and other places to draw the sheets together tightly.

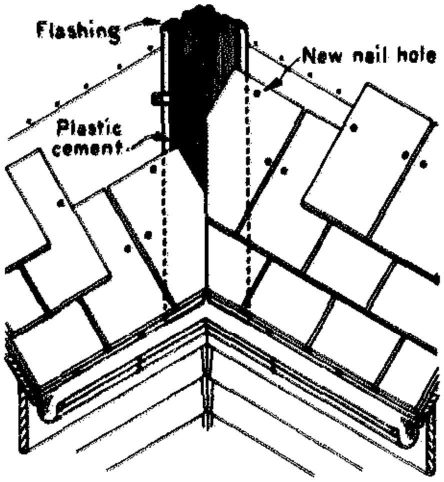
Asphalt Shingles—A tight sheathing deck is required for asphalt shingles. Install an asphalt-saturated layer of roofer's felt to the sheathing first. The layers of roofer's felt should be lapped. An eaves flashing strip should be used, and the first course of shingles should be installed at the eaves. The installation of asphalt shingles is not difficult. Follow the directions of the manufacturer when installing asphalt shingles.

Flashing—Flashing must be installed in the valleys between roof surfaces that intersect and also where the roof meets vertical surfaces. Flashing is necessary to make a roof watertight. Flashing consists of strips of metal or other material. The flashing strips are placed in the valley under the roofing material and are fastened to the roofing material by plastic cement to form a watertight valley. Flashing where a roof meets a vertical surface should extend under the roofing material and up the side of the vertical surface. Plastic cement or other means should be used to form a watertight joint between a flashing and a vertical surface. See Fig. 30.19 for flashing installation in a valley.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 30.18. Plywood used as sheathing over wood trusses.



(Courtesy U.S.D.A.)

Fig. 30.19. Flashing installed in a closed valley.

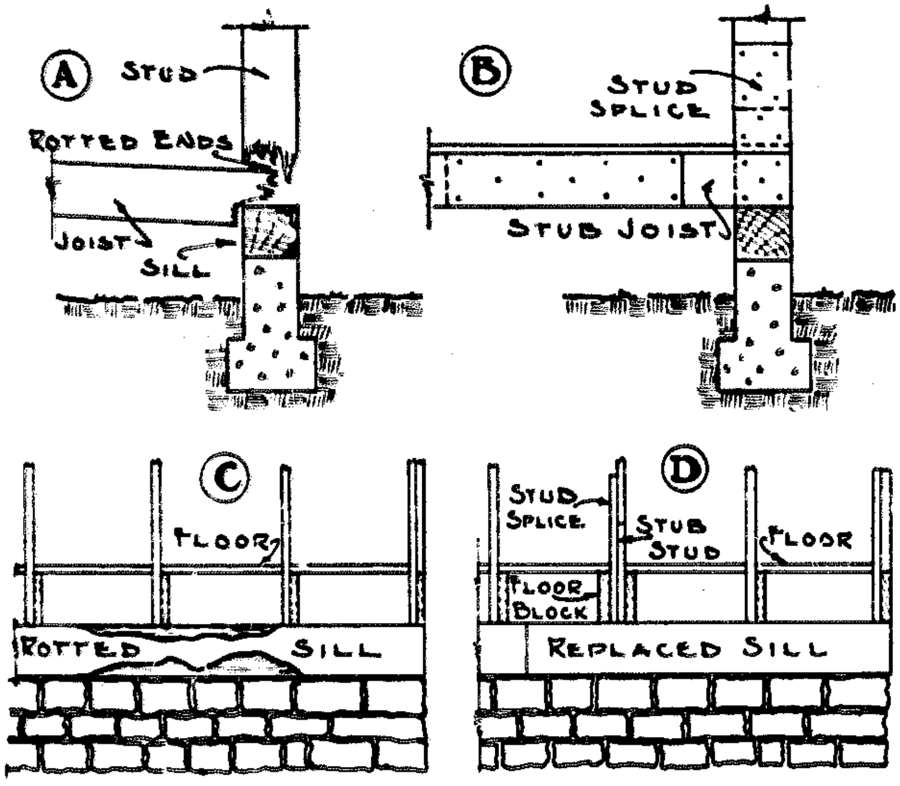
REPAIRING AND PROTECTING BUILDINGS

Replacing Broken or Rotted Parts of Buildings—It is often necessary to replace certain parts of wood buildings which have rotted away or been broken. Such parts should be given immediate attention, and the proper repairs should be made before further damage to the building results. Several practical procedures for repairing buildings are illustrated in this chapter.

Repairing the Foundation—Building repairs are frequently necessitated by foundation failures. A frequent foundation failure is the tilting out of the foundation. When this happens, the wall should be jacked up. The foundation should then be straightened and reinforced by the pouring of additional footing as shown in Fig. 30.23. When the additional footing has cured, lower the wall back into place.

Another frequent foundation failure is the splitting of the foundation at the corners of the building. When this occurs, jack the foundation and wall back into place and pour a shaft of concrete at the corner to hold the foundation in place.

Occasionally failures result from the erosion of the earth from beneath the foundation. When this occurs, jack the foundation and wall back into place. Then pour a concrete footing underneath the foundation. Replace the earth that has eroded away and take steps to prevent future erosion.

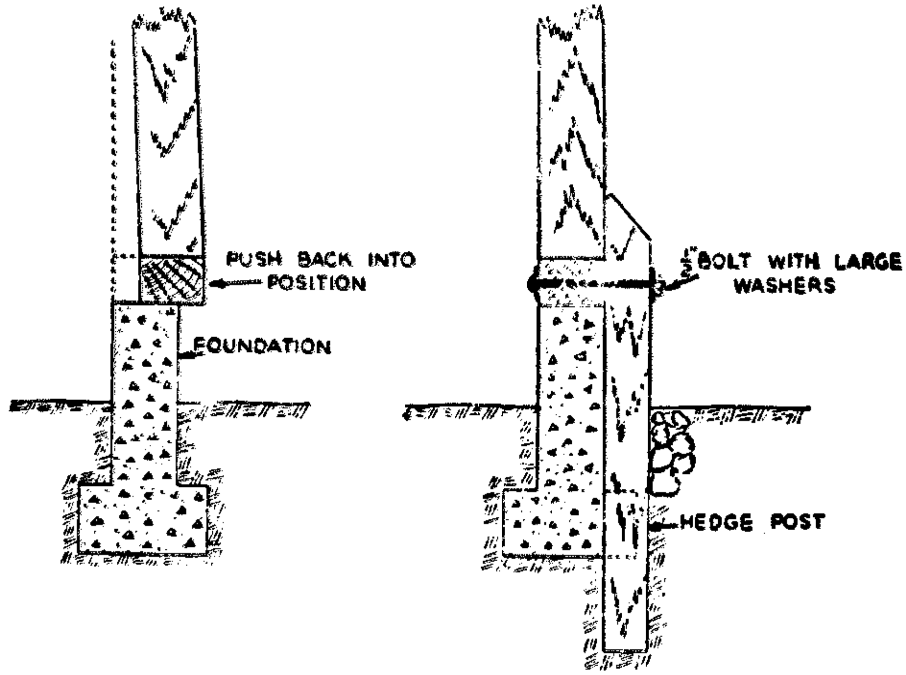


(Courtesy College of Agriculture, University of Nebraska)

Fig. 30.20. Replacement of joists, studs, ends, and sills. Rotted joist, "A"; repaired joist and stud, "B"; rotted sill, "C"; replaced sill, "D."

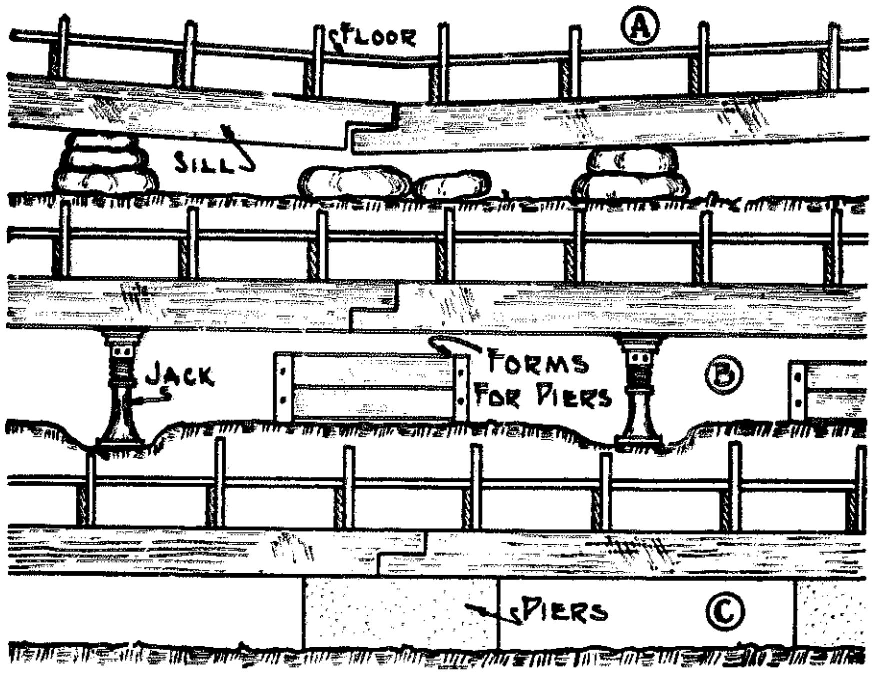
Bracing—Agricultural buildings that sag or get out of plumb may often be repaired by the installation of additional braces. The first step is the straightening of the building with jacks until the walls are plumb. Then install additional braces as needed. Nail the braces to the rafters, joists, and studding.

Rat-Proofing Buildings—In some areas, rats are a serious pest on farms and in nonfarm agricultural businesses. In these areas, precautions should be taken to keep rats out of the buildings. In new buildings, rat-proofing should be done at the time of construction. In old buildings which are not properly protected, some



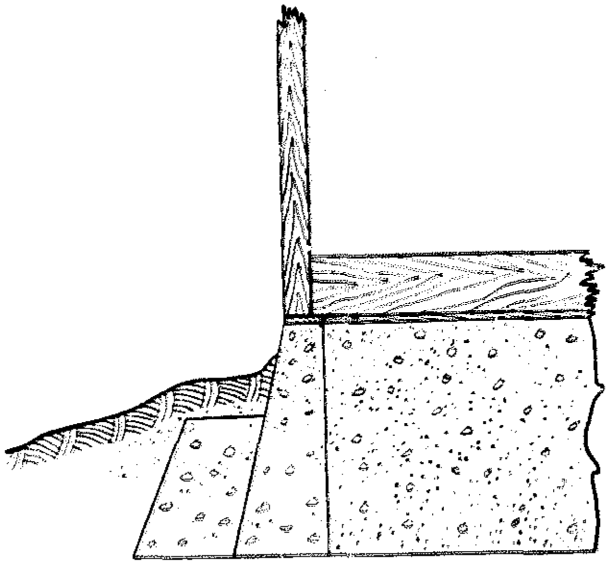
(Courtesy College of Agriculture, University of Nebraska)

Fig. 30.21. Securing a sill with a post.



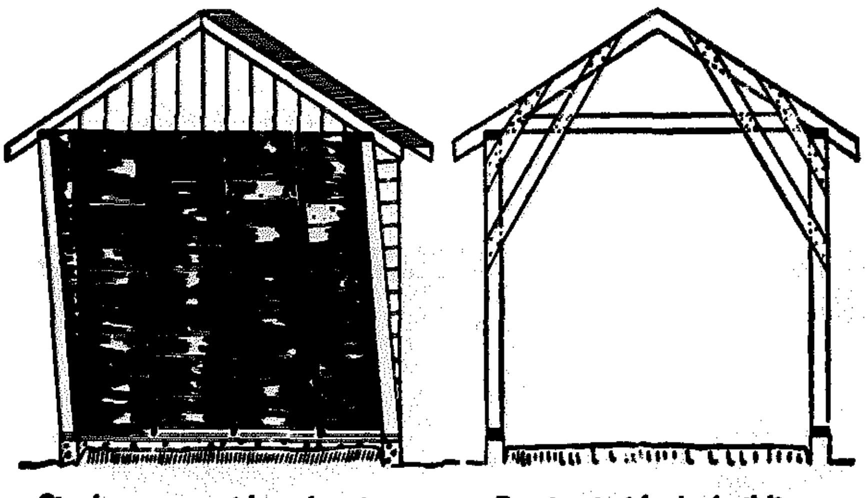
(Courtesy College of Agriculture, University of Nebraska)

Fig. 30.22. Replacement of a stone foundation with concrete. Jack up the sill as shown in "B." Remove the old stone or rock foundation and place forms for concrete piers. The concrete should extend from 12 to 20 inches below the ground line, depending upon the type of building and soil. Complete piers and remove forms and jacks as shown in "C."



(Drawn by Ronald Ipsen)

Fig. 30.23. Notice the additional footing that was poured after the foundation had been straightened.

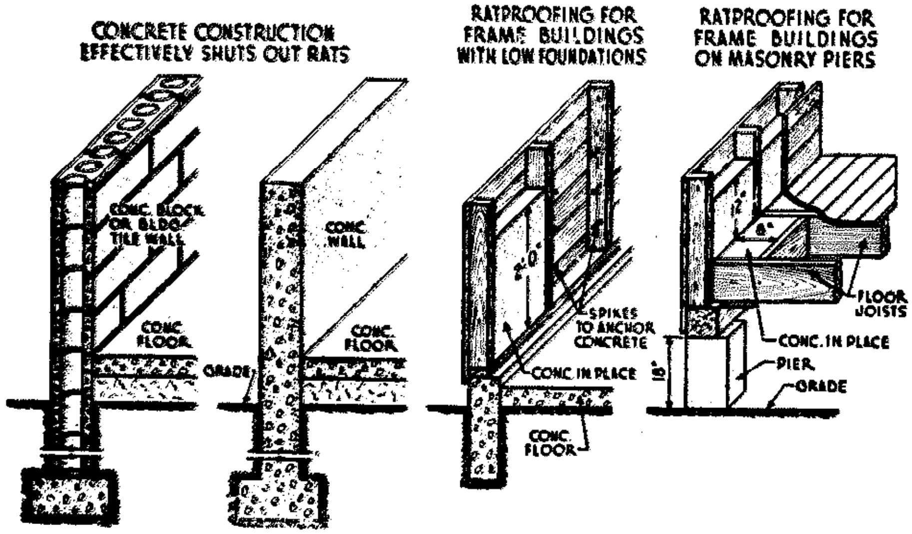


(Courtesy West Coast Lumberman's Association)

Fig. 30.24. Notice how the additional braces are nailed to the rafters, joists, and studding.

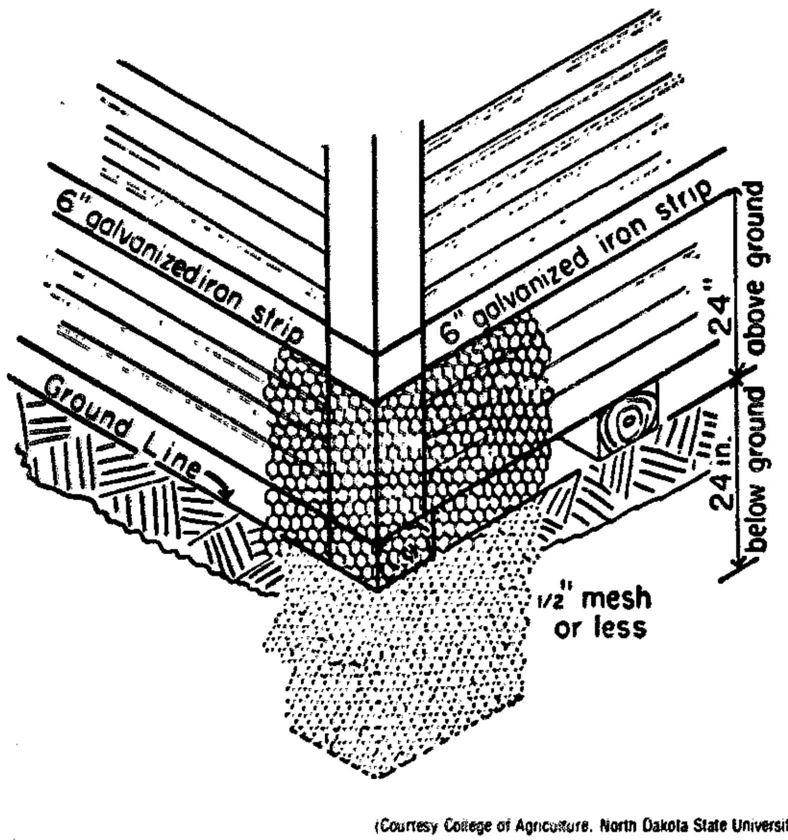
method of keeping the rats out should be used, such as those shown in Figs. 30.25 and 30.26.

Termite-Proofing Buildings—If construction procedures are correct, agricultural buildings will be protected from damage by termites. Proper construction is the cheapest control for termites. No wood should be in contact with the



(Courtesy Portland Cement Association)

Fig. 30.25. Principal methods of rat-proofing buildings.



(Courtesy College of Agriculture, North Dakota State University)

Fig. 30.26. Rat-proofing an old storage building.

soil. Termites must have moisture and woody tissue to live. The source of moisture is usually the soil. If they cannot get to the soil, they cannot live in the wood and destroy it. All wood in an agricultural building should be isolated from the soil so that termites cannot get to it without building their shelter tubes in the open where they can be detected and destroyed. Metal termite shields should be installed between the foundation walls and the superstructure of the building.

Using Paint and Preservatives—All wood parts of buildings should be painted to protect the wood and to keep it attractive. Farmers and nonfarm agricultural businesspersons should take pride in keeping their buildings repaired and painted. Wood deteriorates rapidly when not painted. It is important to have a knowledge of paints and how to apply them. Proper use of this knowledge should be made in selecting paint of good quality and in applying it properly. Painting is discussed in Chapter 11.

Any wood such as floors, posts, or runners which comes in contact with the soil should be properly preserved. Preservative materials may be applied to posts or runners by the brush method, or they may be dipped in a tank containing a preservative solution. Boards used in floors, such as in hog feeders, which may be in close contact with the soil should be painted with a wood preservative, with a brush being used to apply it. In painting tongued and grooved boards, it is well to paint the tongue and grooved portion of the boards before nailing the boards in place.

For a discussion of the types of wood preservatives used in agriculture, see Chapters 11 and 36. Posts and lumber treated commercially with preservatives are available from lumber dealers.

CONCRETE WORK

Student Abilities to Be Developed

1. Ability to appreciate the values of concrete as a practical building material for many agricultural buildings.
2. Ability to select cement, sand, and gravel suitable for concrete jobs.
3. Ability to estimate the quantities of cement and aggregate, or ready-mix, needed for a given job.
4. Ability to build forms for concrete.
5. Ability to mix, pour, finish, and cure concrete.
6. Ability to use concrete blocks in constructing agricultural buildings.

CHAPTER 31

Understanding Concrete Technology

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is the practical importance of concrete on farms and in nonfarm agricultural businesses?
2. Why is concrete so extensively used?
3. Why is a knowledge of the proper use of concrete important?
4. What are the qualities of good concrete?
5. What are the ingredients of concrete? What is cement? Aggregate?
6. Where can materials for concrete be secured?
7. What precautions should be observed in selecting the ingredients of concrete?
8. What equipment is necessary for mixing and using concrete?
9. What are the advantages of being able to estimate the proper amounts and proportions of materials required for concrete jobs?
10. What are the characteristics of a good mixture of concrete?
11. What is meant by a 1:2:4 mixture?
12. What constitutes a "workable" mixture?
13. Why is the amount of water used especially important?
14. What are some recommended mixtures?
15. How may the quantities of materials needed for a given job be estimated?
16. Why is the proper mixing of concrete important?
17. How should concrete be placed in forms?
18. How should new concrete be finished?
19. How should concrete be cured?
20. What forms are necessary for concrete work? When may forms be removed?
21. How should concrete be reinforced?
22. When and how should ready-mixed concrete be used?

USES AND COMPOSITION OF CONCRETE

Agricultural Uses of Concrete—Concrete has become an extensively used material in the construction of agricultural buildings and semi-permanent equipment. Some of the more common uses of concrete on farms are as follows:

Fence posts	Garages	Manure pits
Watering troughs	Milk houses	Stucco walls
Feeding troughs	Well curbs and platforms	Feeding floors
Foundations and walls	Septic tanks	Building blocks
Floors	Porches	Tile
Driveways	Flower boxes and pots	Culverts
Walks		

Some of the reasons why concrete is widely used are:[1]

1. It is adaptable and serviceable in a great variety of situations.
2. It is permanent when properly made.
3. It is sanitary and easily cleaned.
4. It is more nearly fireproof than other building materials.
5. It is rodent-proof.
6. It can be used for almost any purpose when properly reinforced.
7. It may be made attractive and decorative.
8. It is economical in installation and in maintenance.

Concrete will have these desirable qualities only when it is properly made and handled. Examples of undesirable concrete work—cracking, crumbling, heaving, excessive wearing, sagging out of alignment—are common in all localities. Work of this type is costly, unsightly, unserviceable, and, for the most part, unnecessary. Standard approved practices in selecting and apportioning materials, and in mixing, pouring, and curing concrete have been developed, by practical and experimental methods which, if learned and carefully followed, will produce successful results.

What Concrete Is—Concrete is an artificial stone. It is composed of a mixture of cement, sand, gravel or broken stone, and water, which, when put together in proper proportions, soon "sets" or hardens into a mass of "homemade" stone. The cement and water form a binder which holds the sand and gravel or rock, commonly spoken of as aggregates, together. The quality, strength, and durability of concrete depend upon:

1. The quality and amount of cement used.
2. The kind, size, and amount of aggregate used.
3. The amount of clean water used.
4. The way the ingredients are mixed and placed.
5. The proper curing of the mixture after it is placed.

Cement—Cement is a manufactured product. It consists primarily of a mixture of a suitable kind of limestone and clay or shale, which is ground and then heated until it melts together into a sort of clinker. The clinker is then finely ground, forming the grayish powder known as cement. When mixed with water, it undergoes a chemical change and "sets" permanently. Cement is ordinarily pur-

[1]Fred D. Crawshaw and E. W. Lehmann, *Farm Mechanics*, Peoria, Illiniois: The Manual Arts Press, p. 111.

chased in paper bags, each containing 1 cubic foot and weighing 94 pounds. Standard brands are tested, and, when used properly, good results are guaranteed. Cement should be stored and kept in a dry place. Bags of cement placed directly on the ground may absorb moisture from the ground, which may cause the cement to become lumpy. If lumps in cement cannot be crushed easily with the hand the cement should not be used.

Air-entrained cement is a special type of cement. It is used to make air-entrained concrete, which contains billions of very small air bubbles. The air-entrained cement has the ability, which ordinary cement does not have, to provide for air entrainment in hardened concrete. Air-entrained concrete is superior to ordinary concrete when the concrete is subjected to freezing and thawing action and to the action of salt. Air-entrained concrete will not scale as badly as ordinary concrete when subjected to de-icing chemicals. Air-entrained concrete is more watertight than concrete without entrained air. The air in air-entrained concrete provides reservoirs that relieve the pressure on the concrete during freezing and thawing.

Aggregates—This is the name given to the materials used to give bulk and body to concrete. They are commonly spoken of as "fine aggregates" and "course aggregates."

Fine aggregate is defined as material which will pass through a ¼-inch mesh screen. Sand or crushed stone screenings are usually used as the fine aggregate.

Coarse aggregate is any suitable material, such as gravel, pebbles, or crushed rock, ranging in size from ¼ inch up. The maximum size of coarse aggregate that should be used depends upon the thickness of the concrete being made. In thin slabs or walls the largest pieces of aggregate should not exceed one-third the thickness of the section of concrete being placed.

All aggregates should be clean and hard, and free from dust, loam, clay, or vegetable matter. Foreign material keeps the cement from adhering to the aggregate particles, and thus weakens the concrete and makes it more porous. Sand particles should be extremely hard, flinty, and sharp. They should range in size from very fine particles to those which will just pass through a ¼-inch mesh screen. Pebbles or crushed stone used as coarse aggregate should be tough, fairly hard, and free from impurities. Stone containing a considerable quantity of soft, flat, or elongated pieces, such as shale or soft sandstone, should not be used.

Water—Water used in mixing concrete should be clean, and free from oil, alkali, and acid. The amount to be used should be measured accurately in order to secure a concrete mixture of uniform consistency.

Equipment Needed for Concrete Work—Elaborate equipment is not needed for mixing and laying concrete, although for efficient work certain simple tools are essential. They are:

1. Water and pail for handling water and washing tools.
2. Square-pointed shovels for turning and mixing.
3. Tamper for compacting concrete or foundation bases.
4. Steel pan wheelbarrow for moving aggregates and concrete mixtures.

Concrete Float

Brick Trowel

Concrete Finishing Trowel

(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 31.1. Tools used in concrete work.

5. Mixing box or platform if concrete is mixed by hand for small jobs.
6. Straightedge for leveling concrete.
7. Wood float and trowel for finishing concrete.

Quantities and Proportions for Concrete Mixtures

Guessing is poor economy in handling concrete. Without a great deal of experience with concrete, persons who guess at the quantities of cement, sand, and gravel needed for concrete jobs are likely to have a surplus of some of the ingredients, which cannot then be used economically. On the other hand, a shortage of one or more ingredients results in delays in finishing or in a poor job. A concrete job should be planned and estimated according to standard procedures, so that the necessary quantities of materials can be provided with foresight and economy.

The materials in concrete should be measured accurately and mixed according to recommended specifications and procedures, which are the result of extensive research and practical experience. To disregard recommended mixtures and procedures or to be careless in their application may result in excessive costs in addition to an inferior, unsatisfactory product.

For small jobs mixed by hand, a bottomless box with handles, made to hold exactly 1 cubic foot when placed on a mixing platform, may be used as a measuring box for sand and other aggregates. A pail with marks on the inside to indicate gallons and half gallons is frequently used for measuring water. Cement need not ordinarily be measured, because a sack contains 1 cubic foot.

A Proper Mixture—Usually the proper mixture is "workable" and contains enough fine aggregate to fill the air spaces around the coarse aggregates, and enough cement paste around each particle to bind the whole mixture together in a dense, plastic, solid mass. The amount of air space in a mixture depends upon the size of the aggregates. The following general rules have been established to help determine the relative proportions of fine and coarse aggregates. The suggested proportions assume that moist sand will be used. If the sand available is absolutely dry, use 25 per cent less sand than suggested.[2]

1. For coarse aggregate ranging from 1/4 inch to 1/2 inch, use approximately equal parts of sand and pebbles.
2. For coarse aggregate ranging from 1/4 inch to 3/4 inch, use about three-fourths as much sand as pebbles.
3. For coarse aggregate ranging from 1/4 inch to 1 1/2 inches, use about half as much sand as pebbles.

Note that 1 cubic foot of cement, 2 cubic feet of sand, and 4 cubic feet of pebbles do not make 7 cubic feet of concrete, as the inexperienced worker might expect. Only slightly more than 4 cubic feet of concrete will result due to the filling of the "chinks" or air spaces between the aggregates.

It is a common practice to speak of concrete mixtures in terms which indicate the proportions of the materials. For example, a "1:2:3 mixture" consists of one part by volume (cubic foot) of cement, two parts of sand, and three parts of pebbles.

A "workable" mixture can be placed in forms readily and, with spading or tamping, will result in a dense concrete. It contains enough sand and cement (1) to give smooth surfaces, free from rough spots called "honeycombing," and (2) to bind the pieces of coarse aggregate into the mass so they will not separate when the mixture is handled.

If a mixture is too stiff or dry it will not pack tightly enough, especially in corners and in thin sections. If it is too sloppy, the heavy aggregate may settle, and the concrete will be porous and weak. Figure 31.3 shows stiff, medium, and wet mixtures and indicates the type of construction for which each is best suited.

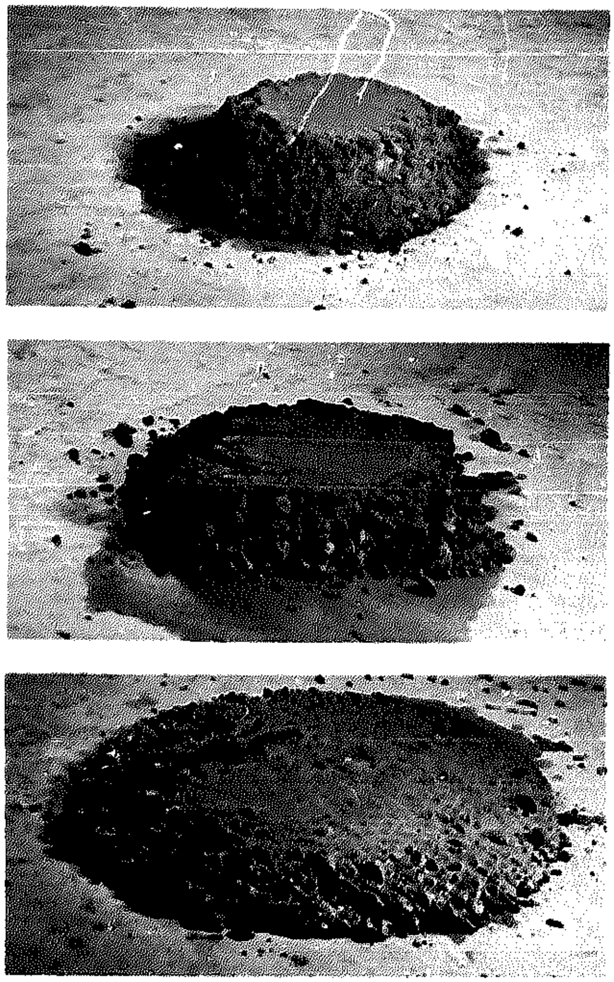
Water-Cement Relationship—There is a direct relationship between the strength of concrete and the amount of water used per sack of cement. For this reason it is very important to use the *correct amount of water per sack.* Excess water weakens the concrete and makes it more porous and permeable to water. Notice in the recommended mixtures in Table 31.1 that the amount of water to be added varies according to the degree of wetness of the aggregates used.

Recommended Mixtures—Table 31.1 shows the proportions of cement,

[2]"Permanent Farm Construction," Portland Cement Association, Chicago.

(Courtesy Portland Cement Association)

Fig. 31.2. Testing workability of mixes with a trowel. Top—a harsh mixture that does not contain enough cement and sand mortar to fill spaces between the coarse aggregate. Its use produces a porous, rough concrete. Middle—a mixture that contains the correct amount of cement, sand, and coarse aggregate. Bottom—a mix that contains too much sand. Such a mix requires more cement and may be porous.



(Courtesy Portland Cement Association)

Fig. 31.3. Views showing stiff, medium, and wet mixtures of concrete. A stiff mixture (top) can be used for flat surfaces such as barnyard pavements and walks. A medium mix (middle) is suitable for placement in forms. A wet mix (bottom) is suitable for thin sections heavily reinforced with steel bars or welded mesh.

sand, and pebbles and the amounts of water to be added for each sack of cement for several types of concrete construction on farms.[3]

Watertight Concrete—Watertight concrete is made with a rich mixture such as the 1:1:1¾ or the 1:1¾:2 mixtures given in Table 31.1. When a watertight concrete is desired, it is important not to use more water than is recommended for the mixture. A slow curing period is also essential. The concrete should be kept moist for at least seven days. The use of air-entrained cement will also produce a more watertight concrete.

Determining Quantities of Materials for a Concrete Job—Tables 31.1, 31.2, 31.3, and 31.4, giving quantities of cement and aggregates required for a

[3]Henry Giese, "A Practical Course in Concrete," Portland Cement Association, Chicago, p. 19.

Table 31.1—Recommended Proportions of Water to Cement and Suggested Trial Mixes[1,2]

Intended Primarily for Use on Small Jobs

Kind of Work	Add U.S. Gal. of Water to Each One-Sack Batch If Sand Is			Suggested Mixture for Trial Batch			Maximum Aggregate Size
	Very Wet	Wet	Damp	Cement	Sand	Pebbles	
5-gallon paste for concrete subjected to severe wear, weather, or weak acid and alkali solutions							
Colored or plain topping for heavy wearing surfaces; all two-course work such as pavements, walks, and residence floors.	4¼	4½	4¾	*Sacks* 1	*Cu. Ft.* 1	*Cu. Ft.* 1¾	⅜"
Fence posts, flower boxes, garden furniture; work of very thin sections; all concrete in contact with weak acid or alkali solutions.	3¾	4	4½	1	1¾	2	¾"
6-gallon paste for concrete to be watertight or subjected to moderate wear and weather							
Watertight floors such as basement, dairy barn, milk house. Watertight basement walls, pits, walls above ground, grain bins, silos, manure pits, scale pits, dipping vats, dams, lawn rollers, hotbeds, cold frames, and storage cellars. Water storage tanks, cisterns, septic tanks, sidewalks, feeding floors, barnyard pavements, driveways, barn approaches, steps, porch floors, corner posts, gate posts, piers, columns, sills, lintels, and chimney caps. All reinforced concrete.	4¼	5	5½	*Sacks* 1	*Cu. Ft.* 2¼	*Cu. Ft.* 3	1½"
7-gallon paste for concrete not subjected to wear, weather, or water							
Foundation walls, footings, retaining walls, engine bases, and mass concrete not subjected to weather, water pressure, or other exposure.	4¾	5½	6¼	*Sacks* 1	*Cu. Ft.* 2¾	*Cu. Ft.* 4	1½"

[1] "Permanent Farm Construction," Portland Cement Association, Chicago.

[2] It may be necessary to use a richer paste than is shown in the table because the concrete may be subjected to more severe conditions than are usual for a structure of that type. For example, a water storage tank ordinarily is made with a 6-gallon paste. However, the tank may be built in a place where the soil water is strongly alkaline, in which case a 5-gallon paste is required.

Table 31.2—Pints of Water to Add for Batches Using 1/2, 1/4, 1/5, or 1/10 Sack of Cement[1]

Size of Batch	Pints of Mixing Water to Add: Very Wet Sand	Wet Sand	Damp Sand	Dry Sand
5-gallon water per sack of cement				
1/2 sack	14	16	18	20
1/4 sack	7	8	9	10
1/5 sack (18.8 lb.)	5 3/5	6 2/5	7 1/5	8
1/10 sack (9.4 lb.)	2 4/5	3 1/5	3 3/5	4
6-gallon water per sack of cement				
1/2 sack	17	20	22	24
1/4 sack	8 1/2	10	11	12
1/5 sack	6 4/5	8	8 4/5	9 3/5
1/10 sack	3 2/5	4	4 2/5	4 4/5

[1]Taken from Henry Giese, "A Practical Course in Concrete," Portland Cement Association, Chicago, p. 19.

Table 31.3—Quantities of Cement (C.), Fine Aggregate (F.A.), and Coarse Aggregate (C.A.) Required to Make 1 Cubic Yard of Compact Mortar or Concrete[1]

Mixture: C.	F.A.	C.A.	Resulting Volume of Concrete in 1-Bag Batch	Quantities Required for 1 Cubic Yard of Compact Mortar or Concrete: Cement	F.A. (Sand)		C.A. (Pebbles, Stone)	
Bags	*Cu. Ft.*	*Cu. Ft.*	*Cu. Ft.*	*Bags*	*Cu. Ft.*	*Cu. Yds.*	*Cu. Ft.*	*Cu. Yds.*
1	2		2.1	12.8	25.6	0.95		
1	1 1/2	3	3.6	7.6	11.4	0.42	22.8	0.85
1	2	3	3.9	7.0	14.0	0.52	21.0	0.78
1	2	4	4.5	6.0	12.0	0.44	24.0	0.89
1	2 1/2	4	4.8	5.6	14.0	0.52	22.4	0.83
1	3	5	6.4	4.6	13.8	0.51	23.0	0.85

(1 bag cement equals 1 cu. ft.; 4 bags equal 1 barrel.)

For example, the materials necessary to lay a feeding floor for hog lots 30′ × 30′ × 6″ thick with a 1:2:3 mixture would be computed as follows:

30 × 30 × 1/2 = 450 cubic feet, or approximately 17 cu. yds. of concrete. Referring to the table we find that for every cubic yard of concrete, using a 1:2:3 mixture, the following quantities are required: 7 bags of cement, 14 cu. ft. of sand, and 21 cu. ft. of gravel.

Hence: 17 × 7 = 119 bags of cement.
17 × 14 = 238 cubic feet of sand.
17 × 21 = 357 cubic feet of gravel.

[1]Based on data taken from Frederick W. Taylor and S. E. Thompson, *Concrete, Plain and Reinforced*, New York: John Wiley & Sons, Inc., pp. 228–235.

given amount of concrete using different mixtures, are helpful in calculating the amount of materials necessary for a given piece of concrete work.

Table 31.4 may be useful in determining quantities of materials needed for floors and sidewalks.

Table 31.4—Materials Required for 100 Square Feet of Surface for Varying Thicknesses of Concrete[1]

	1 : 2 : 3			1 : 2 : 4			1 : 2½ : 5		
Thickness	**C.**	**F.A.**	**C.A.**	**C.**	**F.A.**	**C.A.**	**C.**	**F.A.**	**C.A.**
Inches	*Bags*	*Cu. Ft.*	*Cu. Ft.*	*Bags*	*Cu. Ft.*	*Cu. Ft.*	*Bags*	*Cu. Ft.*	*Cu. Ft.*
3	6.5	13.0	19.3	5.6	11.2	22.4	4.6	11.5	23.0
4	8.6	17.2	25.8	7.5	14.9	29.8	6.2	15.4	30.7
6	12.9	25.8	38.6	11.2	22.4	44.7	9.2	23.0	45.9
8	17.2	34.4	51.6	15.0	29.8	59.7	12.3	30.7	61.3

[1]Based on data taken from Frederick W. Taylor and S. E. Thompson, *Concrete, Plain and Reinforced.* New York: John Wiley & Sons, Inc., pp. 228–235.

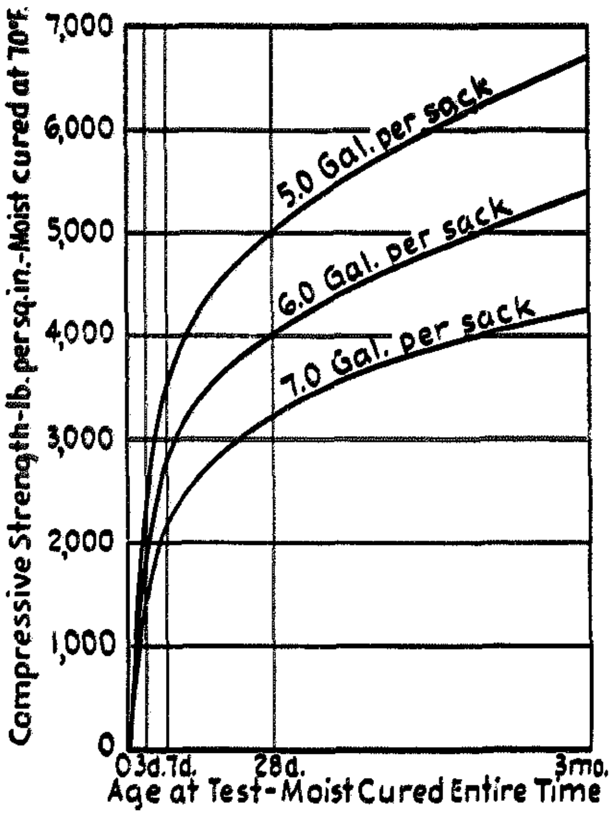


Fig. 31.4. The effect of different quantities of water on the strength of concrete.*

*Henry Giese, "A Practical Course in Concrete," Portland Cement Association, Chicago, p. 19.

MIXING

Proper Mixing Essential—Thorough and proper mixing is an important part of making concrete. Time used to measure the aggregates, cement, and water in concrete will to a large degree be wasted if these ingredients are carelessly and hurriedly thrown together. When a good job of mixing has been done:[4]

1. Every particle of sand and stone is coated with the cement paste.
2. The sand and stone are evenly distributed throughout the mass.
3. The whole mixture is of uniform consistency.
4. The whole mixture is uniform in color, with no visible streaks of cement or sand running through it.

Hand Mixing—Hand mixing is often used for smaller concrete jobs and is, if done thoroughly, entirely satisfactory.

A watertight floor or mixing platform is necessary. A space about 7 by 12 feet will permit two people using shovels to work together upon it at one time. The platform should be rigid, strong, and fitted together without cracks. A board 2 inches wide placed around its edges will keep the materials from falling or being washing off the platform. The procedures generally followed in hand mixing are:

1. Spread out evenly on the platform the measured quantity of sand for a one-bag batch of concrete.
2. Empty a bag of cement on the sand and distribute it evenly over the pile.
3. Turn the cement and sand over with square-pointed shovels enough times to mix the two together thoroughly, making a uniformly colored mixture which does not show streaks of unmixed sand and cement running through it. At least three turnings are necessary.
4. Spread the mixture out evenly on the platform.
5. Spread the measured quantity of pebbles or coarse aggregate over the cement-sand mixture.
6. Turn the coarse aggregates, cement, and sand at least three times, until the pebbles are distributed uniformly through the mixture.
7. Form a hollow or depression in the center of the mixture.
8. Pour into the depression the exact quantity of water recommended per sack of cement for the desired mix. (See Table 31.1) Remember that the ratio of water to cement is an important factor in determining the quality of concrete.
9. Turn the materials toward the center of the hollow with the shovels until the whole mixture is of uniform consistency, color, and plasticity or workability.

READY-MIXED CONCRETE

Ready-Mixed Concrete—In many localities it is possible to purchase ready-mixed concrete which is delivered to the job ready for pouring. If the supplier of ready-mixed concrete is reliable and knows how to mix concrete properly, the purchase of ready-mixed concrete is a great convenience.

[4]Fred D. Crawshaw and E. W. Lehmann, *Farm Mechanics*, Peoria, Illinois: The Manual Arts Press, p. 123.

Whether concrete is purchased ready-mixed or is mixed on the job should be determined by (1) the quantity needed for the job and (2) the time and labor available.

When ordering ready-mixed concrete, the purchaser should give the following information to the person taking the order:

1. Use to be made of ready-mix. Will it be used for flat work or for formed work?
2. Amount of exposure the concrete will receive. Will it receive severe exposure, normal exposure, or mild exposure?
3. Amount of ready-mixed concrete needed.

See Table 31.5 for information regarding the type of concrete to order for various conditions.

In determining the quantity of ready-mixed concrete to order, do as follows:

1. Measure the surface area of the job. For flat work, the area equals the length in feet times the width in feet. For walls, the area equals the wall height in feet times the length of the wall in feet.
2. Determine the number of cubic yards by dividing the surface area in square feet by 300 if the concrete is to be 1 inch thick, by 100 if the concrete is to be 3 inches thick, by 75 if 4 inches thick, by 50 if 6 inches thick, or by 25 if 12 inches thick.

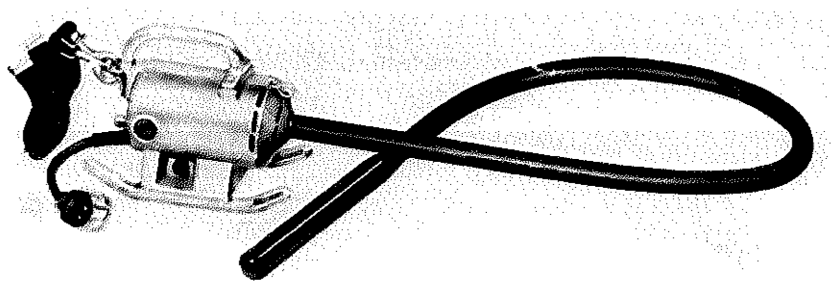
Table 31.5—A Guide for Ordering Ready-Mixed Concrete[1]

WHEN ORDERING CONCRETE FOR—					
FLAT WORK (Using 1½-In. Max. Size Aggregate)			**FORMED WORK (Using ¾-In. Max. Size Aggregate)**		
Severe Exposure	**Normal Exposure**	**Mild Exposure**	**Severe Exposure**	**Normal Exposure**	**Mild Exposure**
Garbage feeding floors, floors in dairy plants	Paved barnyards, floors for farm buildings, sidewalks	Footings, concrete improvements in mild climates	Mangers for silage feeding, manure pits	Reinforced concrete walls, beams, tanks, foundations	Concrete improvements in mild climates
SPECIFY cement content: minimum number of sacks per cubic yard of concrete.					
7	6	5	7¾	6½	5½
SPECIFY water content (includes that contained in aggregates): maximum gallons per sack of cement.					
5	6	7	5	6	7
GET medium-consistency concrete (3-in. slump).					

[1]Adapted from *Ready-Mixed Concrete for the Farm*, Portland Cement Association, Chicago, p. 3.

POURING, CURING, AND REINFORCING

Placing Concrete—A concrete mixture should be placed in the forms as soon as possible, for it will begin to "set" within 30 to 45 minutes after the water has been added. Place the concrete in even layers about 6 inches deep. Tamp and spade the concrete mixture thoroughly so that it will settle together into a dense, solid mass without air pockets or unfilled spaces around the aggregates, in the corners of the forms, or around the reinforcing materials. A spade or thin board may be used to work the mixture against the sides of the forms; however, a powered vibrator is available for this task. Such a vibrator can usually be rented from a tool rental establishment. Tamping and spading force the larger pieces of aggregate into the concrete, leaving a smooth, dense surface of fine materials on the face of the work. A straightedge and level should be used to level the top face of concrete forms.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 31.5. A powered vibrator used to work a concrete mixture against the forms for the concrete.

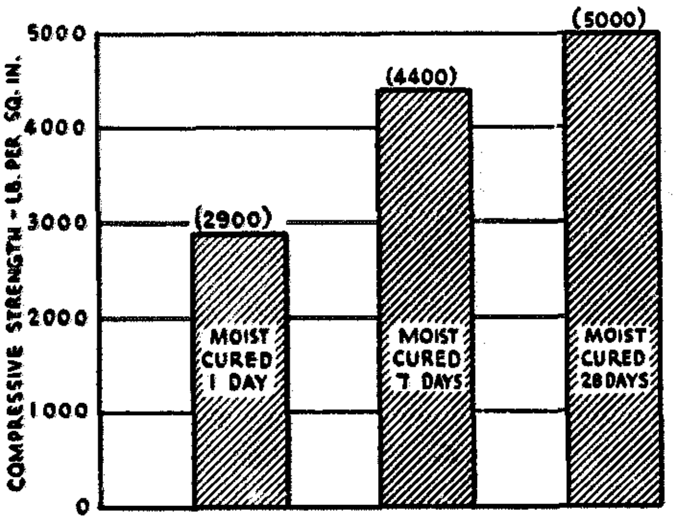
(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 31.6. A tamper. Tamping newly placed concrete forces the large aggregates below the surface and brings mortar to the surface for finishing.

Striking Off—After concrete is placed for flat work, it is "struck off." This refers to the leveling and compacting of the surface with a straight-edged board, usually a two-by-four. This "strike-off" board is drawn across the surface of the concrete at a slight angle with a "seesaw" motion. The excess concrete is pushed ahead of the "strike-off" board, and the larger aggregates are worked downward into the concrete. The surface, after being "struck off" one or more times, should be smooth.

Finishing the Surface—A wooden float is recommended for smoothing the surfaces of concrete that are exposed to the weather and to wearing actions such as walking and the movement of machinery. A metal trowel brings a thin film of cement to the top, making a very smooth surface. This film of cement does not wear as well as a cement and sand mixture, and it is slippery when wet.

Curing Concrete—Concrete hardens because a chemical "setting" process takes place when water is added to the cement. It has been emphasized previously that the quality of concrete depends, to a great extent, upon the proportions of cement and water used. If newly laid concrete is exposed to the sun and wind, the moisture in the mixture will evaporate, and the concrete will dry without setting properly. Excess evaporation can be prevented by covering the concrete with canvas, burlap, straw, earth, or other materials which can be kept damp for a week or 10 days after the concrete is poured. Special precautions to prevent the excessive loss of moisture are especially necessary during hot, dry weather when evaporation takes place very rapidly.



(Courtesy Portland Cement Association)

Fig. 31.7. Continuous moist curing increases the strength of concrete.

Handling Concrete in Cold Weather—Freezing is injurious to fresh concrete. Concrete work can be done in cold weather, however, if simple precautions are taken to protect the new concrete against severe freezing until it has hardened.

During cold weather many smaller jobs such as making blocks, posts, and troughs can be done indoors and the finished products stored inside for a few days. Aggregates should also be stored inside during cold weather to make sure that they are free from frost.

In very cold weather, the water and aggregates used should be heated before they are mixed so that the mixture will have a temperature of about 80 degrees Fahrenheit. New concrete should be covered with building paper and straw or manure to a depth of 10 to 12 inches to retain in it as much heat as possible until it has hardened. If newly placed concrete can be kept at a temperature of 55 to 60 degrees Fahrenheit for two to three days, it will usually set satisfactorily. When the temperature goes lower than 50 degrees, setting proceeds slowly and ceases entirely at the freezing point. A chemical is also available which can be added to the mixture. The chemical will help the concrete cure properly in cold weather.

Forms for Concrete—Forms are necessary to mold and hold new concrete in shape until it has set. The forms for concrete must be strong and rigid in order to prevent sagging, bulging, and spreading. For a smooth finish, they should be made of well dressed, tongued, and grooved lumber. Good forms are essential for good concrete work, but for ordinary construction work, anyone with a fair degree of skill in carpentry should be able to construct satisfactory forms. Sharp corners and angles should be avoided. By using strips of sheet metal to round off corners, you will get a neater and stronger piece of concrete.

Forms may be removed easily without the concrete's sticking to them if they are greased on the inside with crude oil or old crankcase oil before they are used. All pieces of concrete should be removed from forms before they are used again.

Removing Forms—When new concrete has hardened sufficiently so that it will not be damaged in the process, the forms may be removed. Ordinarily during warm weather, two or three days should be sufficient for forms to remain in place for walls and small objects. In cold weather, the forms should remain in place about twice as long. In determining when to remove forms, the weather, the temperature, and the nature of the work must be taken into consideration. In no case should the forms be removed until, by careful examination, it has been determined that the concrete has thoroughly set and that there is no danger of its breaking apart or becoming damaged.

Reinforcing Concrete—Concrete is a material, like stone, that will support great loads placed directly upon it. However, concrete is used where there are forces that tend to bend or pull it apart. Reinforcing is necessary to increase its power to resist these forces. The coefficients of expansion and contraction of concrete and steel are practically identical, which makes steel reinforcing practical for concrete construction. Reinforcing concrete will usually increase the cost about 10 to 15 per cent, but it will make the concrete last much longer.

The reinforcement material most frequently used is steel mesh or bars. This material should be free from rust, scale, grease, or other coatings that tend to reduce the bond between the concrete and the steel. Reinforcing bars should be bent cold, and the bends should not be sharp. All reinforcements should be protected by a minimum covering of ¾ inch of concrete. At laps, the ends of the reinforcing materials should extend past each other a distance 48 times the diameters of the materials; e.g., ½-inch rods should be lapped 24 inches. The two pieces should be tied securely together in at least two places. No. 18 annealed (soft) wire is usually used for tying.

Most plans for concrete construction in agriculture give the size, spacing, and placement of the reinforcement which should be used. When it is necessary to determine these, it is recommended that an experienced engineer be consulted. Information on the construction and the reinforcing of simple concrete projects is given with the plans presented in the following chapter.

CHAPTER 32

Using Concrete Blocks and Concrete

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

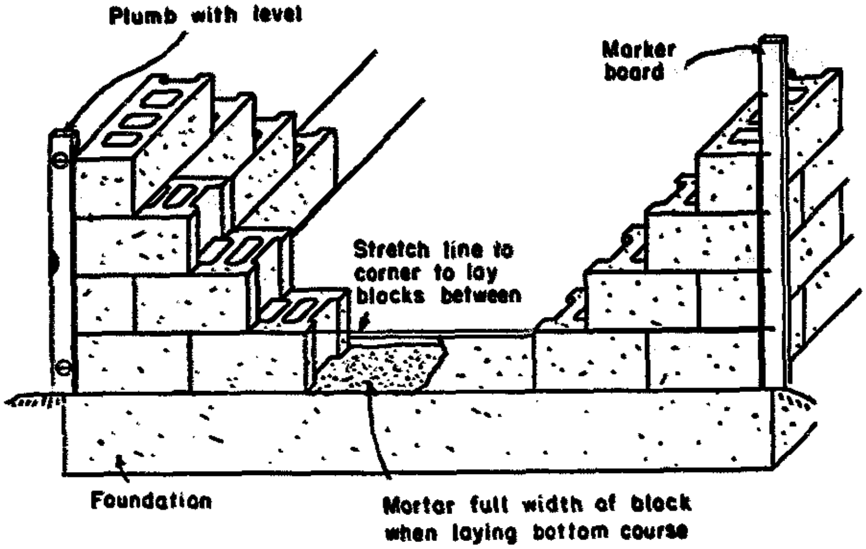
1. What are the precautions that should be observed in laying a concrete block wall?
2. How are plates fastened to a concrete block wall?
3. What procedures should be followed in waterproofing a concrete block wall?
4. What mixture is most suitable for small blocks and stepping stones?
5. Why is the preparation of the base important in making sidewalks, driveways, or floors?
6. What is meant by "one-course construction"?
7. Why should driveways and floors be placed in sections?
8. What precautions should be taken in using earth forms for retaining walls?
9. How is concrete placed in wall forms to secure a smooth face?
10. Why is it necessary to pour corner and gate posts in the place where they are to be used?

CONCRETE BLOCKS

Buildings properly constructed with concrete blocks are fireproof, durable, and strong. Blocks are made from various materials such as cinders, limestone, or slag. The quality of concrete blocks depends to a considerable extent on the ratio of the cement to the aggregate. Only good-quality concrete blocks should be used. Unsound blocks, and blocks that chip and pulverize easily, should not be used.

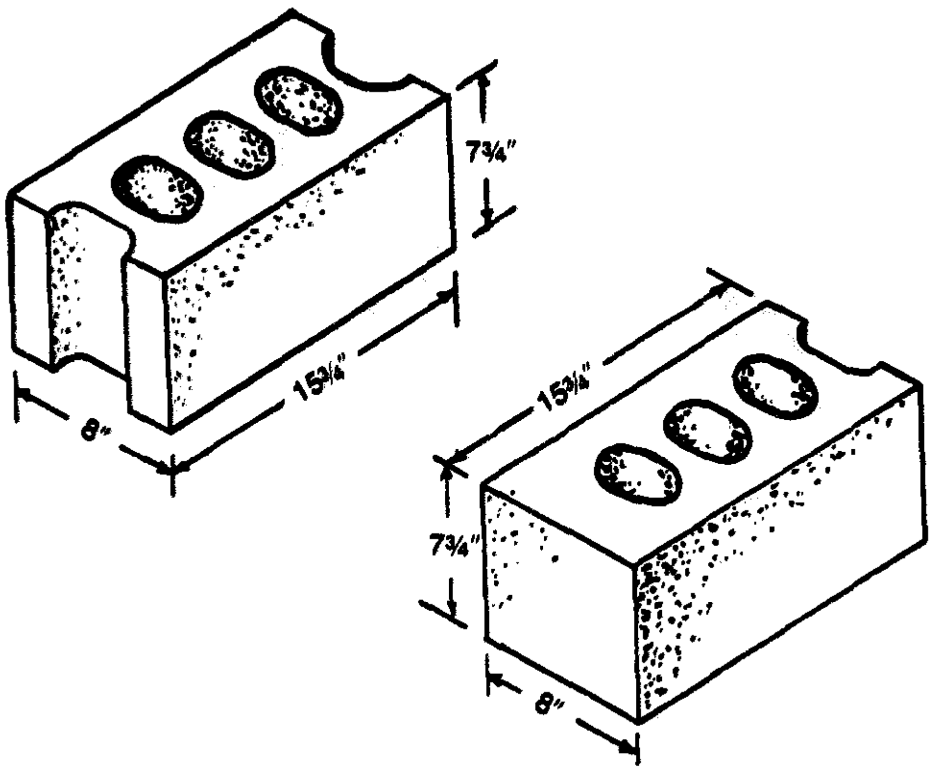
Laying a Wall—The first prerequisite of a concrete block building is a good concrete foundation. See Chapter 30 for laying out a foundation, and see Chapter 31 for information on using concrete for foundations.

Start the laying of concrete blocks at the corners of the foundation. Use blocks with one flat end for the corners. Spread the mortar the full width of the corner blocks. The mortar used for average walls should be made with one part cement and two or three parts of mortar sand, or one part cement and one part of



(Courtesy E. S. Holmes, College of Agriculture, University of Kentucky)

Fig. 32.1. Notice the methods used to keep each course in a concrete block wall plumb and straight. Also notice that the mortar is placed the full width of the blocks on the bottom course.



(Courtesy E. S. Holmes, College of Agriculture, University of Kentucky)

Fig. 32.2. The common shape and size of concrete blocks used in constructing agricultural buildings. The bottom block is for use at the corners of a building.

hydrated lime plus four to six parts of mortar sand. A mix may also be purchased which requires only the addition of water for making the mortar.

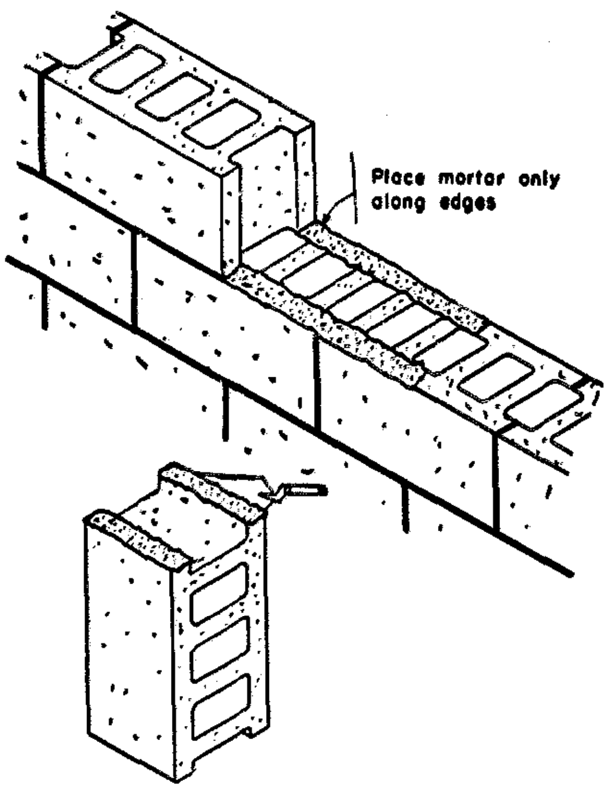
The corners are built up three or four blocks or courses high. A course is one layer of blocks. In laying all courses after the first course, place the mortar only on the mortar strips or face shells of the blocks.

A level is used to keep the corners and the wall straight or plumb. After the first course of blocks, the blocks are lapped half. See Fig. 32.1 and note how the corner blocks are placed so that the blocks will be lapped half.

When the two corners of a wall have been placed, a string is stretched between the corners. The string is stretched at the top of the course to be laid and is used to level and align the course of blocks.

Adequate mortar should be used on the mortar strips of the blocks for the horizontal and vertical joints. When placing blocks, tap them with the trowel to get them level and straight. Use a mason's level to check whether or not the blocks are being placed level and plumb.

The mortar squeezed out between the joints should be removed with a trowel. Be sure that the horizontal joints are straight and level. After the mortar has become stiff between the vertical and horizontal joints, use a rounded or

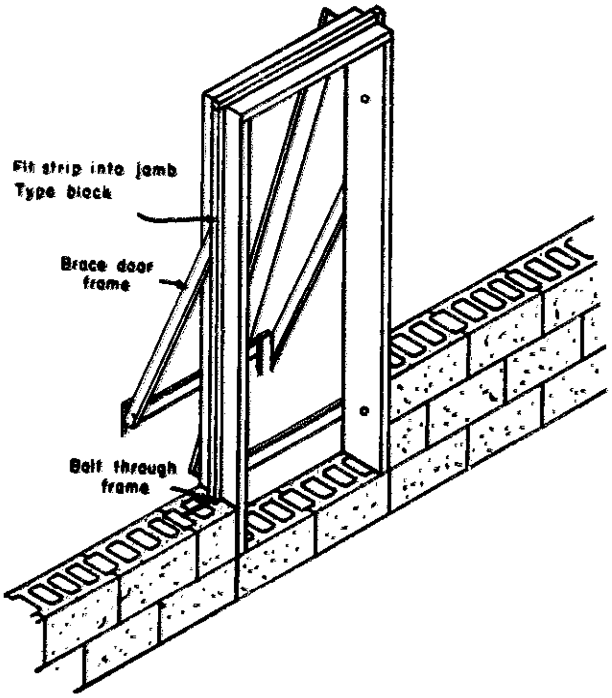


(Courtesy E. S. Holmes, College of Agriculture, University of Kentucky)

Fig. 32.3. When constructing a concrete block wall, place the mortar on the edges of the blocks, as shown in the drawing.

V-shaped jointing tool to compress and smooth the mortar between the joints. The use of a jointing tool improves the appearance of a concrete masonry job and makes the joints watertight.

Often it is necessary to install doors or windows in a concrete block wall. A common procedure is to brace the windows or doors in place and build the wall against them. Precast pieces of concrete are usually used for the door and window sills. The lintel, a beam bridging the distance over the top of a window or door, may also be a precast beam of concrete.



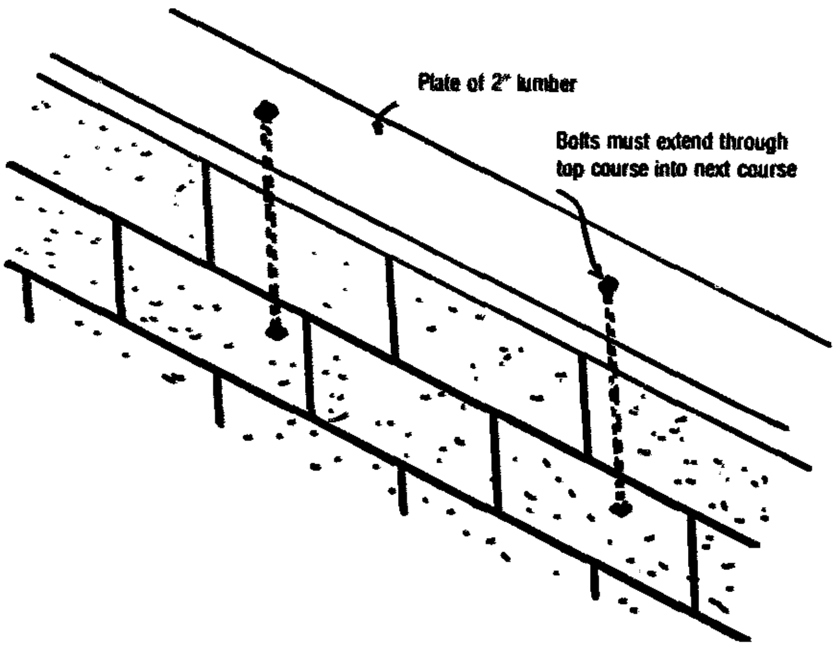
(Courtesy E. S. Holmes, College of Agriculture, University of Kentucky)

Fig. 32.4. This drawing illustrates a method of providing temporary bracing for a door until the wall is finished. Notice the bolts that extend through the door frame and into the mortar joints to help secure the door.

Fastening Plates—When the top course of blocks is in place, obtain some newspapers and place them in the core of the blocks at the proposed locations of the anchor bolts for the plates. The newspaper will hold the mortar in place in the cores of the blocks until it becomes hard. The anchor bolts are imbedded in the mortar which is placed in the block cores. Anchor bolts should be long enough to extend through two courses of blocks, through the plate, plus 1 inch above the plate. Usually ½-inch by 14-inch bolts are used. The anchor bolts are usually placed about 4 feet apart and are placed in the mortar, head down.

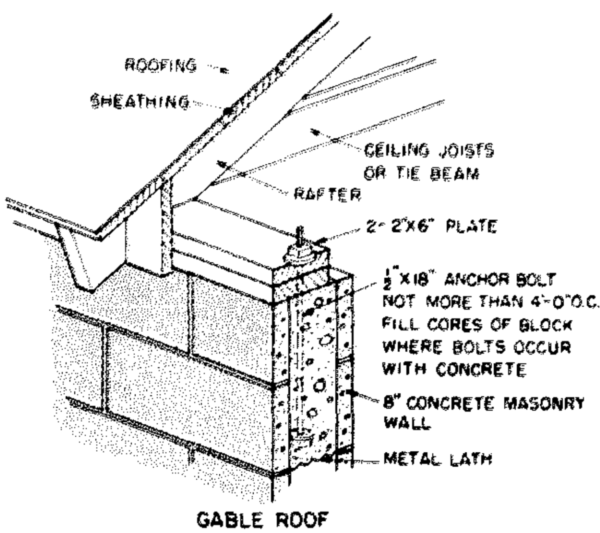
Waterproofing Concrete Block Walls—Often concrete block walls are used for basements. Concrete block basement walls can be waterproofed by the application of a reliable commercial waterproofing compound to the outside of the wall.

The waterproofing compound should extend from the ground line to the outside edge of the footing at the bottom of the wall. The compound should be coated with one or two coats of asphalt. A drain tile placed at the edge of the footing provides added protection.



(Courtesy E. S. Holmes, College of Agriculture, University of Kentucky)

Fig. 32.5. A wooden plate is added to the top of a block wall to furnish a base for fastening a roof to the wall. Note the method of attaching a wooden plate to a block wall.



(Courtesy Portland Cement Association)

Fig. 32.6. How to secure a wooden gable roof to a block wall.

Concrete block walls above the ground level may be waterproofed by applying two coats of a cement paint. See Chapter 11 for information on painting concrete.

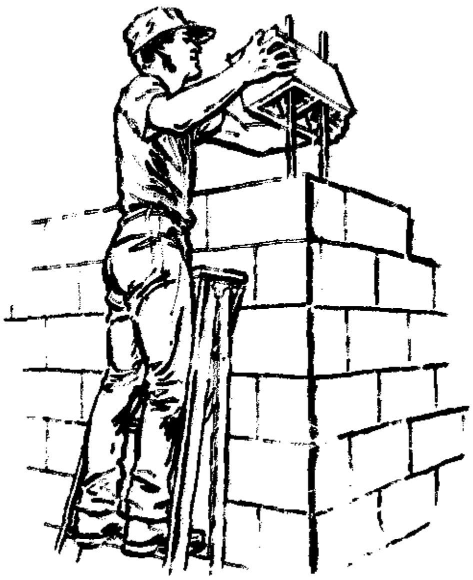
Surface Bonding—Surface bonding is a technique of erecting concrete block walls without using mortar. The walls are constructed with concrete blocks without mortar, and the walls are then coated with a thin layer of a cement-glass fiber mixture. This provides a surface bonding of the concrete blocks. The advantages of this type of concrete block wall construction are as follows:

1. The time for erecting walls is reduced.
2. The skill required of workers is less.
3. The wall joints are stronger.
4. The surface bonding mixture usually waterproofs the walls.
5. The walls may be colored by adding a color to the surface bonding mixture.

The surface bonding mixture is as follows:

78 parts cement
15 parts hydrated lime
2 parts calcium chloride (flake or crystal form)
1 part calcium stearate (bulky wettable grade)
4 parts glass fiber, type E, coated with a chrome binder or silane binder in $\frac{1}{2}$-inch lengths

The surface bonding mixture dries quickly and should be mixed in small quantities. For one plasterer, prepare 25 pounds of the mixture in each batch. In preparing a batch, mix all ingredients together except calcium chloride. Mix the calcium chloride with 1 gallon of water and add slowly to the mixture of other



(Courtesy U.S.D.A.)

Fig. 32.7. Stacking a concrete block wall without mortar for surface bonding.

(Courtesy U.S.D.A.)

Fig. 32.8. Surface bonding of a stacked, mortarless, concrete block wall.

ingredients. Mix thoroughly. Then add additional water to bring to correct consistency for troweling. The mixture should be as thin as possible for trowel handling. A thin mixture will bond better than a stiff mixture. Usually about 1½ gallons of water is needed for a 25-pound batch.

Before plastering the walls, spray them with water until they are thoroughly wet. Apply the surface bonding mixture with a trowel from a plasterer's hawk. The bonding coat should be 1/16 inch thick. Trowel just enough to bond the mixture to the concrete block. Excessive troweling weakens the bond. Do not attempt to get too smooth by heavy pressure on the trowel or by too much troweling.

The surface bonding mixture should be applied when the temperature is between 40 and 90 degrees Fahrenheit. A 25-pound batch of the mixture will cover 40 to 50 square feet.

The surface bonding mixture may also be applied with stucco spraying equipment. When this method is used, the coating should be troweled to obtain better bonding.

After the mixture is applied, it should be allowed to set. It should then be kept damp for two days to help it cure properly.

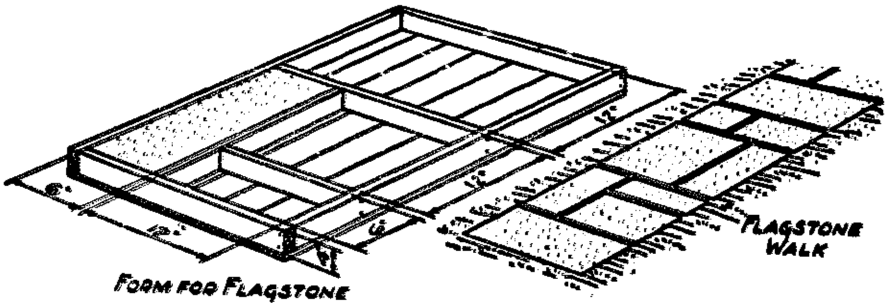
USING CONCRETE

Estimate, as nearly as possible, the amount of concrete needed. Make simple drawings for the forms needed. Construct the forms according to the sketches made, and *follow the directions* given in the previous chapters for mixing or purchasing ready-mix and for reinforcing, placing, and curing the concrete.

CONCRETE OBJECTS

Flagstones for Walks

1. Use a 1:2:3 mixture with coarse aggregate less than 1 inch in diameter.
2. Construct the forms. The forms may be made of rough planks and two-by-fours. Since the forms will be used several times, they should be assembled so that they may be taken apart easily. Various designs and sizes of blocks may be made.
3. Oil the forms before placing the concrete.
4. Finish with a wood float, after the concrete has hardened slightly, to secure an even, gritty surface that will not be too slippery.

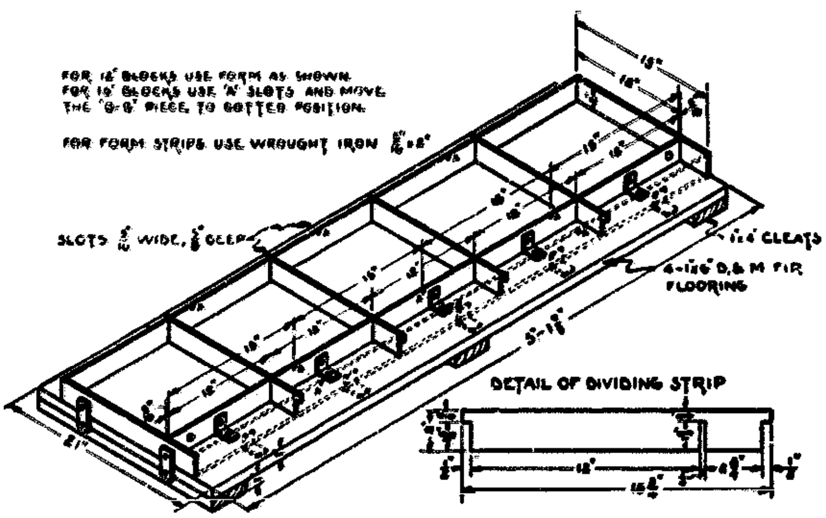


(Courtesy Portland Cement Association)

Fig. 32.9. Forms for flagstones.

Stepping Stones

1. Use a 1:2:3 mixture. Use damp, well compacted sand or clay for forms.
2. Pour the concrete into shallow depressions of the desired shape and size.
3. Make the top flush with the form, and finish with a roughened surface.

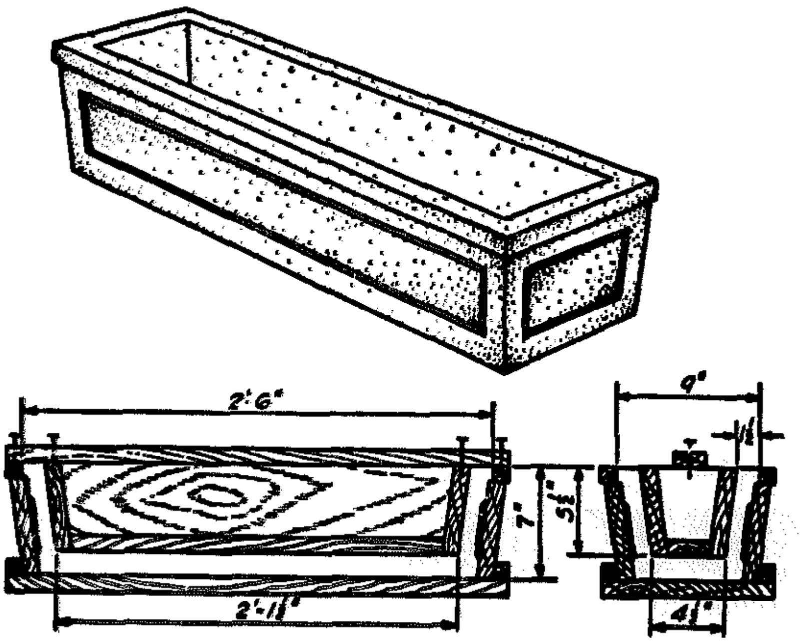


(Courtesy Portland Cement Association)

Fig. 32.10. Forms for stepping stones.

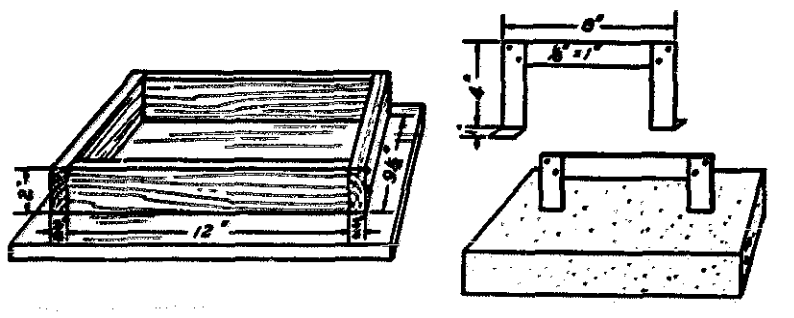
Flower Boxes and Pots

1. Use a 1:2:2 mixture with coarse aggregate not over ¾ inch in diameter.
2. Construct the forms carefully and neatly. The size and shape may be varied according to preference and use. The surface of the forms next to the concrete should be sandpapered smooth and given two coats of shellac to prevent them from warping.
3. Center the inside and outside forms exactly.
4. Oil the faces of the forms before placing the concrete.
5. Work the concrete into the corners of each form.
6. Leave the forms in place for 48 hours. Remove the outer form first.
7. Paint the inside and the outside of the finished flower box or pot with cement and water mixed to the consistency of thick cream.
8. Cure for at least a week, wetting thoroughly every day.



(Courtesy Portland Cement Association)

Fig. 32.11. Plans for a concrete flower box, suitable for either window ledges or pedestals.



(Courtesy Portland Cement Association)

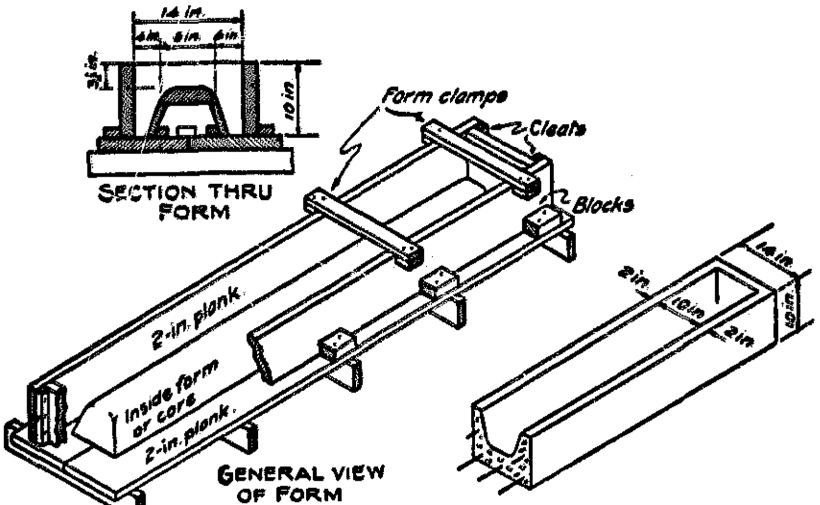
Fig. 32.12. Plans for a movable shoe scraper.

Movable Shoe Scraper

1. Use a 2:2:2 mixture.
2. Rivet the iron straps for the scraper.
3. Place the scraper in the center of the form, raising the flanges about ¾ inch from the bottom.
4. Tamp, smooth, and round the outside edges with an "edger."
5. Remove the form after 36 to 48 hours, and cure for 10 days, sprinkling daily.

Feeding and Watering Troughs—Concrete troughs for watering hogs and poultry are easy to clean, will stand weathering and rough usage, and are not easily upset.

1. Use a 1:2:3 mixture and water as indicated in Table 31.1.
2. Use 2-inch material for the forms.
3. Oil the inside surfaces of the forms.
4. Fasten the forms together securely, as shown in Fig. 32.13.
5. Vary the length of the trough as desired.
6. Reinforce the concrete with ¼-inch steel rods, placed as shown in Fig. 32.13.
7. Mix, place, and cure as directed in Chapter 31. A 6-foot trough, using a 1:2:3 mixture, requires 1 sack of cement, 2 cubic feet of sand, 3 cubic feet of pebbles, and 30 feet of ¼-inch reinforcing rod.



(Courtesy Portland Cement Association)

Fig. 32.13. Construction details for a concrete hog trough.

Concrete Fence Posts—Good fencing is an essential part of a good farmstead. Good fences require good posts. Concrete posts have many superior qualities. They will not rot and are not injured by borers and fungus growths. They are easy to set and align because they are of the same size and shape. They are attractive when properly made, and fence rows harboring weeds and insects may be burned without being harmed.

The shape and size of concrete posts may be varied. The most common length used for line posts is 7 or 8 feet, allowing them to be set 2 to 3 feet into the ground. A post of a useful size is one with a 4- by 5-inch base tapering to 4 by 3 inches at the top.

Forms may be made of lumber at home, or manufactured metal forms can be purchased. Homemade forms are satisfactory if properly made, although the commercial metal forms may produce truer shapes and smoother faces. Metal forms are preferable for making triangular, half-round, or T-shaped posts. Lumber used for forms should be sound, straight-grained, and planed smooth. Forms should be securely wedged and clamped.

Use ¼-inch steel rods to reinforce posts, placing the reinforcing as shown in Fig. 32.14.

1. Use a 1:1¾:2 mixture with about 4 gallons of water per sack of cement (see Table 31.1).
2. Mix according to the directions.
3. Place the mixture about 1 inch deep in the form.
4. Place two reinforcing rods, one in each corner, ¾ inch from the side and from the bottom of the form.
5. Fill the form to within 1 inch of the top of the mold. Compact well. "Spade" along sides with a trowel.
6. Place two more reinforcing rods, one in each corner, ¾ inch from the side and from the top of the form.
7. Fill the form to the top, smooth, and trowel.
8. Remove the form in 24 to 48 hours.
9. Cure the post for 10 days. Keep it damp. Posts should not be used for one to two months.

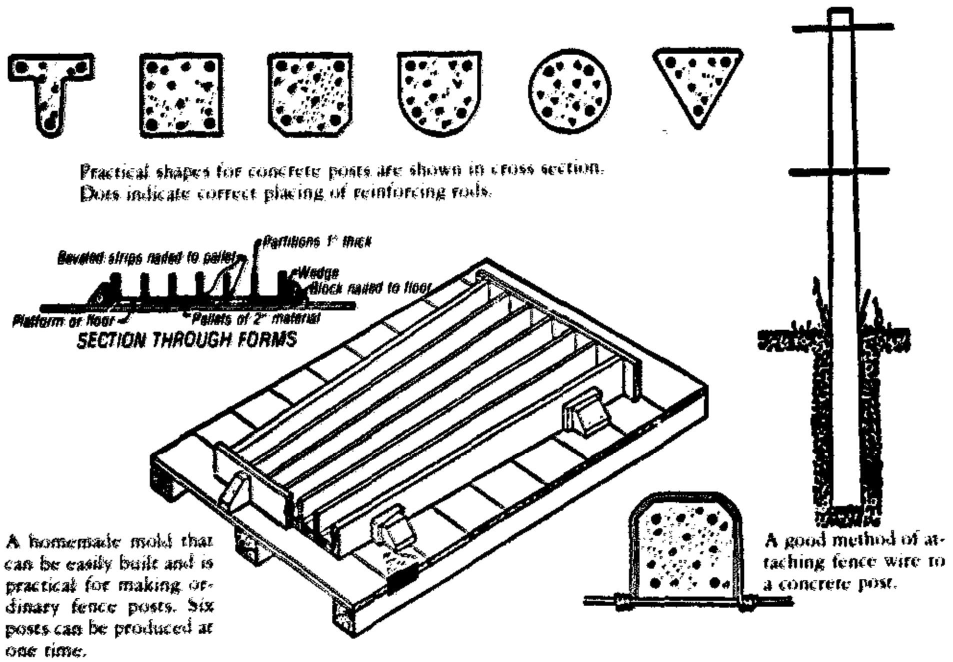
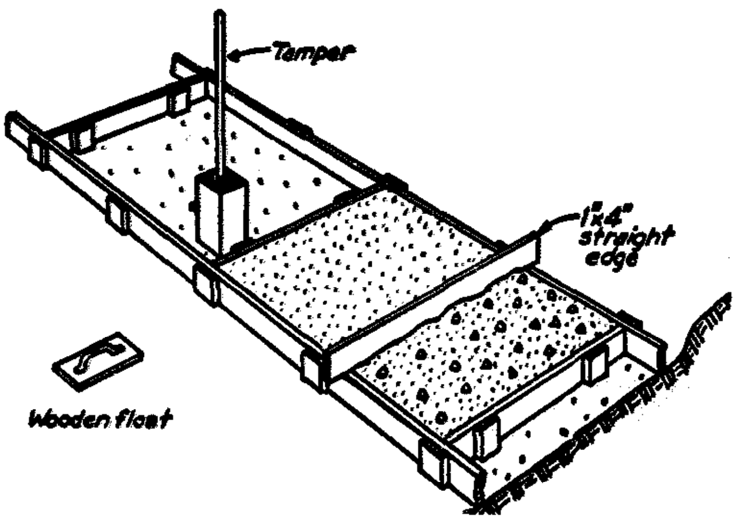


Fig. 32.14. Practical post design and a simple six-post mold for making a rectangular concrete post.

SIDEWALKS, DRIVEWAYS, PAVEMENTS, AND FLOORS

The general principles of concrete construction discussed previously apply to this type of concrete construction. In addition, there are some other special points and steps that need attention. They are as follows:

Preparation of Base—A good base is absolutely necessary for sidewalks, driveways, and floors if they are to be permanent and satisfactory. A base must be well compacted and solid to prevent future settling. It must be even and level, with low spots filled and tamped firm. It must be well drained to prevent freezing and heaving. The concrete can be placed directly upon the soil, after it has been compacted, if it is sandy or gravelly so that it will drain. In clay or heavy soils that do not drain well, a sub-base of coarse gravel or stones about 6 inches thick should be provided and tamped.

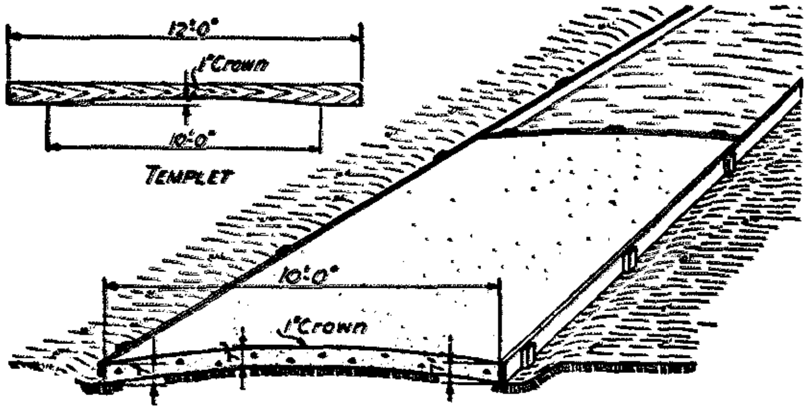


(Courtesy Portland Cement Association)

Fig. 32.15. Forms for sidewalks usually consist of two-by-fours set on edge. These serve as guides in striking off the surface. For convenience, and to allow for expansion and contraction, sidewalks are generally built in sections.

One-Course Construction—One-course construction means that the full thickness of the concrete is placed at one time, using the same mixture throughout. The thickness to use will depend upon the load to be carried; 4 inches of concrete is usually sufficient for walks and basement floors, while a farm driveway should be at least 7 inches thick. Forms should be made so that the proper thickness is secured by leveling the concrete flush with the top edges of the forms.

Placing in Sections—For greater convenience in building and to allow for expansion and contraction of the concrete due to changes in temperature, the work should be partitioned into sections. Alternate sections are then concreted. When



(Courtesy Portland Cement Association)

Fig. 32.16. Design for the construction of a concrete driveway.

they have hardened, the other sections may be concreted. Strips of tarred paper may be used to separate the sections.

Finish—To produce a gritty surface that will not become slippery when wet, finish walks and floors with a wood float. A steel-trowel finish is not recommended unless a very smooth finish is desired.

Curing—As soon as the concrete has started to harden, a 2-inch layer of sand or earth should be placed on it. This layer should be kept damp for about 10 days, after which the concrete will be ready for use.

Sidewalks—The location of walks should be planned with care so that they will add to the attractiveness of the lawn and the shrubbery. They should be placed so that they will be convenient and will eliminate any temptation to "cut across corners."

1. Estimate the quantities of cement and aggregates or ready-mix that will be required.
2. Prepare a level, well drained, compact base. Build up the base so that the top of the walk will extend 2 inches above the ground.
3. Use two-by-fours for side forms. Use stakes to hold the forms in position. Level tops of forms so that the concrete will be of the desired thickness; ordinarily a thickness of about 4 inches is sufficient. A slight slope to one side of ⅛ inch per foot will allow water to drain off rapidly.
4. Place partition strips at intervals of 4 to 6 feet.
5. Use the recommended mixture (Table 31.1). Mix thoroughly.
6. Place the concrete in alternate sections. Tamp solidly and spade next to the forms. Level with a straightedge or strike board.
7. Finish with a wooden float.
8. Place the concrete in the missing sections when the first sections have hardened enough so that the partitions may be removed.
9. Cover with damp sand or earth after the concrete has hardened slightly. Cure for 10 days.

Driveways—A good concrete driveway leading from a highway to a house, garage, or machine shed is of great practical value, especially in wet weather, and adds to the attractiveness of a farmstead or the site of a nonfarm agricultural business. The arrangement and location of a driveway should be planned with care. A solid pavement driveway should be constructed if it is to be used for heavy hauling. For occasional use, such as an entrance to a garage, a driveway made of parallel strips of concrete may be satisfactory.

In constructing a concrete driveway, follow the principles and practices presented for laying sidewalks:

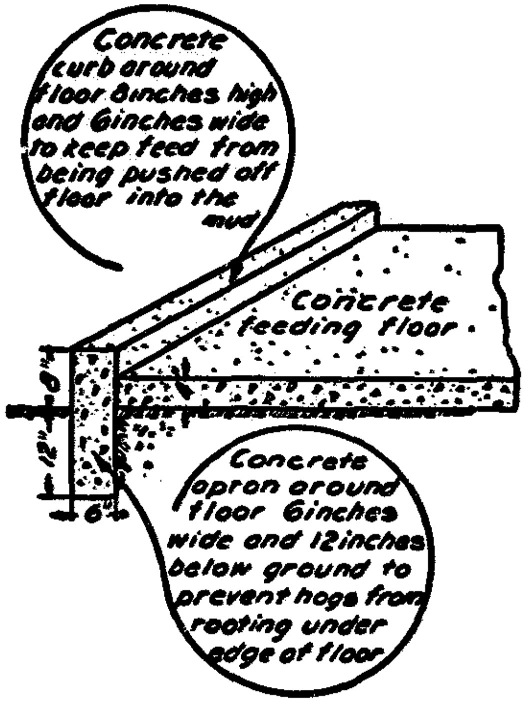
1. Measure the site and estimate the quantities of cement and aggregates or ready-mix that will be required. The concrete should be 7 inches thick for heavy usage.
2. Prepare a compact, well drained base. The center of the base should be 1 inch higher than the edges, and the base should be rounded uniformly so that the concrete will have a uniform thickness of 7 inches.
3. Use two-by-sixes for side forms. Level the forms and stake them securely. Place partitions about 20 feet apart and allow space for the expansion and the contraction of the concrete.
4. Use the recommended mixture (Table 31.1). Mix thoroughly.
5. Place alternate sections, using one-course construction. Tamp and spade well.
6. "Strike-off" with a strike board cut so that the center of the concrete section will be 1 inch higher than the outer edges.
7. Finish with a wooden float on a long handle or with a stiff strip of heavy belting, drawing the float or belting back and forth across the concrete to form an even but slightly roughened surface.
8. Cover with sand or earth after the concrete has partially set, keeping the sand or earth damp for at least 10 days.

Feeding Floors—A concrete feeding floor for a barn lot or hog lot is a worthwhile farmstead improvement. Besides eliminating the unsightliness and inconveniences of a muddy yard, additional advantages such as the saving of feed and better sanitation should result. Carefully choose the site of a floor, keeping in mind its convenience to the feed supply and its protection from cold winds.

It is advisable to construct a curb or apron around a concrete feeding floor as shown in Fig. 32.17. The upper portion of the curb prevents the grain from being pushed off the floor, and the lower part of the curb prevents hogs from rooting underneath the floor.

The steps to be taken in constructing a concrete feeding floor are as follows:

1. Determine the size of floor needed. Estimate the quantities of cement and aggregates or ready-mix necessary.
2. Measure site and set boundary stakes.
3. Smooth, roll, and tamp base. If the soil is well drained, the concrete may be placed directly upon the ground; if not, a layer of gravel or cinders should be used. Give the base a slope toward one side for surface drainage of 1/4 inch to the foot.
4. Construct forms for curb and apron.
5. Place concrete for curb, using proper mixture (Table 31.1).
6. Use two-by-fours to construct forms for the floor. The concrete should be laid in sections about 10 feet square. Level the forms, with proper grade, so that the concrete may be "struck off" flush with the top of the forms.



(Courtesy Portland Cement Association)

Fig. 32.17. A sketch showing how to construct a concrete curb and apron.

7. Place concrete in alternate sections, using one-course construction and recommended mixture. Tamp and "strike off" smoothly.
8. Fill the missing sections after the ones laid first have hardened enough to be self-sustaining without the forms.
9. Finish with a wooden float to obtain a roughened surface that will not be slippery.
10. Cover with straw or earth and cure for 10 days before using.

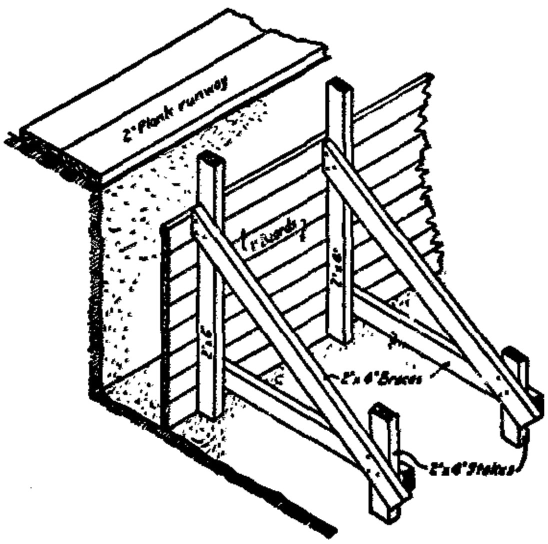
CONCRETE FOUNDATIONS, RETAINING WALLS, AND FOOTINGS

Concrete walls, foundations, and footings for buildings are not difficult to build but require good forms and proper mixtures. A well constructed foundation should not allow a building to sag or settle out of shape. A foundation should not be disturbed by freezing and thawing.

The thickness and depth of foundations or footings below the surface of the ground depend upon the weight of the load to be carried, the nature of the soil, and the frost line. Usually concrete foundations 12 inches in depth and 8 inches thick are sufficient for small agricultural buildings. If the soil is soft or spongy, a wider footing is necessary.

The foundations and walls for large agricultural structures should be designed by a competent engineer or builder.

Earthen Forms—If the soil is compact and does not cave in easily, underground footings for walls may be made without the usual wooden forms. Using a form, one side of which is made of earth and the other of wood, is a common practice. When an earthen form is used, the trench should be dug carefully with straight, vertical sides. When placing and tamping the concrete, be careful not to push earth into the trench or crumble dirt from the sides into the concrete. If the ground is soft or caves in readily, regular wooden forms are necessary.



(Courtesy Portland Cement Association)

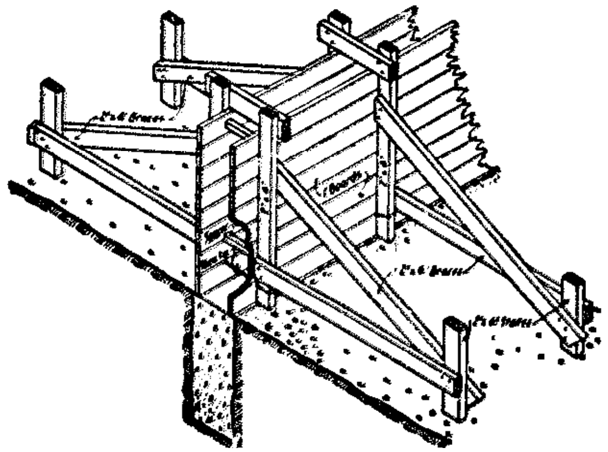
Fig. 32.18. Forms for a foundation or retaining wall with the earth serving as one side of the form.

Wooden Forms—For walls aboveground, strong, rigid, well braced forms are essential to prevent bulges, unevenness, and warping. Wet concrete is very heavy, weighing about 150 pounds to the cubic foot; consequently, a weak form will spread and bulge. Seasoned 1-inch boards are often used for forms. They should be well seasoned, straight, of uniform thickness, and fitted together without cracks. If a very smooth face is desired, the boards should be tongued and grooved, and planed.

Bracing and tying are important. Two-by-four posts should be placed at about 2-foot intervals and braced securely as shown in Fig. 32.19. "Spacers" of proper length should be placed between the forms to hold them securely against the posts. (See Fig. 32.19.) Crossties of wire, twisted tight, will help to keep the forms from spreading.

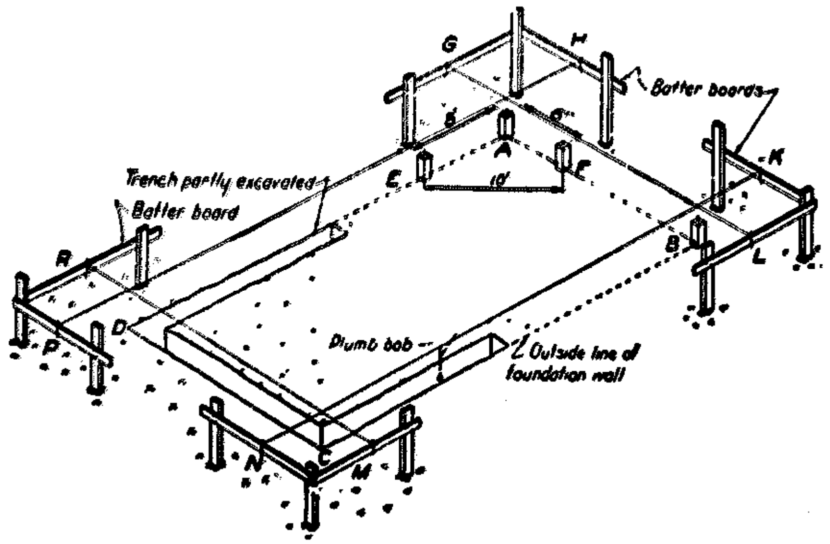
Placing the Concrete—The recommendations in Table 31.1 as to the proportions of cement and water to use should be followed exactly. A concrete wall should *not* be built in sections. The entire wall should be completed in one day's operation to avoid a construction seam in the concrete due to an imperfect connection between the hardened and fresh concrete. If it is necessary to stop work before a wall is completed, the concrete should be leveled and roughened by scratching or by placing large pebbles and pieces of stone in it which project halfway out of the concrete. Before new concrete is poured to complete the wall, scrub the old concrete to remove dirt, soak it thoroughly, and brush it with a paste of cement and water.

If a frame building is to be built on the concrete foundation, anchor bolts for attaching plates and sills should be imbedded in the concrete.



(Courtesy Portland Cement Association)

Fig. 32.19. Forms for walls above grade. These forms can be used for foundation walls or garden walls.



(Courtesy Portland Cement Association)

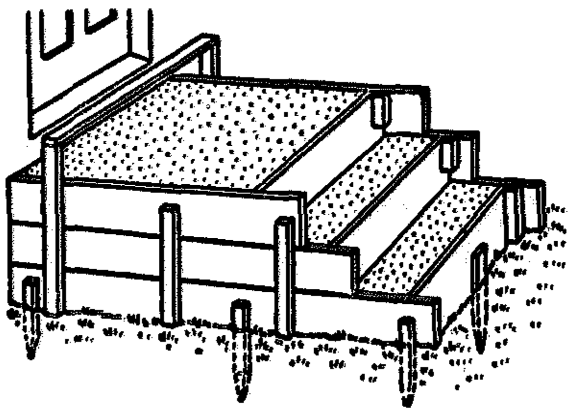
Fig. 32.20. A method of squaring corners and of using batter boards to establish building and excavation lines for foundation trenches. See Chapter 30 for further information on staking out foundations for buildings.

Door and window frames in walls may be set before the concrete is placed for the walls. The frames are placed securely in the forms and the concrete is placed around them. If the frames are to be placed in after the concrete is poured, "dummy" frames must be used which can be removed after the concrete has set. When "dummy" frames are used, nailing blocks to which the regular frames are fastened must be imbedded in the concrete.

MISCELLANEOUS CONCRETE CONSTRUCTION

Detailed construction plans for all kinds of concrete work useful in agriculture cannot be given in this book. Very excellent plans can also be obtained from the manufacturers of cement. In this chapter plans for projects are suggested, and in many instances the drawings are in sufficient detail to serve as working plans. The general directions for proportioning and mixing the materials and for curing the concrete are the same as those given previously for other types of concrete construction.

Concrete Steps—The steps should not be over $7\frac{1}{2}$ inches in height. The width of the tread should be about 10 inches. One-inch lumber can be used in building forms for ordinary door steps. Finish the concrete with a wooden float.



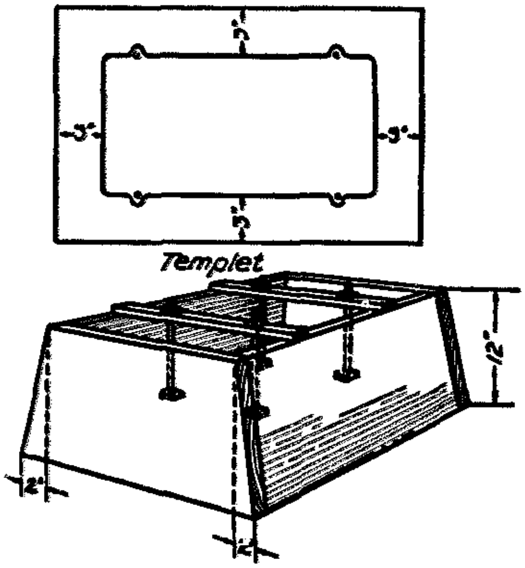
(Courtesy Portland Cement Association)

Fig. 32.21. Simple forms for building concrete steps.

Machine Foundations—Concrete makes durable and solid foundation bases for stationary machines. The size of foundation to use will depend upon the size and weight of the machine. Most foundations for machines should have a margin of at least 3 inches of concrete on all sides of the machine.

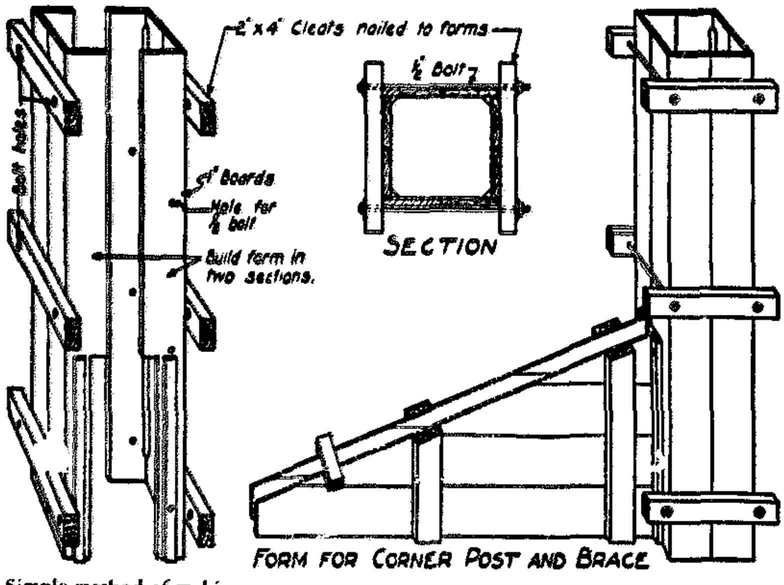
Corner and Gate Posts—Corner and gate posts, because of their great weight, are usually made in the place where they are to be used. The hole should be at least 3 feet deep and dug carefully so that the earth may serve as the form below the ground level.

1. Use 1:2¼:3 mixture (see Table 31.1).
2. Build forms for upper part of post. Brace and place forms in position. Provide bolts and fittings for hinges or fastening wires.
3. Insert reinforcing rods so that they will extend from the top of the post



(Courtesy Portland Cement Association)

Fig. 32.22. The form for a base for stationary machines.



Simple method of making forms for corner posts and brace.

(Courtesy Portland Cement Association)

Fig. 32.23. The form for corner, end, and gate posts which are cast in place.

to at least 2 feet below the level of the ground. Tie them in place when placing the concrete.

4. Fill the forms, tamping and spading properly.
5. Remove forms when the concrete has hardened.
6. Cure the post for two months before using it.

(Courtesy Portland Cement Association)

Fig. 32.24. An attractive concrete mailbox stand.

RURAL CONVENIENCES AND SANITATION

Student Abilities to Be Developed

1. Ability to select plumbing equipment for a farm or nonfarm agricultural business.
2. Ability to install and repair plumbing fixtures.
3. Ability to select and install water systems for farms and nonfarm agricultural businesses.
4. Ability to establish sewage disposal systems for farms and nonfarm agricultural businesses.

CHAPTER 33

Establishing Water Supply Systems in Rural Areas

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What are the water requirements of a farm? How does this compare to your farm, agricultural business, or home?
2. What are the sources of water in rural areas?
3. How should the sources of water supply be protected?
4. How may water be disinfected?
5. How may water be softened?
6. What is a water system?
7. What types of pumps are used with water systems, and when and where is each used?
8. What are the principles of operation of automatic switches and pressure tanks?
9. What size of piping should be used in the installation of a water system?

INTRODUCTION

Importance of Planning—A study of the problems which may be encountered in the selection and installation of water supply systems in rural areas should always precede any action. Proper planning often saves time and money.

Water Requirements of Farms—Water requirements of farms will vary. The amount of water which will probably be consumed should be considered in planning a system. When an abundance of cool, fresh water is always available, the amount of water used is higher than it is when the water is difficult to obtain.

Table 33.1 gives the amount of water used under various conditions and for various purposes.

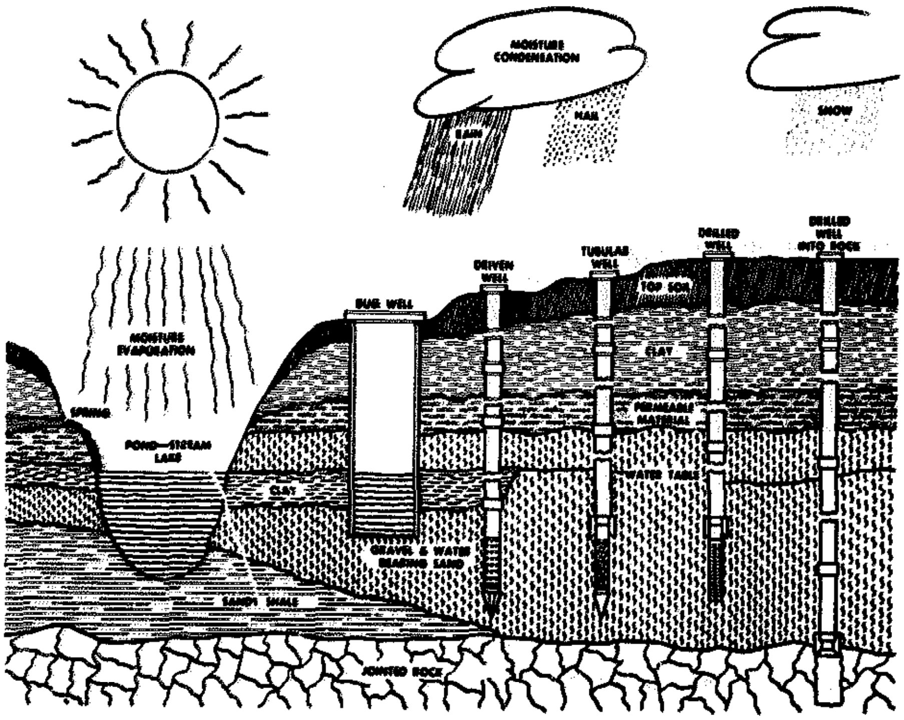
Table 33.1—Daily Water Requirements per Person or Animal

Water Use	Quantity (Gallons)
Each person in family	50–70
Each horse	10–15
Each cow	
with drinking cups	30–40
without drinking cups	10–15
Each hog	3
Each sheep	1½
Each 100 chickens	4–9

SAFE WATER

The type of water supply system installed may be influenced by the source and quantity of the water available. Water may be secured from several sources:

1. Ground water is the ideal source of supply where it can be obtained and when its quality is good. Usually the State Geologist can advise as to the suitability of a particular ground water supply. Types of ground water supplies are wells and springs. Wells may be dug, bored, driven, drilled, or self-flowing. Subsoil characteristics should be determined so that pollution can be prevented. The direction of slope of subsurface formations



(Courtesy F. E. Myers & Bro. Co.)

Fig. 33.1. The sources of water.

may cause the underground water to flow in an opposite direction to what the surface slope might indicate.

2. Cisterns to catch rain water or to store water from another source are occasionally used. Rain water is soft and comparatively pure as it falls, but it may gather impurities before it enters a cistern and before it is used.
3. Surface water from streams, ponds, reservoirs, and ditches may sometimes be used. Surface water is often unsafe because it may be easily contaminated. If it is necessary to use surface water as drinking water, it should be disinfected or boiled.

Characteristics of Good Water—Water for domestic use must be pure. Good water is clear, odorless, colorless, somewhat soft, neither strongly acid nor alkaline, and cool with a preferable temperature of about 50 degrees Fahrenheit. Water should be tested for purity by a reputable chemist, because pure water cannot always be determined by its appearance and taste.

Protecting Well Water—Water supply sources should be protected against possibilities of pollution. Dug wells should be curbed with durable materials, such as concrete, brick, stone, or galvanized metal. The curb should extend above the surface of the ground. A tight-fitting, durable cover should be provided.

Drilled wells should have a tight platform to eliminate the possibility of pollution entering the casing and to prevent damage to the casing.

Safeguarding Springs—Spring water is often assumed to be wholesome, but this may be an unsafe assumption. The water may not have filtered through enough soil to free it of organic matter, or it may collect impurities as it seeps to the surface. The outlet of a spring should be fenced or boxed to keep animals and refuse out of the water. A pit with concrete walls and a gravel bottom is a very desirable type of spring outlet. The overflow from the pit should have a spillway to prevent the undermining of the pit by the erosion of the soil.

Disinfecting Water—Home methods of disinfecting drinking water (destroying disease germs) should be employed if any danger of impurity is suspected. Water should be tested by health authorities or by competent chemists. When wells start to go dry, the danger of impure water is increased.

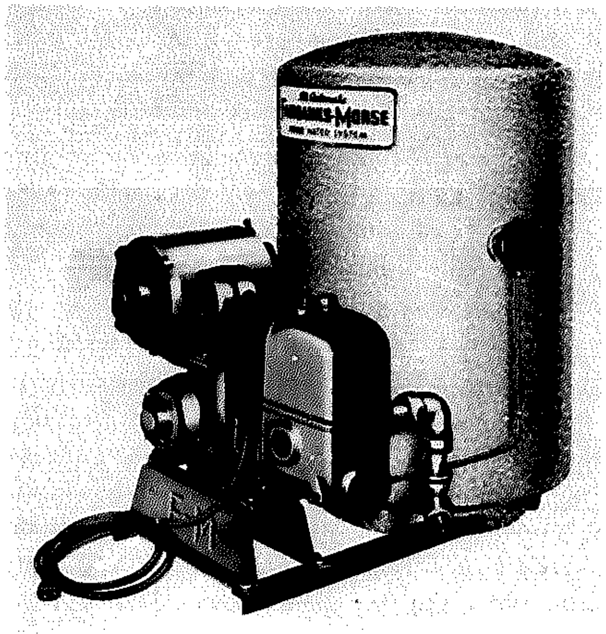
Often conditions exist making it necessary to disinfect the water available. When disinfectants are used, follow the directions explicitly and keep the chemicals labeled and out of reach of children. Most disinfectants are poisonous. The amount of disinfectant necessary for water from a certain source should be determined by a chemist or bacteriologist. If small amounts of water are needed, the water may be boiled.

WATER SYSTEM

A water system supplies hot or cold water under pressure, and soft water if necessary, at all times and at all locations where water is needed. Such a system usually includes the use of an electric motor, a pump, a pressure tank with automatic air control, an automatic switch, a water heater, a water softener, and adequate piping of the water to the locations where water is needed.

Shallow Well Pumps—The kind of pump needed depends on the type of well. A shallow well pump is needed for a well 22 feet or less in depth at sea level. For each increase of 1,000 feet in elevation above sea level, a shallow well pump can be used for a well 1 foot less in depth. For example, at a 6,000-foot elevation, a shallow well pump can be used on a well not over 16 feet in depth. A deep well pump is needed for wells over 22 feet in depth.

Manufacturers make several types of shallow well pumps such as reciprocating, centrifugal, turbine centrifugal, jet centrifugal, and rotary gear pumps.



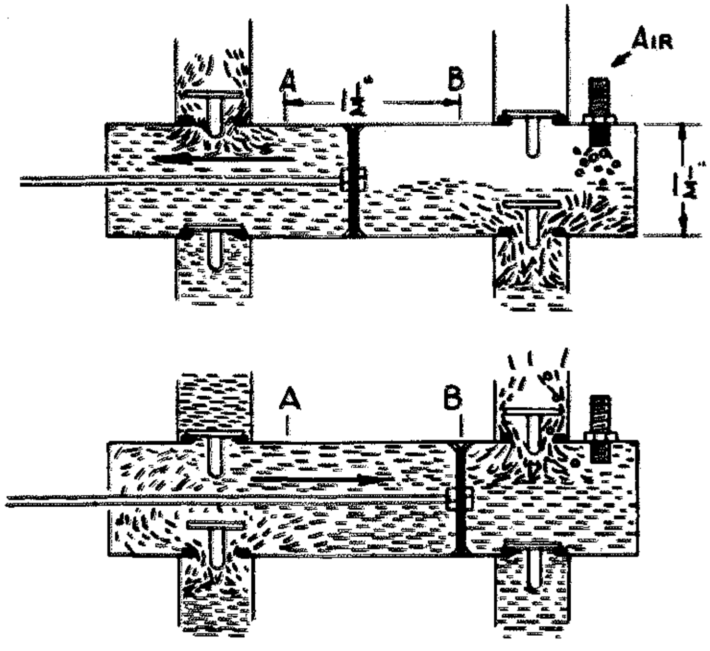
(Courtesy Fairbanks, Morse and Co.)

Fig. 33.2. A shallow well piston pump with pressure tank, automatic switch, air volume control, and ¼-H.P. capacitor motor.

Deep Well Pumps—There are many types of deep well pumps on the market, but they can usually be classified as piston, jet centrifugal, submersible, or deep well turbine. The *deep well jet centrifugal pump* is usually the only pump that can be used in either a shallow or deep well. It is not a desirable pump to use for wells over 75 feet in depth, however, because its cost of operation on deeper wells is greater than the cost of operating a piston pump.

Operating Principles of Pumps—If the distance from pump to water level is 25 feet, atmospheric pressure may be used to obtain a flow of water. If a pump removes the air from a pipe leading to the water, the atmospheric pressure will push the water up the pipe.

In the *double action piston* or *plunger pump*, illustrated in Fig. 33.3, the stroke of the piston forces water out of the well and at the same time creates a vacuum which draws water from the well.

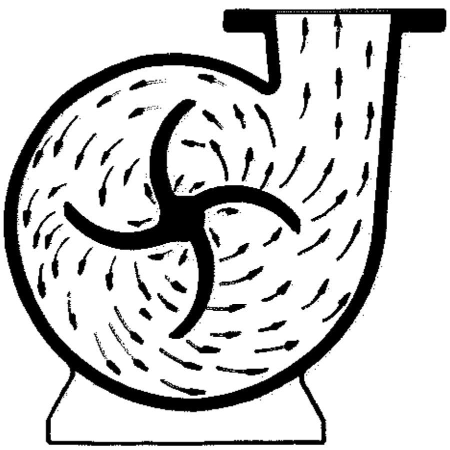


(Courtesy Deming Division Crane Co.)

Fig. 33.3. A schematic drawing of a double action piston pump.

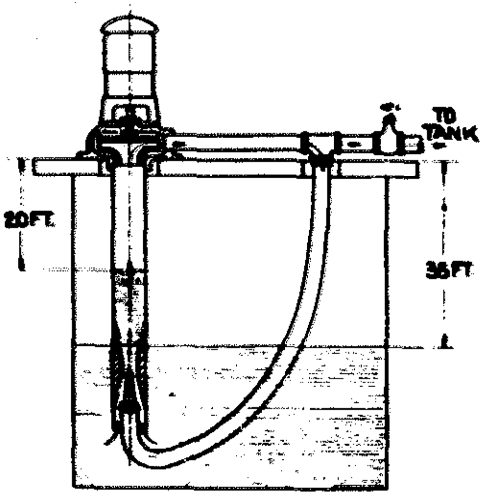
A *centrifugal pump* has a rotating element called an impeller, with vanes that project. In Fig. 33.4 the center is the impeller, and the vanes project from the center. When the impeller is turned, the water is moved as shown in Fig. 33.4. When the water moves out from the impeller a vacuum is produced, and atmospheric pressure acting on the surface of the water forces water into the impeller.

A *jet pump* uses part of the water being pumped to provide a jet of water in the suction pipe as shown in Fig. 33.5. The water from the jet nozzle creates a



(Courtesy Deming Division Crane Co.)

Fig. 33.4. A schematic drawing illustrating how a centrifugal pump works.



(Courtesy Deming Division Crane Co.)

Fig. 33.5. A schematic drawing illustrating how a jet pump works.

partial vacuum in the pipe. The partial vacuum sucks additional water from the well.

A *turbine pump* is a type of centrifugal pump.

A *submersible pump* is a pump with a motor that is designed to be submersed or lowered into the well below the water level. The motor is below the pump, which is a multistage centrifugal pump. The motor is waterproof and is connected to a waterproof electrical cable. The advantage of a submersible pump is that it cannot be seen or heard.

Pump Size and Location—In selecting either a shallow or deep well pump, choose a pump of sufficient size to supply the maximum needs of the farm or nonfarm agricultural business. If the well will supply the water, a pump that will deliver 650 gallons of water an hour will take care of the needs of most farms. A pump of this size will handle a sprinkling system for the irrigation of a lawn and a garden. It will supply enough water for a ³/₄-inch garden hose, which should be the minimum amount of water available for fighting fires in a rural area. If a water system is to be of much value for firefighting, however, it should have a separate wiring system. If the well is inadequate for a pump that will deliver 650 gallons an hour, a larger storage tank and a smaller pump should be used. It is not wise to use a pump that is too large for the capacity of the well.

It is not necessary to place a shallow well pump or a deep well jet centrifugal pump directly over a well. These pumps may be placed in a basement or at some other convenient location. The piston-type deep well pump must be installed directly over a well. If the deep well piston-type pump is used, it should be placed in a pump house or in a pit.

Electric Motor—Pumps come equipped with motors of the correct size. When a motor needs to be replaced, however, it should be replaced with a motor of the same size and type. Check the nameplate on the old motor for information regarding the size and type of motor needed. The motor should not be replaced with a split-phase motor, because a split-phase motor will not start a heavy load.

Automatic Switches—An automatic switch is used with a pressure tank water system to start and stop the motor of the pump. When the water pressure drops below a certain point, the motor is automatically started. When the pressure is increased to a certain point, the motor is stopped. An automatic switch is connected by means of a series of levers to a diaphragm. The diaphragm is connected to the pressure tank. When the pressure increases above a certain point, the diaphragm expands and opens the switch, which stops the motor. When the pressure decreases below a certain point, the diaphragm recedes sufficiently to close the switch and start the motor.

Pressure Tank—A pressure tank is a closed tank. When water is pumped into it, the air in the tank is compressed at the top of the tank. This compressed air at the top of the tank provides the pressure for the water system. The automatic switch keeps the pressure of the tank within a certain range.

A pressure tank is an essential part of a water system. It provides a reserve of water so that the pump does not have to operate whenever a faucet is opened. If a pressure tank is not used, the motor has to start and stop frequently.

A 42-gallon tank is the size pressure tank often used. However, a 120-gallon or larger tank is often installed on farms when the amount of water used is large, as it is on a dairy farm. A large tank may also be necessary if the capacity of the well being used is low.

A 42-gallon pressure tank operating at normal pressure is filled 3/5 full of water and 2/5 full of compressed air. This relationship between water and air must be maintained. Since water absorbs compressed air, air is removed from the tank whenever water is withdrawn from the tank. Some method of replenishing the air in the tank is therefore needed. Air may be added by draining a tank completely and refilling it, but this is a laborious process. An automatic air volume control is the method frequently used to maintain the correct air-water ratio. A float-type air control is the type often used. With this type of air control an auxiliary air pump is provided which operates when the water pump operates. If too much air is added, the float lowers with the level of the water. This opens a valve and lets the excess air escape.

Water Heaters—Water heaters are necessary to make a water system fully modern. A heater should be located as near as possible to the places where hot water is needed. If hot water is needed in a milk house, it may be advisable to install an additional heater there. A heater holding 52 or more gallons is usually needed for rural residences.

Water Softener—The difficulty in using well water is that it is often "hard" and not suited for such uses as washing clothes. This difficulty may be eliminated by the use of a water softener.

A popular type of water softener contains a special sand. When water flows through this sand, the calcium and magnesium which cause hardness are removed.

The sand will only remove so much calcium and magnesium, and then it must be regenerated by having common salt washed through it.

Piping—Pipe of adequate size must be used, or the pressure of the water at the faucets will be inadequate. Ordinarily, ½-inch pipe or copper tubing is used within a house. For piping to the outbuildings on a farm or nonfarm agricultural business, 1-inch pipe is used for distances of less than 100 feet. For distances of 100 to 300 feet, 1¼-inch pipe is used. Bends in a pipe increase the resistance to the flow of water and reduce the pressure. An elbow causes a reduction in pressure equal to the addition of 6 feet of pipe.

Piping between buildings should be as straight and short as possible. It should be installed so that it can be completely drained to prevent freezing.

Maintenance and Service—The causes of difficulties with a water system are easily detected if the principles of operating the system are understood. If the pump has to start frequently, the size of the pressure tank may be too small, or the pressure tank may be waterlogged. If the tank is waterlogged, the air control mechanism is probably not working correctly. A leak in the tank may also be causing the trouble.

If the water spurts when a faucet is opened, there is too much air in the tank. Again difficulty with the air control mechanism is indicated.

If the pump fails to deliver water at its full capacity as shown by the amount of time the pump operates, the need for new leathers or valves may be indicated. If this is not the cause of the difficulty, look for such things as air leaks, obstructions, loose belts, or worn gears.

If the pump gets noisy, look for obstructions in the suction pipe, or for sticking valves. A noisy pump may also be caused by the locating of the pressure tank at too great a distance from the pump.

Service a water system by keeping all belts tight and by lubricating parts according to the manufacturer's directions.

CHAPTER 34

Selecting and Using Plumbing Equipment

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Should farmers and nonfarm agricultural workers do plumbing and pipe fitting?
2. What are some terms frequently used in plumbing?
3. What plumbing tools should be purchased?
4. What are the common kinds of pipe and their uses?
5. What are the names and uses of common pipe fittings?
6. When should plastic pipe be used? Copper tubing?
7. How should pipe be measured and marked?
8. How should pipe be cut and threaded?
9. How should pipes and pipe fittings be assembled?
10. How should fixtures be arranged in the bathroom? In the kitchen?
11. How should fixtures be installed?
12. What care should plumbing fixtures be given?
13. What repairs should farmers and nonfarm agricultural workers make on plumbing fixtures?
14. How are faucets repaired?

INTRODUCTION

Planning a Plumbing System—Good plumbing contributes much to the comfort and well-being of both people and animals. It makes sanitary sewage disposal possible. A plumbing system should be carefully planned. Before spending any money, it is recommended that a plan or sketch be made showing pipe sizes and locations and the general arrangement of fixtures. It is desirable to have the laundry, the kitchen, and the bathroom near each other in order to eliminate excessive plumbing.

Qualifications for Plumbing Work—Plumbing involves a knowledge of hydraulics, mechanics, pneumatics, sanitation principles, materials, and fixtures. It should not be attempted by persons without experience, training, or skill in working with plumbing equipment.

PLUMBING EQUIPMENT AND TERMINOLOGY

Definitions of Common Plumbing Terms—The following terms are those most frequently used:

Plumbing is the piping and pipe attachments used to carry water into buildings and to drain away sewage and waste.

Fittings are pieces used to join pipes, to provide openings in them, and to change their direction. Examples are couplings, elbows, and caps.

Fixtures are the appliances connected to the plumbing, for example, bathtubs, kitchen sinks, laundry tubs, and toilets.

A *trap* is a water-sealed bend or chamber in a waste pipe. It is located near or within a fixture. It prevents odors and vermin from entering a building through the fixture. If a short pipe extends from the outlet side of the trap to a vent stack, it is known as a *trap vent*. It prevents the siphonage of the trap, provides ventilation, and promotes the flow of the waste water.

A *house drain* is the pipe which carries all the sewage from the house.

A *sewer* carries the sewage from a drain to the final disposal area.

Soil pipes are large pipes used to carry sewage.

Waste pipes are small pipes used to carry wastes from sources other than toilets and urinals. Sink and bathtub drain pipes are examples.

A *stack* is a soil, waste, or ventilating pipe and is defined by its use. Vent stacks extend through the roof and above the highest fixture.

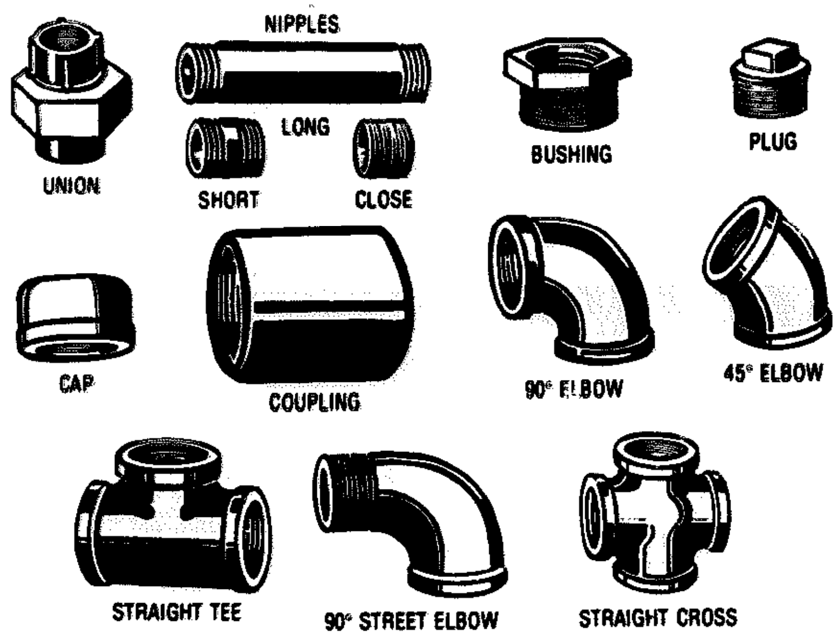
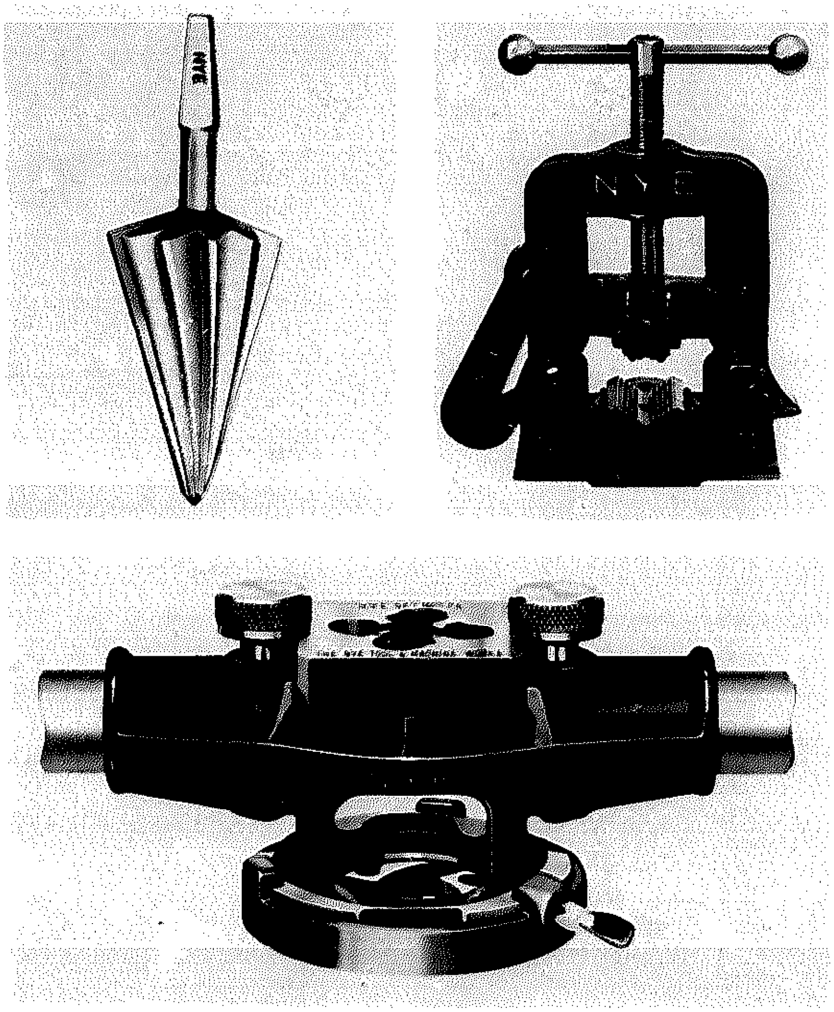


Fig. 34.1. Various types of pipe fittings frequently used.

Tools and Equipment Required—The tools and supplies required for plumbing are calking tools, pipe vise, pipe cutter, pipe threader, reamer, machine oil, pipe wrenches, hammer, file, hacksaw, cold chisel, and measuring tape or ruler. Other tools such as level, plumb bob, and pipe bender are useful but they are not absolutely necessary.



(Courtesy Nye Tool Company)

Fig. 34.2. Pipe fitting tools. Top left—pipe burr reamer. Top right—pipe vise. Bottom—pipe threader.

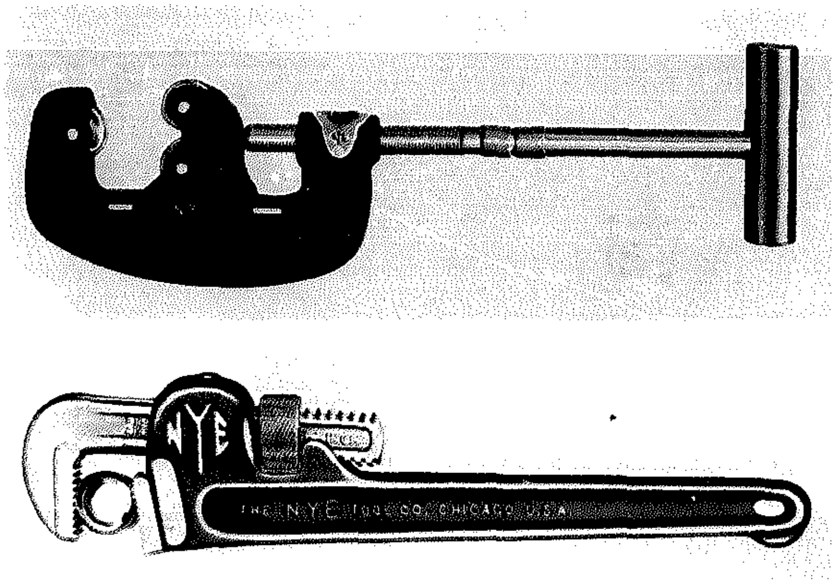
KINDS OF PIPE

Water Pipes—Pipes are made from several different materials. Following are the main kinds of pipe used for carrying water.

Plastic pipe is being used in increasing amounts where local plumbing codes permit its use.

Wrought iron pipe, usually galvanized, comes in three weights: standard, extra strong, and double extra strong. The outside diameter of each weight is the same, but the bore is decreased in the heavier weights. Wrought iron pipe can be welded and bent.

Cast iron pipe coated with hot coal tar pitch is often used for underground water pipes. It has a long life and can be obtained with threaded ends for standard screw fittings, or the ends may have joints for calking.



(Courtesy Nye Tool Company)

Fig. 34.3. Pipe fitting tools. Top—pipe cutter. Bottom—pipe wrench.

Miscellaneous Water Pipes and Tubes—Small pipes often corrode and produce water that is "rusty" in appearance. In addition, the bore of a small pipe may be reduced by corrosion. To overcome corrosion difficulties, pipes can be obtained which are treated to prevent the corrosive action of the salts in the water. Copper pipe is extensively used for interior work.

Tubing is thin pipe varying from $^1/_{50}$ to $^1/_{10}$ inch in thickness. Usually, it requires special threads and fittings. The outside measurement (O.D.) of tubing is usually used as its diameter. Tubing may be used where the water pressure is low or medium.

Drainage and Vent Pipes—The pipes used to carry waste are known as drainage pipes. The pipes connected to a waste system are known as vent pipes. In some cases, the pipes used as drainage or vent pipes might be the same size or kind as those used to carry water. The description of drainage and vent pipes follows:

Sewer pipe is usually made of vitrified clay or concrete and is of rather large diameter, the most common diameters used being 4, 5, and 6 inches.

Drain pipes for soil, waste, and vents, within a building, are usually iron or steel. Short connections to traps and toilets are usually made of lead or brass. Nickel-plated brass tubing is used for exposed fixture connections.

Soil pipe is usually made of cast iron. The most common length of soil pipe is 5 feet, and three thicknesses or weights are available—standard, medium, and extra heavy. One end of a soil pipe is bell-shaped, and the joints of soil pipe are calked.

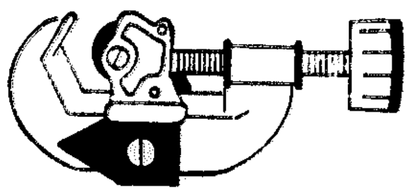
Wrought iron soil pipe is available in longer lengths, is easier to handle, and is lighter and stronger than cast iron soil pipe. It is not as durable as cast iron soil pipe, and it is harder to repair.

Common Pipe Fittings—Pipe fittings are used to join pipes, to change the direction of pipes, to connect branch-off pipes, to reduce the size of pipes, and to cap or plug pipes. Pipe fittings should be of a similar metal and be approximately the same thickness as the pipes on which they are used. The sizes of pipe fittings are designated by the size of pipe they are made to fit. The size of a tee is given as 1 by 1 by $^3/_4$, or shortened to $^3/_4$ by 1. The inside diameters of pipes are used to designate the sizes of pipes.

Common fittings are elbows, couplings, unions, tees, plugs, caps, nipples, bushings, and branches. Most fittings having more than one opening are available with one or more of the openings being smaller in size. This permits a reduction in the size of pipe used.

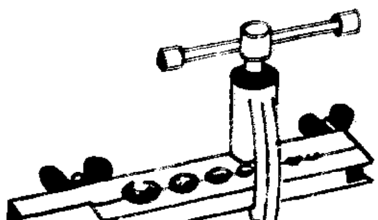
Copper Tubing—Copper tubing instead of other kinds of metal pipe is often used for certain types of pipe work. It is often used in water systems or in other places where corrosion or rust is undesirable. Flexible copper tubing is also used in places where rigid metal pipes would be difficult to install. Copper tubing is frequently used for fuel lines. An advantage of copper tubing is its durability. Both flexible and rigid copper tubing are available.

Copper tubing is an expensive type of pipe. Since it is more flexible than steel, it will stretch some and is not as easily damaged by freezing as steel pipe.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 34.4. A copper tubing cutter.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 34.5. A flaring tool for copper tubing.

Plastic Pipe—Increased use is being made of plastic pipe in agriculture. For certain purposes, it has many advantages over metal pipe. It does not rust, rot, or corrode. It is much lighter in weight than metal pipe. It comes in long lengths—as much as 600 feet of pipe on one reel—and it is flexible. Because of its flexibility and light weight, installation is easy.

Plastic pipe is often used on farms for distributing water around the farmstead and for carrying water to the fields for livestock and for irrigation. Plastic pipe may be bent around corners without the use of fittings. It is easy to cut, and no special tools are required to install the fittings. Plastic pipe may be installed underground or aboveground. Some types of plastic pipe may be used for drinking water. High pressures and high temperatures reduce the life of plastic pipe. Also, there are several grades and types on the market. When plastic pipe is purchased, it is usually wise to buy the best available.

PIPE WORK

Measuring Pipe—In measuring pipe, consider the fittings and fixtures which will be used. *The length of fittings must be taken into account when the length of pipe required is measured.* The length of pipe required for a given job is the distance to be covered minus the threads screwed into the fittings, plus the portion of the fittings extending beyond the pipe. A straightedge ruler is a useful tool for measuring the length of a pipe or for measuring to determine the length of pipe needed.

Marking Pipe for Cutting—When the exact length of the pipe needed has been determined, a permanent mark should be made on the pipe. A good way to mark it is to scratch it with the edge of a three-cornered file. Pencil and chalk marks should be regarded as only rough, temporary marks because they may be rubbed off easily.

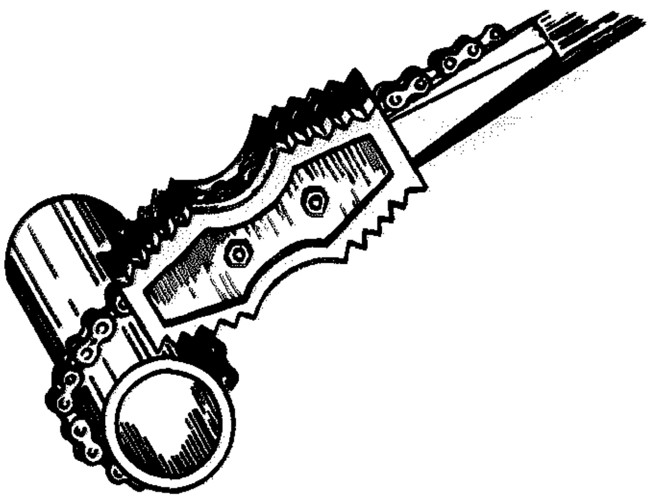


Fig. 34.6. A chain pipe wrench.

Cutting Pipe—Cast iron pipe may be cut with a wheel pipe cutter or with a hacksaw. It is easier to cut pipe straight, and it is quicker to cut pipe, with a wheel pipe cutter than it is with a hacksaw. Standard cast iron soil pipe is usually cut with a cold chisel after it has been grooved with a three-cornered file. The pipe should be laid flat on a 2-by-4 piece of wood and the cold chisel tapped lightly in the groove made with the file. After two or three times around the pipe with a chisel, the pipe should break evenly.

Wrought iron pipe is usually cut with a wheel pipe cutter. A hacksaw can be used to cut any kind of pipe. When a wheel cutter is used on the softer pipes, such as wrought iron, it must be turned and tightened slowly or an excessive burr will result inside the pipe. Any burr formed must be reamed out to prevent the pipe from accumulating foreign particles at this point after it is installed, and to obtain the benefit of the full bore of the pipe.

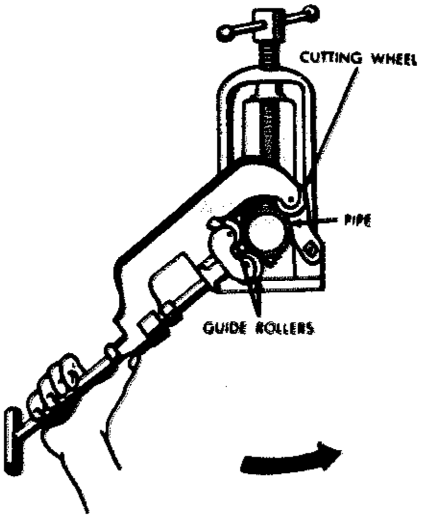


Fig. 34.7. Cutting pipe.

In cutting pipe, place the pipe firmly in a pipe vise with the line to be cut about 5 inches from the jaws of the vise. Adjust the pipe cutter with the pipe between the two rollers and the cutting wheel. Place the cutting wheel on the mark. Tighten the cutting wheel about ¼ turn each revolution of the cutter around the pipe and less than this on the final cuts. Keep the surface of the metal being cut well oiled with a cutting oil. In using a hacksaw, guide the blade with the left thumb to start it on the mark. Saw at right angles to the pipe. As when using a cutting wheel, oiling the metal being cut with cutting oil is desirable. Tubings and thin pipes are cut with a hacksaw or a tube cutter. A tube cutter is better because obtaining a square cut with a hacksaw is more difficult.

Reaming Pipe—Pipe should be reamed after it is cut. Pipe reamers are available that will fit in the chuck of a brace. They are very effective. Reamers containing their own turning handle and swivel are also available. A simple reamer may be made from a flat file. The tang is bent over a handle, and the end of the file is tapered slightly with a grinder.

All the burr in a pipe should be removed. The reaming process should be continued until no raised place can be felt inside the pipe. Outside burrs can be removed with a file.

Pipe Threading—The die used for threading pipe is different from the die used for threading bolts. The pipe thread is a tapered thread which makes a tight joint possible. The solid-type die is commonly used. A die usually has four sets of cutting edges with spaces between them through which the cuttings may drop. A guide is necessary for each pipe size so that the die will cut true and even. Each pipe die and guide is marked for the size of pipe on which it is to be used.

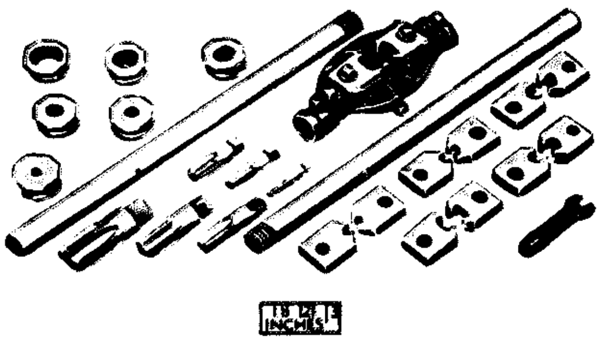


Fig. 34.8. A pipe-threading set.

When cutting threads, do not turn a die back and forth, or the threads will be ruined. Dies must be sharp and in good condition for satisfactory work. For cutting threads on a pipe, follow these procedures:

1. Check whether or not all burrs are removed.
2. Clamp the pipe in a pipe vise.
3. Assemble the stock and die set for the pipe to be threaded.
4. Apply cutting oil to the die and push the *proper size guide* over the end of the pipe.
5. Turn the stock clockwise, at the same time applying considerable pressure inward. When the die is engaged on the pipe, the inward pressure can be discontinued.
6. Oil the pipe frequently just ahead of the die with cutting oil.
7. Continue threading until the pipe is flush with the outside of the die, or not over one thread through the die. This applies to pipes not over 1 inch in size. For larger pipes the number of threads to cut should be increased.
8. Back the die carefully by turning it counterclockwise. Do not use undue pressure in backing a die. Chips may fall into the threads and cause the die to catch. If the die catches, turn it forward again.
9. Strike the handle of the die on the pipe to dislodge chips from the die and from the pipe.
10. Remove the pipe from the vise and tap it with a hammer to remove loose particles.
11. Smooth the end of the pipe, if necessary.

Good threads make a good pipe fitting job possible. Poor threads are difficult to seal, and in many cases impossible to seal.

Assembling Pipe and Pipe Fittings—A plumbing job should be checked to determine the best place to start and to finish. When pipe lines may need to be taken apart at some later time, unions should be used. A union enables a pipe line to be taken apart and put back together easily. Unions often have packing washers of fiber material in them to prevent leakage.

In assembling pipe, follow these steps:

1. See that the pipe and fitting threads are in good shape.
2. Apply a sealing compound to the threads.
3. Use packing material in unions and hose couplings.
4. Screw fittings and pipes together by hand.
5. Tighten the connection with wrenches on both the pipe and the fitting. Use wrenches with smooth jaws whenever possible to prevent excessive marring of the pipe and the fitting.

Joining Copper Tubing—Copper tubing is not threaded. Some fittings for flexible copper tubing fit over flared ends of the tubing. A special, but simple, tool is used for flaring the ends.

Figure 34.5 illustrates a flaring tool used to flare soft copper tubing. The flaring tool consists of a split die block with holes for $^1/_4$-, $^5/_{16}$-, $^3/_4$-, $^7/_{16}$-, and $^1/_2$-inch copper tubing. The copper tube is locked in the die block. The compressor screw with the T-handle is then used to flare the end of the tube. The end of the tube will have a 45-degree flare or bell shape.

Fittings that are soldered to the tubing are also available. Observe the following procedures in sweating (soldering) fittings, tees, and elbows on copper tubing:

1. Cut the tubing square.
2. Clean the inside and outside of the end of the tubing with fine steel wool.
3. Apply the flux to the tubing, and insert the tubing into the fitting.
4. Revolve the tubing in the fitting to distribute the flux.
5. Heat the fitting until it will melt the solder. An acetylene torch is often used as the source of heat. A propane torch may also be used.
6. Flow solder into the joint between the fitting and the tubing. Use solid core solder. Never use acid core solder.
7. Wipe the joint with a damp rag when the solder has set.

Compression rings and special fittings are also available for copper tubing. These make flaring and sweating unnecessary and require less time than flaring or sweating. The compression ring is placed over the tubing and tightened into the special fitting to make the seal.

PLUMBING FIXTURES

Selecting Plumbing Fixtures—The plumbing fixtures selected should conform to the use to be made of them and to the money available for their purchase. The cost of plumbing fixtures, like the cost of many other goods, has a wide range due to differences in design, in quality of materials, and in finish.

Fixtures such as bathtubs, sinks, and lavatories are usually made of enameled cast iron. They have thin cast iron shells, and the glossy enameled finish is fused to the iron. Toilet bowls and tanks are generally vitreous ware (fused China clay) and should be handled very carefully.

Most sinks are enameled. Stainless steel and fiberglass sinks are also used. The common size of sinks is 20 by 30 or 36 inches. Sinks can be hung on the wall, placed in cupboard tops, or placed on legs.

Bathtubs may be obtained in many sizes and shapes. A variety of valves and fittings for bathtubs are also available. The usual size of bathtubs is 30 by 60 inches. Bathtubs may be obtained in colors to harmonize with various decoration schemes.

Lavatories are of different shapes and styles. The type used most frequently is hung on the wall. Corner and leg-type lavatories are also used.

Bathroom Arrangement—A bathroom containing a bathtub, a lavatory, and a toilet bowl should have a minimum of 50 square feet of space. Following are four common arrangements of bathroom fixtures:

1. Bathtub across the end of the room with the lavatory on one side wall, and the toilet bowl on the other side wall.
2. All three fixtures along a wall. This arrangement is suitable for long, narrow rooms.
3. Bathtub along one wall and lavatory and toilet bowl on the opposite wall.
4. Bathtub along the back wall, toilet bowl and lavatory along a side wall.

It is desirable to have closets and storage cabinets in or near the bathroom. In addition to furnishing room for linens and clothing, they make it possible to have the pipes to and from a bathroom hidden but accessible. It is important to keep pipes and valves available. Medicine cabinets and shelves are other useful additions to a bathroom.

The fixtures must be solidly set and securely fastened, as they are heavy articles and will damage the plumbing if allowed to exert strain on the pipes.

Kitchen Sink Location and Installation—Since so much work is done at a sink, it is important for it to be located properly in respect to the other equipment in the kitchen. The sink should be close to the cupboards and to the stove, and should be at a comfortable height. Adequate lights should be provided at the sink, and the plumbing should be accessible so that it can be repaired.

If the sink is on an outside wall, the water supply and drain pipes may have to be insulated to prevent their freezing in winter. A good, solid, serviceable installation is needed because a kitchen sink receives much use. Many modern rural homes have a garbage disposal installed in the sink.

Other Plumbing Fixtures—There are other plumbing fixtures that may be installed when hot and cold water are available.

Space should be provided for installation of an automatic washer and dryer in the laundry area.

Shower baths are easy to install. A shower bath installation can be added to a bathtub installation by the use of a hot and cold water control valve, a shower head, the necessary pipe, and a waterproof curtain. A shower head of noncorrosive metal, which has the right size holes in it, should be used. A shower may be installed easily in a basement, which is a very desirable location for it in a rural home. The water can drain to the basement drain.

In installing plumbing in rural homes, plan the conveniences carefully. Careful planning makes possible minimum plumbing runs, and the cost of the plumbing may be reduced.

MAINTENANCE OF PLUMBING EQUIPMENT

Plumbing should receive proper care because replacements may be hard to make. Repairs should be made when the need becomes apparent or is suspected.

Clogged Pipes—Rust and dirt in short lengths of pipe may be removed by pushing a wire with a chain tied to it through the pipe. By drawing the chain back and forth, the rust and dirt are loosened and can be flushed out. Long pipe lines have to be taken apart to be cleaned.

Commercial muriatic acid may be used to clean pipes that will not be damaged by it. The acid will act on galvanized and iron pipe, and, if used, must be diluted in the ratio of one part of acid to seven parts of water. The diluted acid must not be allowed to remain in the pipe long enough to damage it.

Rubber force cups are also useful in removing obstructions from traps and fixture connections. Clean-out plugs are sometimes placed in the bottom of traps, and traps may be cleaned by removing the plugs. Chemical solvents are on the market which will remove grease, hair, and other materials from clogged pipes.

Frozen Pipes—Never thaw the center of a pipe line first, because the expansion of the water may break the pipe. Start thawing a frozen water line at its outlet end and work toward the source of the water, leaving the outlet end open. Waste or sewer pipe should be thawed from the outlet to the fixture, so it can drain as it thaws.

Boiling water, hot cloths, or a stream of hot air will be effective in thawing frozen pipes. A propane torch can also be used when there is no danger of fire.

Plumbing Fixture Care—When good work quality is employed in the installation of fixtures, the service work needed is decreased.

Keep fixtures solidly in place by tightening their supports whenever any indication of looseness appears. This will prevent strain on the plumbing connections, which might cause leaks.

Keep faucets free of leaks by renewing valves or by removing corrosion and obstructions from them. Drains, traps, and vents should be kept clean.

Fixtures such as bathtubs, lavatories, toilet bowls, and sinks should be kept clean and bright with nonscratching cleaning powders. Sharp instruments and strong chemicals must not be used on the enameled surfaces of fixtures, or rusting, corrosion, and other damage will result.

Good plumbing and good fixtures are of almost immeasurable convenience and satisfaction, and they should be kept in the best condition possible. Usually 5 to 10 per cent of the cost of a house is invested in its plumbing, and this investment justifies adequate care.

Repairing Faucets—If a faucet is noisy or difficult to operate, it needs to be repaired. A new seat washer (a rubber washer for hot water faucets and a leather washer for cold water faucets) is probably needed. There are three principal types of water faucets: the T-handle compression faucet, the round-handle compression faucet, and the lever-handle faucet. However, other types of faucets are available. If the following instructions do not apply, obtain the name of the manufacturer of the faucet, and get repair parts, special tools, and needed advice from a hardware store or a plumbing supply store. The method of repairing all compression faucets is similar. To replace a seat washer, proceed as follows:

1. Shut off the water at its source.
2. Unscrew the cap nut with a smooth-jaw wrench.
3. Unscrew the stem from the body of the faucet.
4. Remove the screw which holds the washer.
5. Replace the seat washer.
6. Replace the screw holding the washer.
7. Screw the stem into place.
8. Tighten the cap nut.
9. Turn on the water at its source.

With the round-handle compression faucet, the procedure is the same except that the faucet is opened two turns before the hexagonal nut is loosened.

Sometimes the replacement of a seat washer will not correct the difficulty because the seat for the washer is damaged or worn. A seat may be reground with a simple seat-grinding tool which may be purchased at most hardware stores.

In replacing a seat washer on a lever-handle faucet, proceed as follows:

1. Shut off the water at its source.
2. Unscrew the body piece from the tail piece by turning the spout and lever part of the faucet with the hands. When this is done, it may be necessary to hold the tail piece hexagonal nut with a wrench to keep it from unscrewing.
3. Unscrew the nut on the body of the faucet that holds the ball (seat washer).
4. Remove the old ball and replace it with a new one of the same size. If too large a ball is used, the faucet will not be able to deliver a full flow of water. Always check the brand name of the faucet and purchase repair parts for that brand and type of faucet. Replacement parts for different brands are often not interchangeable.
5. Replace the brass nut holding the ball.
6. Screw the body of the faucet into the tail piece.
7. Wrap a string around the joint between the body and the tail piece just before the joint closes to produce a watertight connection.
8. Turn on the water at its source.

Occasionally a faucet will leak at the cap washer. When this happens on older faucets, the top washer or the packing needs to be replaced. In replacing the top washer or packing, or the "O" ring on newer faucets, proceed as follows:

1. Unscrew the cap nut counterclockwise.
2. Remove the screw holding the handle to the stem of the faucet.
3. Remove the handle and the cap nut from the stem of the faucet.
4. Remove old washers, a brass washer and a rubber washer, or an "O" ring.

5. Place new washers or "O" ring on the stem. The brass washer can probably be used again. Use the correct size washers or the correct amount of packing. If it is not used, the stem will turn hard, or water will leak or spurt from the cap nut.
6. Replace the handle and the screw holding the handle.
7. Tighten the cap nut.

Some faucets do not contain a top washer. They are packed with candle wicking. In replacing this packing, proceed as follows:

1. Keep the faucet closed.
2. Unscrew the packing nut, which is the nut just below the handle.
3. Wrap candle wicking around the stem. Not much wicking is needed.
4. Tighten the packing nut against the wicking.

In replacing the packing rings on a lever-type faucet, proceed as follows:

1. Shut off the water at its source.
2. Unscrew the body piece of the faucet from the tail piece as described in the section on replacing the seat washer.
3. Remove the handle.
4. Unscrew the cap nut.
5. Remove the spindle and replace the old packing rings with new rings.
6. Reassemble the faucet.
7. Turn on the water at its source.

Packing washers and packing materials for all types of faucets may be purchased from a plumbing store. They are relatively cheap.

CHAPTER 35

Establishing Sewage Disposal Systems in Rural Areas

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. Why is a study of sewage disposal important?
2. What are the principal parts of a sewage system?
3. What precautions are necessary in the installation of a house sewer?
4. What is the purpose of a septic tank?
5. Where should a septic tank be located?
6. How should an outlet sewer be installed?
7. What are the methods of disposing of the overflow from a septic tank?
8. What parts of a septic tank system need care?
9. What is the relative cost of a septic tank system?
10. How should liquid manure be handled?

The installation of a sewage disposal system should be planned when the water supply system is planned. An adequate supply of water is essential for a sewage disposal system.

A sewage disposal system promotes the health, contentment, and happiness of every member of a family.

SEWAGE DISPOSAL SYSTEM

Sewage Treatment Processes—Before sewage can be made sanitary and harmless, it is necessary for it to pass through several distinct and complete processes.

Sedimentation is the separation of the solids from the liquids and is accomplished by giving the solids a chance to settle.

Decomposition or liquefaction of the sewage is of two types. The decomposition of sewage requires the aid of bacteria. When the sewage enters the septic tank, bacteria are present which obtain their food from the carbonaceous and nitrogenous matter in the sewage, and the action of the bacteria on the sewage continues as long as free oxygen exists. This is known as aerobic decomposition.

As the sewage decomposes, there is a gradual decrease in the amount of free oxygen present and an increase in the amount of ammonia present. The bacterial action taking place in the absence of oxygen is known as anaerobic decomposition. Bacterial action continues profusely after the oxygen supply is exhausted, but gradually decreases because of the reduction in food supply and the poisonous effects of the wastes of the bacteria.

Purification of the sewage is accomplished in the disposal field by the aeration of the liquid as it percolates through the soil. The overflow liquid from a septic tank is not always disease-free and pure, and it must be treated accordingly.

Parts of a Sewage System—A complete sewage disposal system in a rural area consists of four principal parts: (1) the sewer to the septic tank, (2) the septic tank, (3) the outlet sewer from the tank to the final disposal area, and (4) the final disposal system. The last-named part should receive first consideration in developing a sewage system in a rural area.

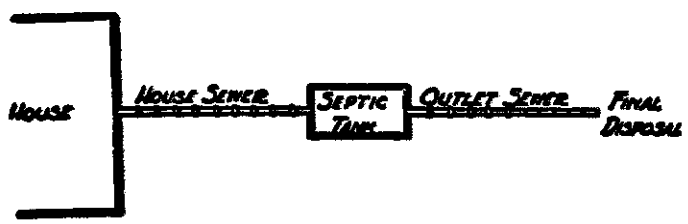


Fig. 35.1. A sewage system for a rural area.

The House Sewer—The length of a house sewer depends on the slope of the ground and the location of the buildings, the well, and the disposal field. The line of tile should be laid straight and at a uniform grade of not less than 2 feet of fall per 100 feet for a 4-inch clay tile or plastic drain pipe, and not less than 1 foot of fall per 100 feet for a 6-inch clay tile or plastic drain pipe. Less clogging trouble is experienced when a 6-inch clay tile or plastic drain pipe is used.

The house sewer should be below the frost line. The depth of a house sewer, in most cases, is determined by the location of the lowest plumbing fixture in the house, which is a considerable depth when basement drains are used. Some shallow house sewers are protected in freezing weather with a straw covering held in place by fencing.

The Septic Tank—A septic tank receives all the sewage piped into it and allows the processes of sewage treatment to take place. The heavier particles rise to the top. The greater part of sewage is liquid, and this passes through the septic tank. However, the solids are held in the septic tank and are slowly decomposed by bacteria. The liquids and gases resulting from the digestion process pass from the septic tank. The portion of the solids not digested by the sewage bacteria remains in the septic tank as sludge in the bottom of the tank and as scum in the top of the tank.

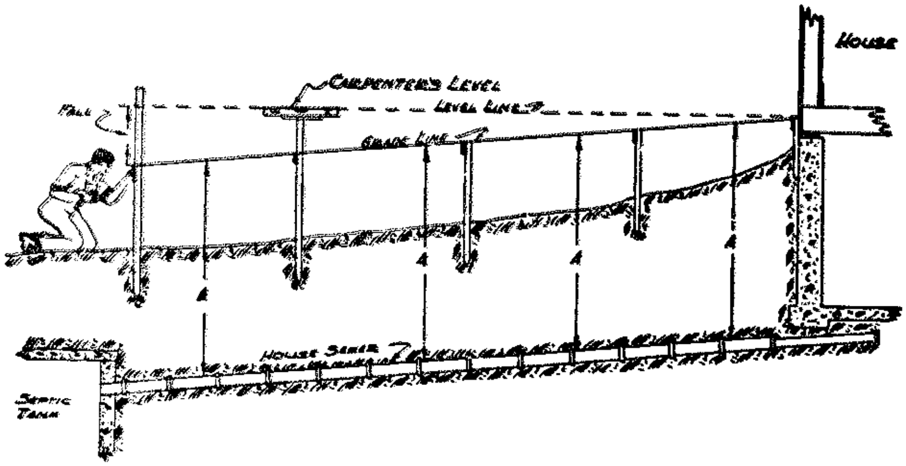


Fig. 35.2. One method of laying sewer pipe to a uniform grade.

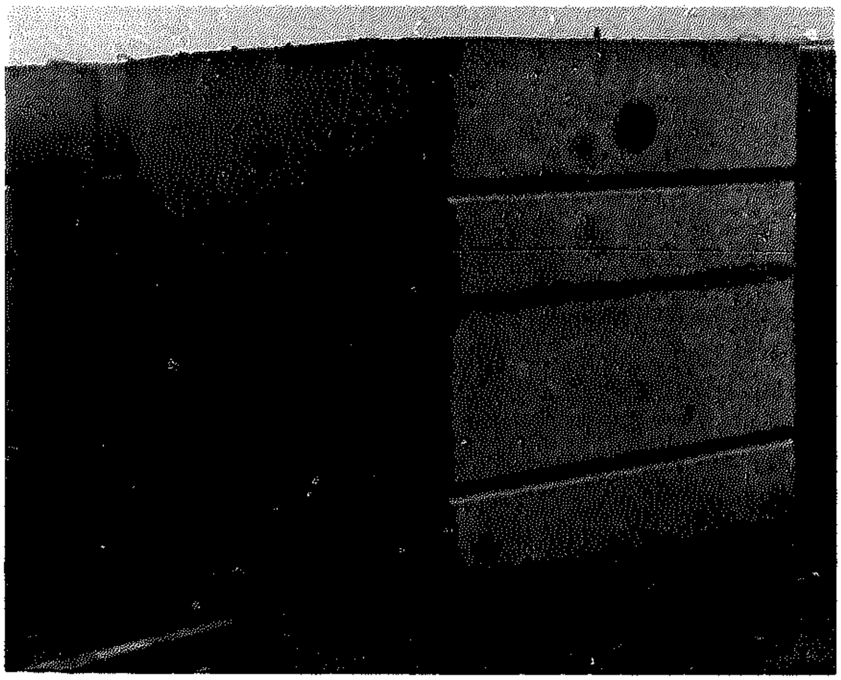
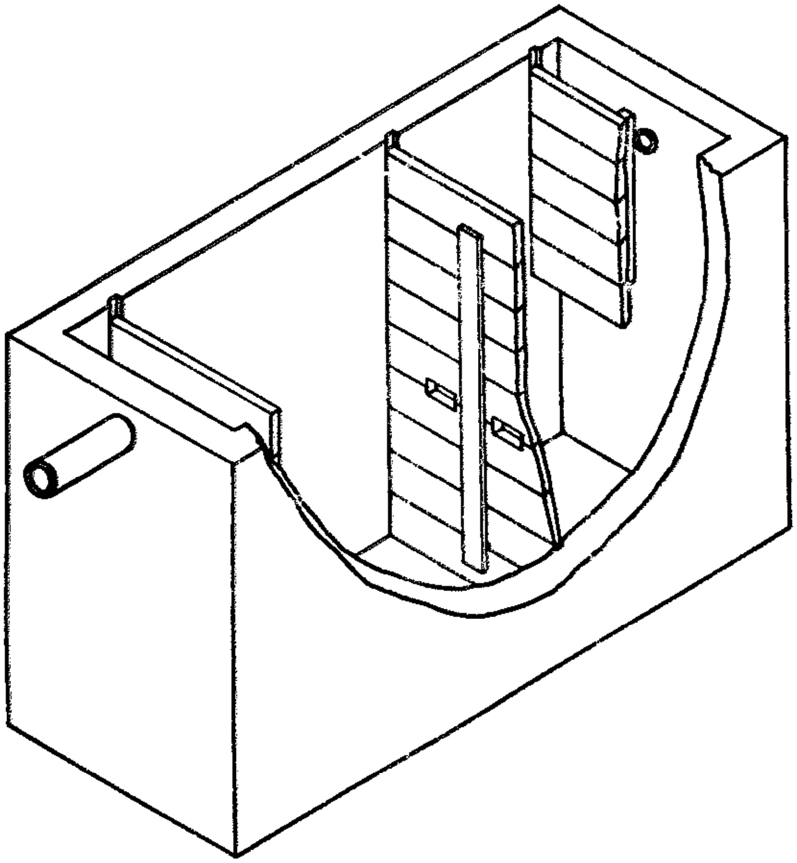


Fig. 35.3. Precast, commercially produced septic tanks.

Design of a Septic Tank—A septic tank should have sufficient capacity, so that the sewage can be retained in the tank for about 70 hours or 3 days. Figure 35.4 shows a cutaway view of a septic tank.

Concrete is a very desirable construction material for a septic tank. Metal tanks are also available commercially and are satisfactory.

Location of a Septic Tank—The first step is to check whether or not there are any local codes for location of septic tanks that apply. If no local code exists,



(Courtesy College of Agriculture, North Dakota State University)

Fig. 35.4. A cutaway view of a septic tank. Sanitary T's may be used instead of baffle boards to prevent scum on top from clogging inlet and outlet pipes.

experience has shown that the minimum distance of 30 feet from the house is necessary for a septic tank. Topography may influence this minimum distance in some cases. The tank should be located downhill from the house, if topography permits, which eliminates the necessity of burying the tank to an excessive depth to obtain the correct grade for the house sewer. The location of the tank should be on a straight line between the house and the disposal field. A location should be selected where there will be a minimum of traffic over the drain lines and the tank.

The Outlet Sewer—The outlet sewer leading from the septic tank to the final disposal area should be laid at a uniform grade. Only liquid passes through this line, and it does not become clogged easily. A good fall will increase its capacity and will decrease the danger of freezing. Usually 4- or 5-inch sewer drains are used. The outlet sewer drain from the septic tank to the absorption bed must be liquid-tight, not permitting leaks into or out of the drain.

Final Disposal of the Sewage—Proper final disposal of the sewage is important. The liquid draining from the septic tank may contain many of the disease germs and filth originally in the sewage. The drainage from a septic tank requires further treatment before it is safe. The best method of purification in a rural area is to let the overflow filter through the soil where plenty of air is present. This is the absorption bed method. The final disposal area should be away from trees or any other plants whose roots might clog the tile. Sweet clover and alfalfa should not be seeded over an absorption bed. The area should be away from the buildings and the roadway, and at least 200 feet from the water supply.

The Absorption Bed Method—As previously mentioned, the absorption bed is the best method to use for the final disposal of sewage. The main requirement of an absorption bed is a reasonably porous soil. In ordinary soils, the lines are laid in parallel runs about 10 feet apart. The shape of the disposal area will depend on the shape and the topography of the available area. In very porous soils, a long trench filled with stones and gravel to a depth of 2 to 3 feet has been used successfully.

The amount of pipe or tile required for an absorption bed depends largely on the ability of the soil to handle the overflow. Check local codes for length of pipe or tile required in an absorption bed. In soils that will absorb 6 inches of water per hour, at least 175 feet of pipe or tile is needed for each bedroom in the house. If only 2 inches of water is absorbed per hour, at least 250 feet of pipe or tile is needed for each bedroom. Fiber or plastic pipe, with perforations on the bottom side, or clay tile may be used for lines in an absorption bed.

An absorption bed must not be located in areas that become wet or flooded in rainy seasons, or the septic tank will not function properly. The whole sewage system must also be located so that the backing of sewage into the house will not be experienced in wet seasons.

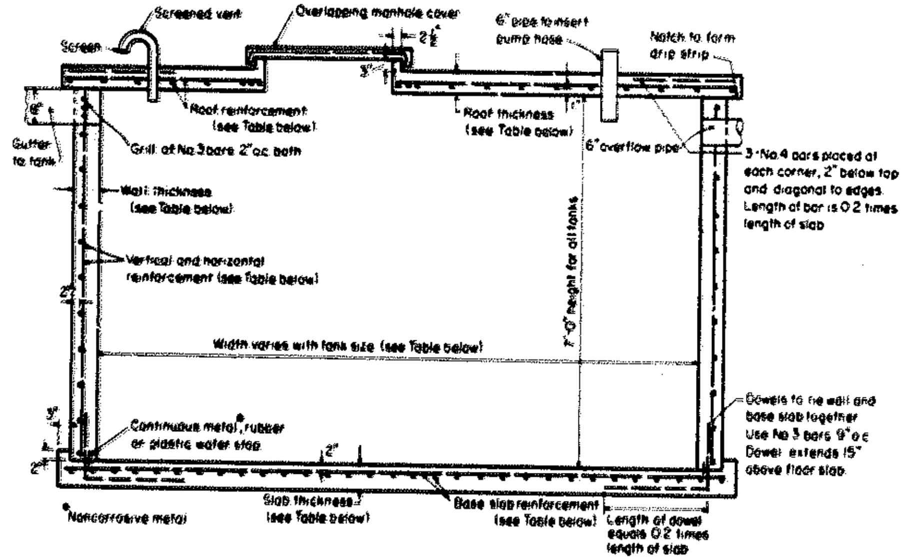
Care and Maintenance of a Septic System—Septic tanks, properly installed and used, cause very little trouble. Care in the house as to the material put into the sewage system greatly influences the performance of the system. In maintaining a septic tank system, observe the following points:

1. Solids not soluble in water should be kept out of the system.
2. Chemicals must be kept out of the septic tank, or bacterial action cannot thrive.
3. Excessive grease and soap should be kept out of the system. A grease trap is strongly recommended.
4. Boiling water is good for a sewage system. It removes greasy collections.
5. Periodic inspection and cleaning is advisable.

A septic tank should be cleaned when the sludge in the bottom of the tank becomes about a foot deep. It may take several years for a foot of sludge to accumulate. Most of the contents of a septic tank can be pumped out, if stirred while the sewage pump is working. After the liquid is removed from a tank, it is advisable to let the remaining contents dry. They may then be removed easily.

LIQUID MANURE DISPOSAL

On some farms the manure is being handled, especially by hog producers, as a liquid. Liquid manure systems are used to a lesser extent by dairy farmers, poultry producers, and beef producers. If no attempt is made to conserve the fertility value of the manure, a livestock septic tank system may be used. If a septic tank system is used, the tank must be large, usually from 1,500 to 2,000 gallons in size. The disposal field must also be large.



Tank Capacity Gal.	Tank Size O.D.	Tank Size I.D.	Thickness, Inches			Reinforcement				Concrete-Cu Yd		
			Base Slab	Wall	Roof	Base Slab	Wall: Horiz Bars	Wall: Vert Bars	Roof	Base Slab	Wall	Roof
3040	7'-10"×9'×9'	7'×8'×8'	6	6	4	No 6 bars 7" o.c. both ways	No 4 bars 10" o.c.	No 4 bars 18" o.c.	No 4 bars 9" o.c. both ways	1.75	4.50	1.25
4790	7'-10"×11'×11'	7'×10'×10'	6	6	4	No 4 bars 7" o.c. both ways	No 4 bars 10" o.c.	No 4 bars 18" o.c.	No. 4 bars 8½" o.c. both ways	2.50	5.50	1.75
6840	7'-11"×13'×13'	7'×12'×12'	6	6	5	No 4 bars 9" o.c. both ways	No 4 bars 8" o.c.	No 4 bars 18" o.c.	No 4 bars 8" o.c. both ways	3.50	6.50	3.00
9210	7'-11"×15'×15'	7'×14'×14'	6	6	5	No. 5 bars 6" o.c. both ways	No 4 bars 6" o.c.	No. 4 bars 18" o.c.	No 5 bars 9" o.c. both ways	5.25	7.50	3.75
13,620	8'-1"×18'-2"×18'-2"	7'×17'×17'	7	7	6	No 5 bars 5" o.c. both ways	No. 5 bars 8" o.c.	No 4 bars 18" o.c.	No 5 bars 7½" o.c. both ways	7.50	10.50	6.50
20,960	8'-3"×22'-2"×22'-2"	7'×21'×21'	8	7	7	No 6 bars 6" o.c. both ways	No 5 bars 6" o.c.	No 4 bars 18" o.c.	No 6 bars 8½" o.c. both ways	13.00	13.00	11.00

(Courtesy Portland Cement Association)

Fig. 35.5. A concrete collection tank for liquid manure, with design data for cast-in-place concrete liquid manure collection tanks.

Septic tanks are not often used unless the farm is in an area that is becoming urbanized, and they cannot be used if the amount of waste to be handled is large. Lagoons may be used if septic tanks cannot handle the amount of waste being produced. Lagoons are constructed ponds in which the animal manure is destroyed by bacterial action. The water in a lagoon should be 3 to 5 feet deep. Lagoons are usually satisfactory if they are of adequate size and if the water level can be maintained.

When the fertility value of the manure is of concern, a collection tank system may also be used. The size of tank needed depends on the number of head of livestock.

In a typical liquid manure system, the waste is washed into gutters with water under pressure. The gutters drain into a collection tank, lagoon, or septic tank. When a collection tank is used, the liquid manure is pumped out of the tank into a mobile spreading tank. The mobile spreading tank is equipped with a pump so that the liquid waste can be pumped out of the tank onto the fields.

FENCING

Student Abilities to Be Developed

1. Ability to select the type of fence best adapted for the function it is to serve.
2. Ability to select the type of fence posts best adapted for the kind of fence being constructed.
3. Ability to construct fences.
4. Ability to brace end and corner posts.
5. Ability to maintain fences.

CHAPTER 36

Constructing and Maintaining Fences

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What are the types of fences frequently used on farms and around nonfarm agricultural businesses, and when should each be used?
2. What types of fence posts are used, and what are the advantages of each type?
3. How are wooden posts treated with preservatives to retard their decay?
4. What are the types of preservatives, and what are the advantages and disadvantages of each?
5. What are the important principles of construction that should be followed in the building of fences?
6. What are the methods frequently used to brace end and corner posts? What are the advantages and disadvantages of the various procedures used to brace end and corner posts?
7. What tools are needed in the building and maintaining of fences?
8. What are the types of repairs which need to be made to maintain fences?

Fences are an important convenience. More skill is required to construct good fences than many recognize. Considerable knowledge is required regarding fencing to select the best type of fencing materials for a specific purpose.

TYPES OF FENCES

There are five types of fences used frequently on farms and around nonfarm agricultural businesses. They are:

1. "Live"
2. Board
3. Electric
4. Woven wire
5. Barbed wire

"Live" fences are barriers formed by living plants such as multiflora rose or osage orange. "Live" fences are popular in some areas because of their conservation value. They are also criticized because of their tendency to spread into cultivated areas. Board fences are usually used for ornamental purposes or for fencing animals of great value.

Electric fences are used frequently to serve as temporary fences or to strengthen existing fences. Electric fence construction is discussed in Chapter 38, "Wiring in Rural Areas."

Woven Wire—The styles of woven wire ordinarily used on farms and around nonfarm agricultural businesses have 7, 8, 9, 10, or 11 horizontal wires. The heights ordinarily used are 26, 32, 39, 47, or 55 inches. The styles of woven wire fences are designated by numbers such as 1155, 1047, 939, 832, or 726, the first one or two numbers indicating the number of horizontal wires and the last two numbers indicating the height of the fence.

The sizes or gauges of wire used in woven wire are 9, 11, or 12½ for ordinary livestock fencing. Gauge 14½ wire is ordinarily used for poultry or garden fences.

Barbed Wire—Barbed wire may be used for a fence, or it may be used in combination with woven wire. It comes on spools containing 80 rods or 1,320 feet of wire. The gauge of wire ordinarily used is 12 or 12½, with the barbs made of 14-gauge wire.

Barbed wire may be obtained with two or four barbs. The barbs for hog fencing are usually 3 or 4 inches apart, and the barbs for cattle fencing are usually 5 or 6 inches apart.

POSTS

Types—Fences require posts of some type. The supply of good wooden posts of osage orange, black locust, red cedar, or catalpa is becoming scarce in some areas, making the use of other types of posts necessary. Farmers and others are therefore using less desirable woods for posts or are using steel or concrete posts. When wooden posts, especially posts of the less desirable types of wood, are used, treatment is necessary to retard decay. Wooden posts as small as 3 inches in diameter are satisfactory for line posts. Wooden posts of the small diameters are preferred by many because they are easier to set and handle, and the cost of treating them is less. The cost of treating fence posts increases rapidly as the size of the posts increases.

Round posts are preferred by most farmers and others, but split posts may hold better in fencing on the contour.

Metal posts are often used because good wooden posts are not available or because they are easier and less costly to set. They are also used frequently for temporary fences. The chief disadvantage of metal posts is that they are sometimes bent by the pressure of livestock. They are resistant to fire, however, and they make a safer fence during storms because every post is a ground for lightning.

Concrete posts are being used in areas where sand and gravel are available and where the cost of other types of posts is becoming excessive. Plans for forms for concrete posts may be found in Chapter 32, "Using Concrete Blocks and Concrete." The success of concrete posts depends on the care used in making them. If they are made properly, they will last for years. They are attractive in appearance, and they are resistant to fire.

TREATMENT OF WOODEN POSTS

Posts are treated to retard decay. Posts of woods of the less desirable types will decay so rapidly that they are not worth using unless they are treated. Paint has very little value as a preserver of posts. Setting posts in concrete also has very little value in preventing decay, because the posts will crack away from the concrete.

Preservatives—Two types of preservatives are used to treat posts: (1) oil-soluble preservatives and (2) water-soluble preservatives. The oil-soluble preservatives are preferred. Those that are usually used are pentachlorophenol (penta), coal tar creosote, and copper naphthenate. Penta is becoming very popular because of its superior qualities as a wood preservative. In the past, coal tar creosote was the most popular preservative.

Wood treated with penta or copper naphthenate can be painted. Wood treated with creosote is difficult to paint, because the creosote tends to bleed through the paint.

The water-soluble preservatives ordinarily used are zinc chloride and copper sulfate. Wood treated with them can be painted. The water-soluble preservatives are usually used to treat unpeeled, green posts. The oil-soluble preservatives are used to treat peeled, seasoned posts. Before purchasing commercially treated posts, check regarding the treatment method.

METHOD OF CONSTRUCTION

Spacing, Bracing, and Aligning Posts—Posts for a strong, substantial fence are usually placed 12 feet apart and set 2½ feet into the ground. A spacing of one rod between posts is also frequently used. Posts are usually allowed to extend 6 inches above the top wire; therefore, good line posts need to be 7 to 8 feet long.

The tops of wooden posts are often sawed after they are set so that all the posts are the same height. This produces a fence with a more pleasing appearance.

The first essential of a good fence is good end and corner posts that are braced properly. *Fence failures* often result because the corner posts are not well braced. Figures 36.1 to 36.8 illustrate some of the common ways used to brace corner posts. The brace post should be set 10 feet from the corner or end post so that a 12-foot brace strut can be used. Under no circumstances should a brace post be set closer than 8 feet from the corner or end post. When a brace post is set too close, the effectiveness of the diagonal bracing struts and ties is reduced. Figure 36.1 illustrates a simple type of bracing. It is not as effective as some of the types of braces illustrated in the other figures, but it is better than the type of brace shown in Fig. 36.2. Figure 36.8 illustrates a very effective type of bracing. A double brace

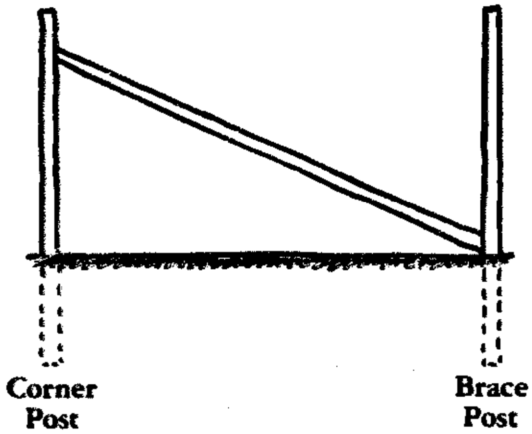


Fig. 36.1. Bracing a corner post with a single strut placed at an angle.

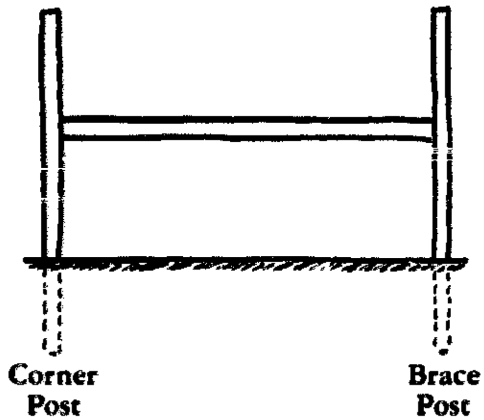


Fig. 36.2. Bracing a corner post with a single horizontal strut.

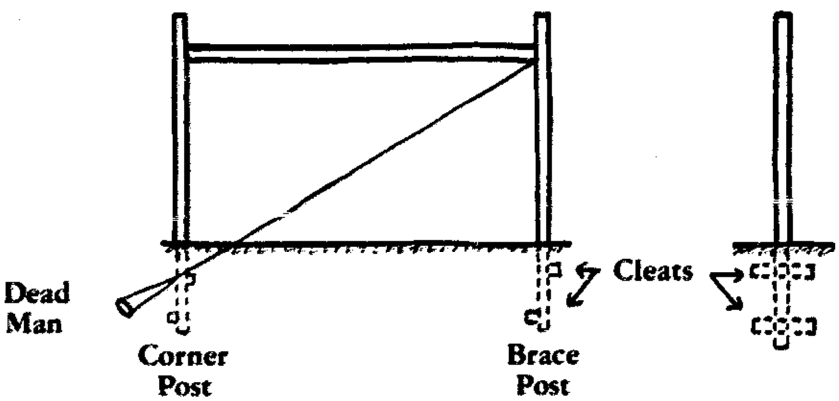


Fig. 36.3. Bracing a corner post with a strut, a dead man, and cleats on the brace and corner posts.

is used to divide the strain or pull. The bracing shown in Fig. 36.4 is the least effective of those shown.

For a tie, such as the one shown in Fig. 36.5, to be effective, it must be fastened properly (see Fig. 36.10). Also, sloping the top of a post facilitates the removal of moisture.

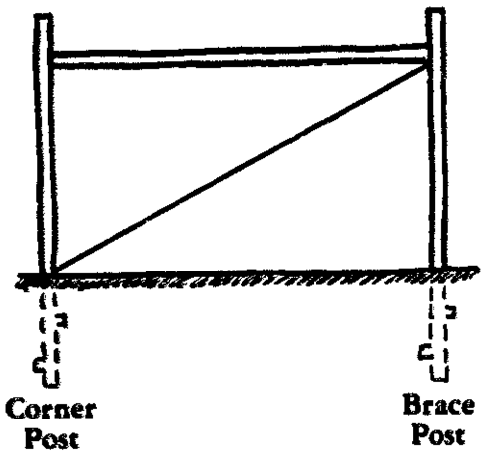


Fig. 36.4. Bracing a corner post with a horizontal strut, a tie, and cleats.

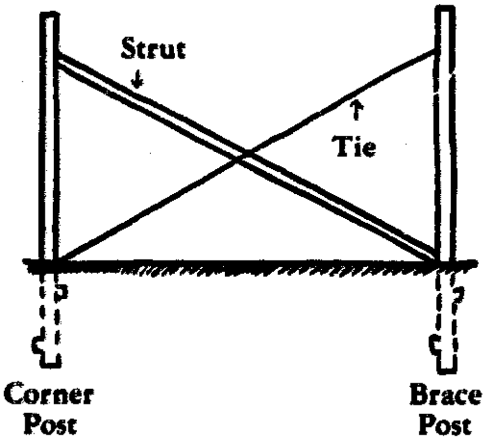


Fig. 36.5. Bracing a corner post with a crossed strut and tie, and with cleats.

Before a fence is started, the ground should be cleared. The location of the corner posts should be established and some sight posts set at strategic points. The location of the other posts should then be indicated with stakes. All posts should be the same distance apart, and they should be aligned whether the fence is straight or on the contour.

Installing Wire—The first step in installing wire after the posts are set is to unroll enough wire to fasten it to a corner post. The wire should be placed, when

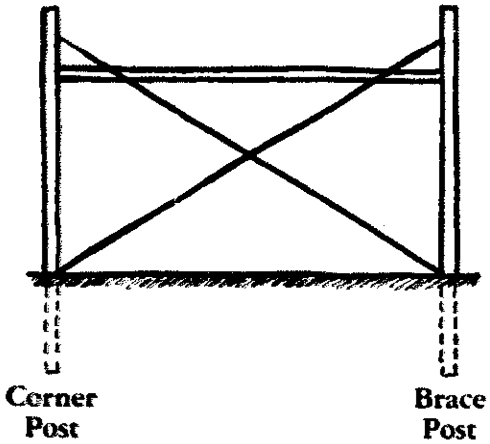


Fig. 36.6. Bracing a corner post with a horizontal strut and with crossed ties.

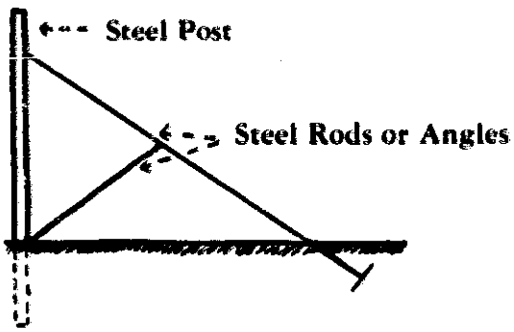


Fig. 36.7. Bracing a steel post.

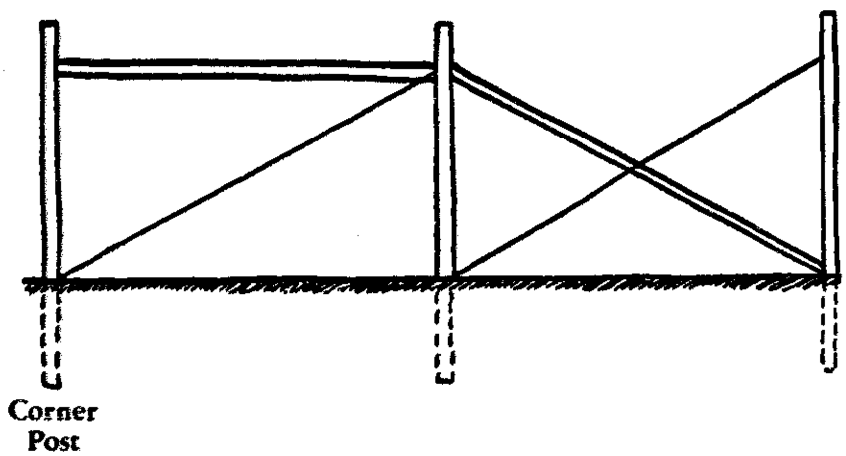
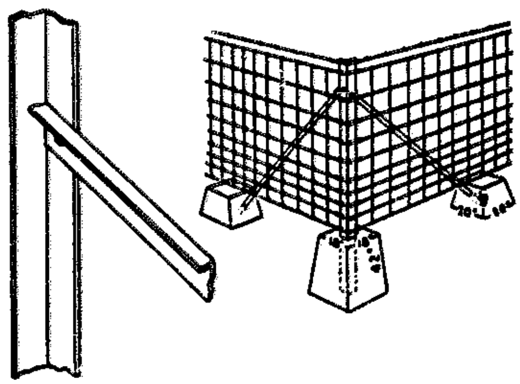


Fig. 36.8. Bracing a corner post using two brace posts.

practical, on the side of the posts next to the livestock. In unrolling woven wire, keep the bottom wire close to the posts. The use of a wire stretcher is essential in the installation of woven wire. A block and tackle may be used for stretching barbed wire. It is not a good practice to stretch wire around a corner at an angle sharper than 45 degrees. It is also ordinarily not a good practice to try to stretch more than 40 rods or 660 feet of wire at one time. In the installation of wire, a pair of wire cutters is an essential tool.

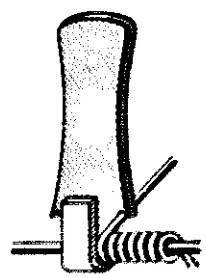
Rolls of wire often have to be spliced together when a fence of over 40 rods or 660 feet in length is being installed, in which case a western union splice should be used. See Fig. 36.10 for an illustration of the type of splice to use. Also illustrated is a fence splicing tool which will make the splicing of woven wire easier. A splicing tool may be made in a shop or purchased from a manufacturer of wire. In attaching woven wire to a corner post or in splicing wire, keep the stay parallel to the posts.

Fences should be grounded every 40 rods to protect livestock from lightning. A fence with wooden posts may be grounded by using a steel post every 40 rods. A fence with steel posts is grounded by each post.



(Courtesy Republic Steel Corporation)

Fig. 36.9. Concrete being used in anchoring and bracing a steel corner post.



(Courtesy U S D A)

Fig. 36.10. A wire splicing tool.

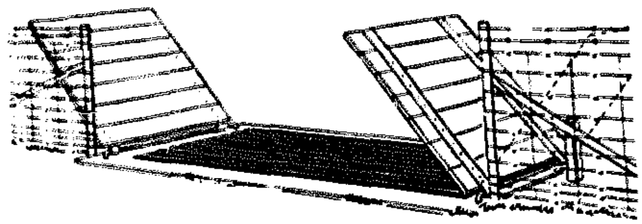
MAINTAINING FENCES

The life of fences may be increased many years if they are maintained properly. Fences should be inspected and repaired in the spring and fall. Posts that become decayed may need to be removed. See Fig. 36.12 for an example of an easy way to remove posts. Posts that are heaved out of the ground should be replaced. Wire frequently needs to be restapled or refastened to the posts.

GATES

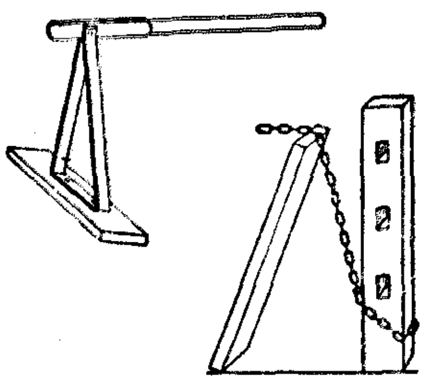
When fences are used, gates are needed. Gates should be attractive, easy to use, safe, and economical to maintain. Many types of gates meet these criteria. Gates are usually 8, 10, 12, 14, or 16 feet wide and 48, 50, or 55 inches high.

Gates should be braced to prevent sagging. Notice the bracing used in Fig. 36.13. The gateposts must be sturdy and of sufficient length. Gateposts should be set into the ground at least 4 feet and should be anchored properly. Use hook bolts instead of lag screws for the hinge anchors for gates. Hook bolts will last longer and will be more satisfactory.



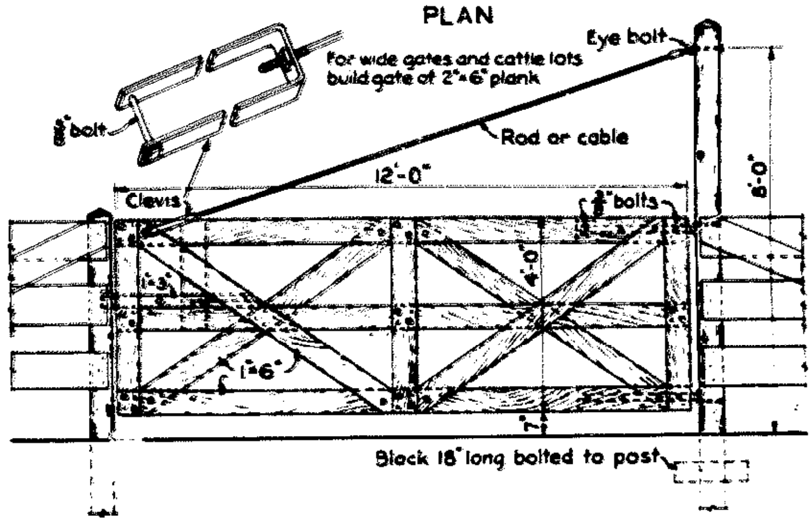
(Courtesy Republic Steel Corporation)

Fig. 36.11. A stock gap with a hinged cover. The cover may be lowered when livestock are to be driven through the gap.



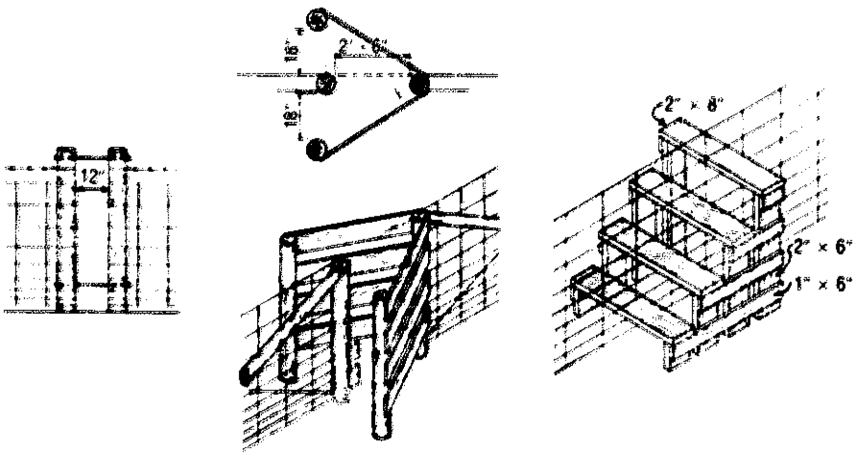
(Courtesy U.S.D.A.)

Fig. 36.12. Equipment for pulling posts.



(Courtesy U.S.D.A.)

Fig. 36.13. A sturdy, well built swinging gate.

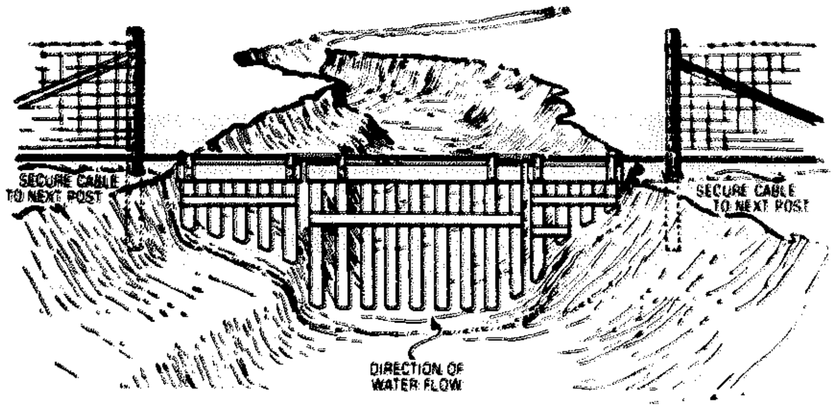


(Courtesy U.S.D.A.)

Fig. 36.14. If a swinging gate is not needed, install one of these devices for getting over or through a fence.

If a swinging gate is not needed, one of the methods of getting through or over a fence shown in Fig. 36.14 may be used.

Floodgates are needed for ditches, gullies, and streams to prevent livestock from swimming or crawling under the fences. Floodgates also prevent the permanent collection of debris which may form dams. Debris collected by a floodgate must be removed after a storm if the floodgate is to continue to operate properly. Floodgates must have strong anchor posts or they will be washed away. Figure 36.15 illustrates one type of floodgate that may be installed.



(Courtesy U.S.D.A.)

Fig. 36.15. A floodgate.

PART V

Rural Electrification

RURAL ELECTRIFICATION

Student Abilities to Be Developed

1. Ability to appreciate the importance of rural electrification.
2. Ability to understand the basic principles of electricity.
3. Ability to understand common electrical terms.
4. Ability to select wiring equipment and appliances.
5. Ability to plan a system of wiring for a farmstead or for a nonfarm agricultural business.
6. Ability to extend the wiring system in use on a farm or in a nonfarm agricultural business.
7. Ability to do simple wiring and electrical repair jobs.
8. Ability to keep all electrical appliances in good condition.
9. Ability to maintain electric motors.
10. Ability to construct electrical equipment for a farm or a nonfarm agricultural business.
11. Ability to use the necessary safety precautions in working with electricity and electrical equipment.

CHAPTER 37

Understanding Electrical Sources and Terms

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What electrical work should agricultural workers other than electricians do?
2. What are some of the basic principles of electricity?
3. What are the sources of electricity in rural areas?
4. What electrical terms are frequently used?
5. Why is grounding necessary?
6. How may grounding be accomplished?
7. What size wires are frequently used?
8. What are some frequently used wiring materials?
9. What are some approved types of switches, devices, and outlet boxes?

INTRODUCTION

Electrical Work Non-electricians May Do—When a house is being built, wiring should be done by a qualified electrician. The average agricultural worker, or rural resident, is not qualified to do this work without assistance. Some states have laws which require that wiring be done by a licensed electrician. In some states a person may do the wiring on his or her own property, but the job must be inspected before it is put into use. Poor wiring is uneconomical and it may not be safe.

Some of the basics concerning electricity that an agricultural worker or a rural resident should possess are:

1. An understanding of electrical terms.
2. Some knowledge of how wiring should be done in order that the person may know whether or not the electrician is doing the job properly.
3. A knowledge of wiring materials and other equipment.
4. The ability to perform simple repair jobs.
5. The ability to care for and maintain a lighting system.
6. The ability to do simple wiring jobs.

7. The ability to select, use, and maintain motors.
8. The ability to select and use electrical controls for various mechanized systems.
9. The ability to follow safe practices.

Sources of Rural Electricity—Various methods are used in providing electricity in rural areas. The two main sources of electricity are:

1. Individual plants which may be driven by gasoline, wind, or water power.
2. Central stations and distribution lines.

Individual plants consist mainly of a generator, a storage battery unit, and the necessary wires and accessories. The generator may be driven by gasoline, wind, or water power. Automatic systems operate when electricity is used and have a storage battery only large enough to start the engine. Nonautomatic systems using wind or water power require large storage battery units for storing the current, and these batteries must be charged at intervals. Plants are obtainable in either 32- or 120-volt sizes. Storage battery plants are of the direct current type. Automatic systems are often used for "standby" electricity when the transmission line source goes off.

Transmission line systems are used when central power companies furnish service to rural customers. Systems of this kind may be furnished by local power companies or by cooperatives organized with the help of the Rural Electrification Administration. The usual current furnished the customer is 120 and 240 volts. The

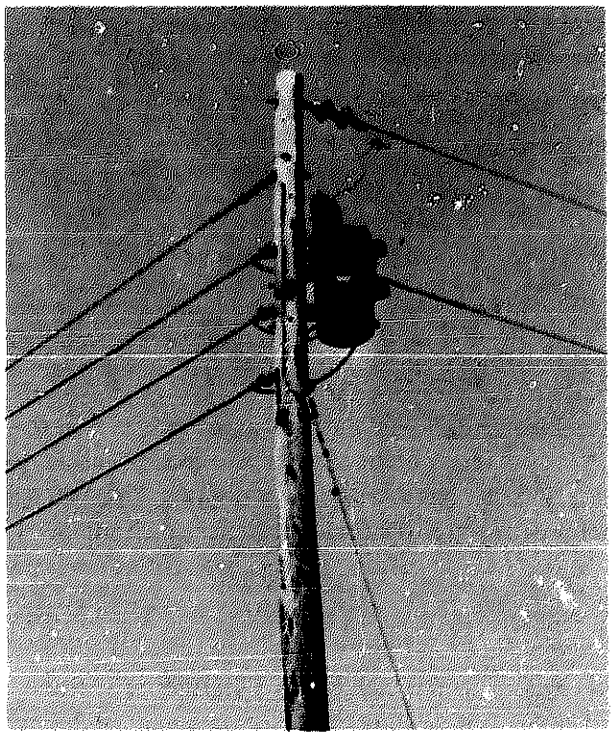


Fig. 37.1. A transformer.

cost of service to rural customers is often somewhat high because of the long length of line necessary to serve a few customers, and because every customer requires a transformer. Losses of electricity are higher over a long line.

The economical use of a rural transmission line system requires the use of electrical energy for a maximum number of jobs, because the rate charged per unit of electricity decreases as the electricity used increases. The use of electricity for lights exclusively makes the service relatively high in cost.

ELECTRICAL TERMS

A knowledge of electrical terms is of value in planning a wiring system and in selecting and maintaining electrical equipment.

Ampere (a)—An ampere is a unit for measuring the rate of flow of electrical current. It may be compared to gallons of water flowing through a pipe. It is also used in designating the size of fuses and switches.

Volt (v)—A volt is a measure of electrical pressure. It may be compared to pounds of pressure in a water system.

Voltage Drop—The loss in electrical pressure from its source to its point of use is called voltage drop. An example of voltage drop is the loss of electrical pressure from the service entrance switch to an outlet for a motor. Voltage drop is increased when the wires are overloaded.

Watt (w)—The watt is a unit of measure used in determining the amount of energy supplied. The size of electric light bulbs and electrical appliances is stated in watts. Volts × amperes = watts.

Kilowatt (kw)—The prefix *kilo* means 1,000; hence, *kilowatt* means 1,000 watts. A kilowatt-hour refers to the use of 1,000 watts of electricity for a total elapsed time of one hour. A kilowatt is equal to approximately 1½ horsepower. One horsepower equals 746 watts.

Direct Current (D.C.)—Direct current flows in only one direction.

Alternating Current (A.C.)—The current reverses at regular intervals. The most frequently used alternating current is 60-cycle. Transmission lines supply an alternating current.

Circuit—It is necessary to have at least two wires to have a flow of current; that is, one wire to carry the current from the source of supply to where it is to be used, and the other wire to carry it back. If only two wires are used, 120 volts will be available. A three-wire system permits both single-phase 120- and 240-volt service. The two outside wires are black, and each with the neutral wire carries 120 volts. The voltage between the two black wires is 240 volts. The center wire is a grounded neutral wire and is white.

Phase—Phase refers to the number of alternating currents acting simultaneously. A single-phase motor requires but one current, while a three-phase motor requires three currents acting simultaneously.

"Hot" Wires—The wire or wires in a circuit which carry the power and which are not grounded are the "hot" wires. In a two-wire circuit there is one "hot" wire, and it is usually distinguished by a black or red coloring of the material covering the wire. In a three-wire circuit there are two "hot" wires.

"Neutral" Wire—The grounded wire in a circuit is the "neutral" wire. It is usually distinguished by a white or gray coloring.

Polarizing—The use of colored wires, black or red for "hot" wires, and white for "neutral" wires, is termed polarizing. The identification of "hot" and "neutral" wires by color helps prevent short circuits in wiring.

Short Circuit—A short circuit is an improper connection between "hot" and "neutral" wires or between "hot" wires.

Grounding—In order to prevent shock due to high voltage, insulation leakage, or lightning discharges, an electrical system should be grounded. The grounding may be accomplished by using ground rods which are driven into the ground to a depth of at least 8 feet. The rods should be driven to moist earth. Galvanized pipes, at least $^3/_4$ inch in diameter, or copper rods, at least $^5/_8$ inch in diameter, are often used as grounding rods. Water systems are often used, along with grounding rods, to ground electrical systems. A common practice is to use bare, uninsulated wire, protected by a conduit, for the ground wire. No. 6 wire is often required. The local code should be checked for the requirements related to grounding.

Underwriters' Laboratories—The Underwriters' Laboratories is an organization, national in scope, which tests all types of wiring materials and appliances to determine whether or not they meet minimum standards for quality and safety. Their tests are accepted as reliable. No electrical materials should be used that do not have the approval of the Underwriters' Laboratories.

Transformer—Since transformer lines carry 2,300 to 11,000 volts, and since most rural homes or businesses use appliances or motors which require 120 to 240 volts, it is necessary to use a device called a transformer to decrease the voltage from the main line. Transformers are rated in kilovolt-amperes (kva), which are 1,000 × volts × amperes.

Conductors—The wires which carry the electricity, or through which electricity flows, are called conductors. They are usually made of copper, aluminum, or copper-clad aluminum.

Cable—When two or more wires are put together inside an overall covering, the conductor is called a cable.

Insulation—The covering placed over electrical conductors to prevent the escape of electricity is called insulation. Wire used indoors may be insulated with a covering which is not waterproof. Wire or cable for use outdoors must have a waterproof covering.

Connectors—A connector is a device used to fasten cables and conduit to devices or outlet boxes.

Size of Wire—The common sizes of wire used for wiring vary from No. 0 to No. 14. (See Fig. 37.6.) The size to select depends upon its use. The No. 14 wire is the smallest diameter wire ordinarily used. No. 6 wire is often used on heavy-duty equipment.

Meter—A meter is an instrument which records the amount of current used.

This meter reading is 1375. This meter reading is 1519.

Fig. 37.2. Reading a meter. "The reading on the second dial from the right, although the hand is at number 2 should be read as number 1 until the hand which moves clockwise on the first dial has passed zero. To determine the amount of electricity used in one month, read the meter on the same day each month and subtract the preceding month's reading: 1519 − 1375 = 144 kilowatt hours. The outside meter mounted on the house should preferably be placed on the back porch or near the rear of the structure, where it will not detract from the appearance of the house but may be conveniently read." (From J. B. Kelly, Ida C. Hagman, and Earl G. Welch, "Electric Service for the Farmstead," College of Agriculture, University of Kentucky, Extension Circular 311, pp. 11–12.)

(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 37.3. Always consult the National Electrical Code and local codes before performing electrical work.

Service Entrance Panel—A service entrance panel is the switch which connects the entire wiring system in a building to the source of supply. Branch circuits originate from a service entrance panel which contains fuses or a circuit breaker to protect these circuits. (See Fig. 37.4.)

Fuse—A fuse is a safety device which burns out when the current becomes too great. It protects the appliances, the electrical equipment, and the wiring. The

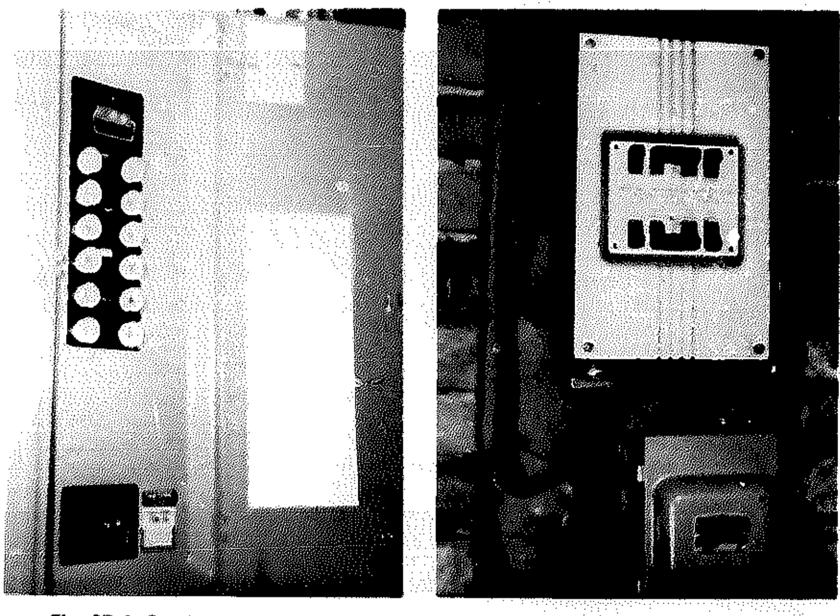
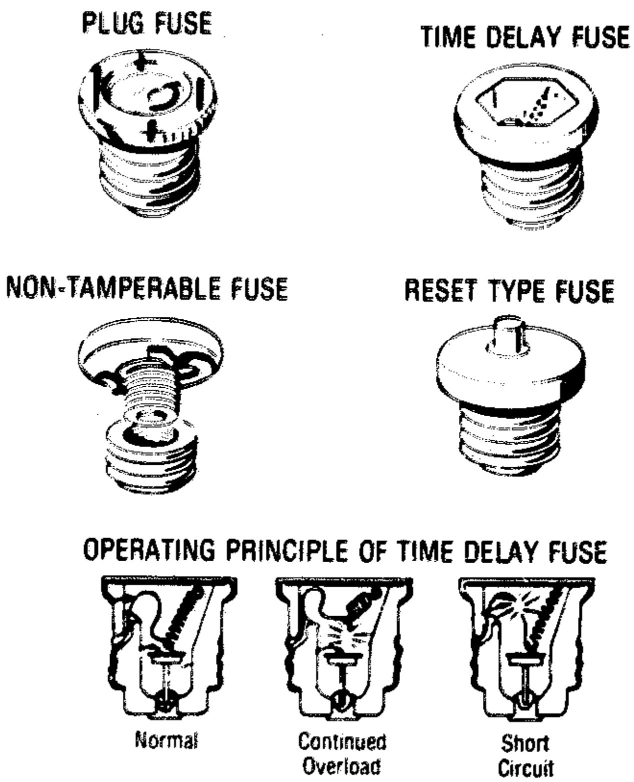


Fig. 37.4. Service entrance panels. Left—a panel with fuses. Right—a circuit breaker panel.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 37.5. Types of plug fuses.

common types of fuses are the plug, the cartridge, and the "nontamper." Fuses are rated in amperes. The sizes of fuses frequently used are 15, 20, 25, 35, and 50 amperes.

Switch—A switch is used to disconnect or break the flow of current.

Device Box—This is usually a box-like device which is used to bring the wires to the place where a switch or outlet is installed. (See Fig. 37.8.)

Junction Box—A junction box is an outlet box with a blank cover. It is used to contain the splices of a circuit when the circuit is to be run or extended in two or more directions.

Outlet Box—An outlet box is a device which contains the splices when a circuit is tapped for an appliance or a light.

WIRES AND WIRING MATERIALS

It is best to use only equipment which has been inspected and approved by the Underwriters' Laboratories.

Conduit—Conduit is a special type of steel pipe. The electrical wires are placed inside the conduit. It may be either rigid or flexible. Rigid conduit is moisture-proof if the outlets, boxes, and connectors are moisture-proof. Conduit is seldom used in wiring except in locations where the wires need added protection.

Armored Cable—The rubber-covered wires in armored cable are protected by a special band of steel. It is used in locations where the wiring needs extra protection and where many bends are required. It is not weatherproof, however, and should not be used for outside wiring or for wiring in buildings such as barns or poultry houses which contain a high percentage of moisture.

Nonmetallic Sheathed Cable (NM)—NM cable has a covering that retards flames and resists moisture. Since it is not weatherproof, UF cable should be used for most agricultural wiring.

Underground Feeder Cable (UF)—UF cable is versatile and very tough. It has a covering that retards flames, and it is resistant to moisture, fungus, and corrosion. It is suitable for direct burial in the earth.

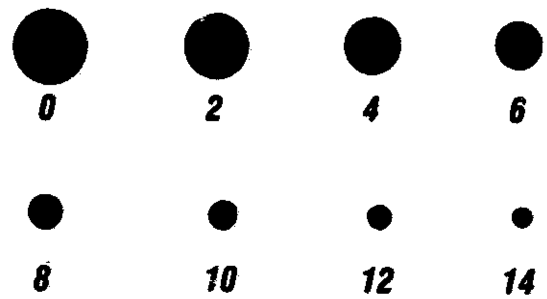


Fig. 37.6. Wire sizes that are often used.

Table 37.1—Safe Carrying Capacity of Insulated Copper Wire, for Electric Current, in Amperes[1]

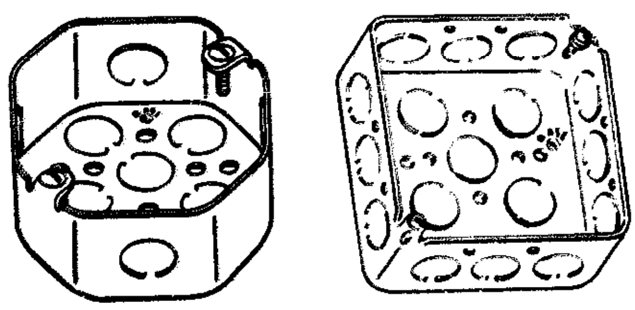
Size of Wire (American Wire Gauge)	Amperes
18	3
16	6
14	15
12	20
10	25
8	35
6	50
4	70
3	80
2	90
1	100
0	125
00	150
000	175
0000	225

[1]From the National Board of Fire Underwriters' Code.

It is recommended for use in all agricultural buildings, especially those that are damp, such as milk houses, dairies, well pits, and outbuildings. UF cable may be used outdoors, indoors, and underground.

Service Entrance Cable—A special service entrance cable is usually used to bring electricity into a building. It consists of rubber-covered wires wrapped with bare wires. An insulation cover is placed over the top of all the wires to form a cable. The bare wires are twisted together and used as a neutral wire.

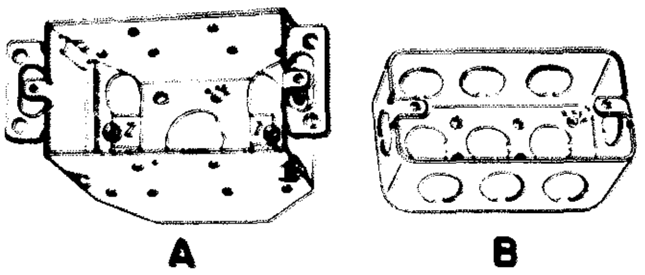
Convenience Outlets, Switches, and Receptacles—In selecting materials, consider neatness and convenience along with quality and price. The more common types of outlets, switches, and receptacles will be briefly discussed in this chapter. Further information about fixtures and electrical appliances may be obtained through the use of catalogues and through the examination of these various materials in electrical supply stores.



A B

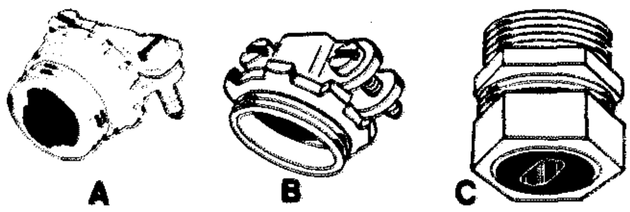
(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 37.7. Outlet boxes. (A) octagonal box, (B) square box.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 37.8. Device boxes. (A) flush-mounted box, (B) surface-mounted box.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 37.9. Cable connectors. (A) nonmetallic cable connector, (B) nonwatertight connector for service entrance cable, (C) watertight connector for service entrance cable.

Convenience outlets of the duplex type are very useful because they permit the use of two appliances. They can be secured in a variety of colors.

Porcelain receptacles are often used in such places as bathrooms, basements, and barns. Some local ordinances prohibit the use of such receptacles.

Switches come in a variety of finishes to meet individual needs and desires. Toggle, tumbler, and push-button types are available.

Attachment plugs are available in various sizes and shapes. The kind to purchase is dependent upon the use to be made of it. Heavy wire cords usually should have a heavy-duty type of attachment plug, which should be of the dead-front type.

CHAPTER 38

Wiring in Rural Areas

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

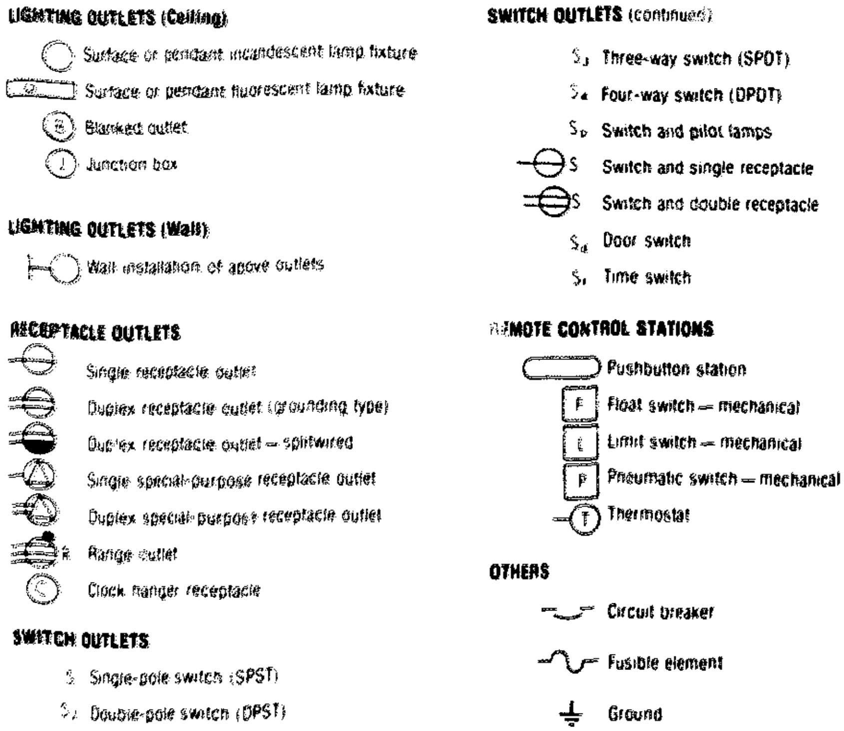
1. What should be included in a plan for the wiring of a farmstead or a nonfarm agricultural business?
2. What is the National Electrical Code? What are a few of its important standards?
3. What safety precautions should be observed in the use of electricity?
4. What tools are used in wiring?
5. What methods should be used in splicing wire?
6. How is the size of wire to use in extending wiring to an agricultural building determined?
7. How is a light fixture added at the end of a run?
8. How is a convenience outlet wired when it is added beyond a junction box? Beyond an existing outlet?
9. How are three-way switches wired?
10. How is a switch wired to control a fixture in the middle of a circuit?
11. What technique should be followed in replacing fuses?
12. What electrical equipment may be homemade?

PLANNING THE WIRING SYSTEM

In making plans for wiring a farmstead or a nonfarm agricultural business, first find out what local codes or ordinances are in effect relative to wiring. All wiring should be done according to the recommendations established by the local codes or the National Electrical Code. These codes have been developed by various associations, architects, and electrical contractors and represent a standard of quality in wiring.

The next step is to study needed equipment, fixtures, appliances, standards of quality, and prices. In determining the equipment needed, it is advisable to sketch the farmstead or nonfarm agricultural business, indicating the location of all buildings and the requirements of each. Simple sketches may be made of each building, showing the location of all wires and outlets. If the user does not want to make all installations at once, a list of the extensions and equipment which may be added later should be developed.

The third step is to present carefully prepared plans, which list the wire and other equipment with standard specifications and quality required, to contractors for bids. The contractor selected to do the job should have an established reputation for doing good work and should be willing to have the work inspected upon the completion of the job.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 38.1. Electrical symbols for wiring plans.

Wiring a House—In wiring a house, plan sufficient convenience outlets. In most homes, wall outlets are used more than ceiling outlets because of the large number of appliances, wall light fixtures, and reading lamps used in modern homes. It is better to install these outlets at the time the house is wired than it is to install them later. All closets should be supplied with outlets. Halls and porches should be provided with lights. Three-way switches should be used where the lights are to be turned on and off from two places such as at the head and at the foot of a stairway. Double outlets should be placed where two or more lamps or other appliances are to be used. All rooms of a house should be well provided with outlets, including the basement and the attic.

Wiring Buildings—All wire exposed to the weather should be weatherproof. Wire of the proper size to carry the load must be used. All wires should be placed high enough above the ground to permit farm and nonfarm agricultural equipment to pass under them.

Some poultry raisers use lights in their poultry houses to stimulate egg production. Regardless of whether or not lights are used for this purpose, poultry houses should be provided with lights. It has been found that a 40-watt lamp with a reflector placed 6 feet above the floor will illuminate 200 square feet of floor area.

Agricultural buildings should be well equipped with lights and three-way switches. The switches should be placed so that they will not be damaged by farm animals.

Cable or conduit for entrance wiring must be run in open or exposed locations on either the inside or the outside of a wall. Agricultural buildings should be wired with UF cable and dust-tight and moisture-tight devices, device boxes, outlet boxes, and connectors.

Regardless of the building being wired, the regulations outlined in the National Electrical Code should be followed. In shops, outlets should be provided near the locations where the appliances are to be used.

PROVIDING AN ADEQUATE SERVICE ENTRANCE

A service entrance includes the wiring connecting the power lines to the service entrance panel. Figure 38.2 illustrates a service entrance. The power lines are tapped, and the wires are brought through a service head, through a meter, to a service entrance panel.

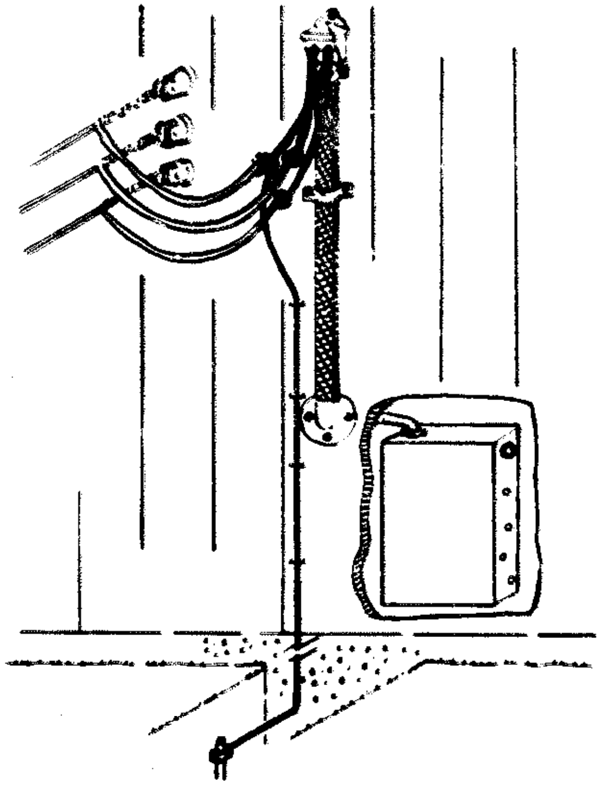
A service entrance must be adequate, because it controls the amount of electricity available to a farm or nonfarm agricultural business. Future needs as well as present needs should be anticipated. The service entrance wires and the service entrance panel installed should be large enough to take care of future demands for electricity. If they are too small, appliances will not work properly, or it may be impossible to install some types of appliances.

No. 4 wire is usually used for a service entrance in rural areas. A three-wire service entrance cable is recommended so that both 120 and 240 volts will be available. A 100-ampere service entrance panel is the minimum size recommended for a farm home. Service entrance panels that are separate from the entrance panel for the house should be used for the major outbuildings on a farm or in a nonfarm agricultural business.

The meter should be located at the load center for the farmstead, as shown in Fig. 38.3.

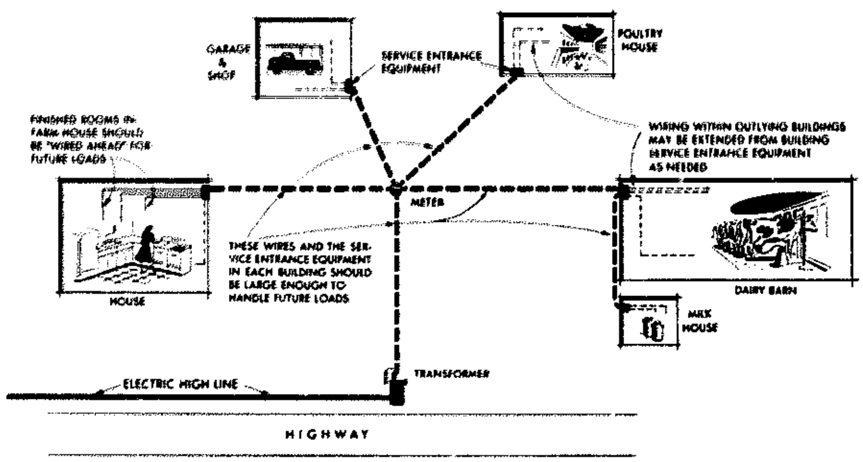
Branch Circuits—Service entrance panels provide for the use of several branch circuits, and each of these circuits is protected by a fuse or circuit breaker. (See Fig. 38.3.) Sufficient branch circuits should be used to avoid the overloading of any circuit. If a circuit is loaded to capacity, a new circuit should be added when new appliances are added.

In houses, a 15-ampere branch circuit is usually provided, for lighting purposes, for each 500 square feet of floor space. In planning the number of branch



(Courtesy Vocational Agriculture Service, University of Illinois)

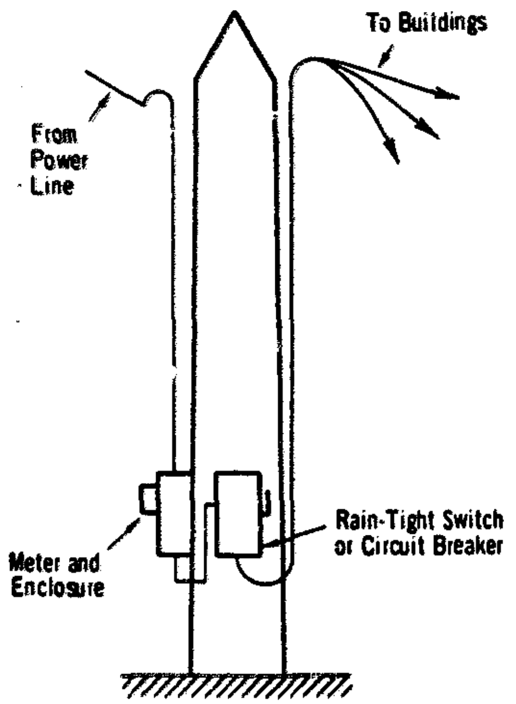
Fig. 38.2. Service entrance installation.



(Courtesy Westinghouse Electric and Mfg. Co.)

Fig. 38.3. Locate the meter at the center of the load for maximum efficiency.

circuits that will be needed, all possible appliances should be listed. Their potential wattage load should then be determined. Additional circuits will be needed because of these appliances. If No. 14 copper wire is used for the branch circuits, only 15-ampere fuses should be used. A maximum load for a 15-ampere fuse is approximately 1,650 watts. If No. 12 copper wire is used for a branch circuit, a 20-ampere fuse may be used. A 20-ampere fuse will carry a maximum load of 1,800 watts. No. 6 and No. 8 wire should be used for circuits handling heavy-duty appliances such as electric motors and electric ranges. Extra branch circuits should be available in a fuse box to provide for additional appliances that were not anticipated at the time the building was wired.



(Courtesy Food and Energy Council, Columbia, Mo.)

Fig. 38.4. A meter pole with a rain-tight circuit breaker. Agricultural buildings should have moisture- and dust-tight wiring.

Rewiring—The wiring for farms and nonfarm agricultural businesses is often extended without the benefit of a master plan. Check your wiring system to determine whether or not it needs to be revised.

WIRING FUNDAMENTALS

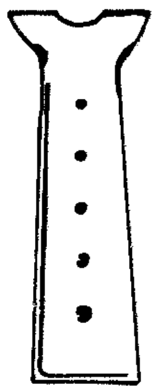
Precautions in Using Electricity—Electrical systems are often not understood by the user. Competent service or advice should be solicited when trouble occurs, other than very simple things such as blown-out fuses, shorts due to worn insulation, or broken wires. In general, the following precautions should be observed:

1. Don't allow two bare wires to touch.
2. Use electrician's tape to insulate wires from each other, either inside a connection or along a line.
3. Don't touch switches and fixtures with wet hands or while standing in water.
4. Don't overload the line. See what amperage is specified on the fixture and compare it with the ampere rating of the fuse.
5. Don't put in fuses larger than recommended, because the fuse is used to protect the system. Consistent blowing of fuses indicates an overload on the line or a short in the circuit.
6. Cover splices with insulation after they have been soldered.
7. Don't touch bare wires with hands or other tools while the line is "alive."
8. Don't touch two wires together to see whether or not they are "alive."
9. Open the circuit before touching any point on the circuit.

Most power companies desire to cooperate and should be called when their services are needed.

Tools and Supplies—A few tools and supplies for electrical work should be available. The following is a partial list which can be purchased for a very small sum:

1. Wire stripper
2. Pocket knife
3. Three screwdrivers with shock-resistant handles, assorted sizes
4. Electrician's pliers, 8″
5. Electric soldering iron, solder, and flux
6. Trouble lamp and cord
7. Solderless connectors
8. Volt-ohm-ammeter
9. Electrician's tape
10. Extra pieces of wire
11. Fuses
12. Flashlight

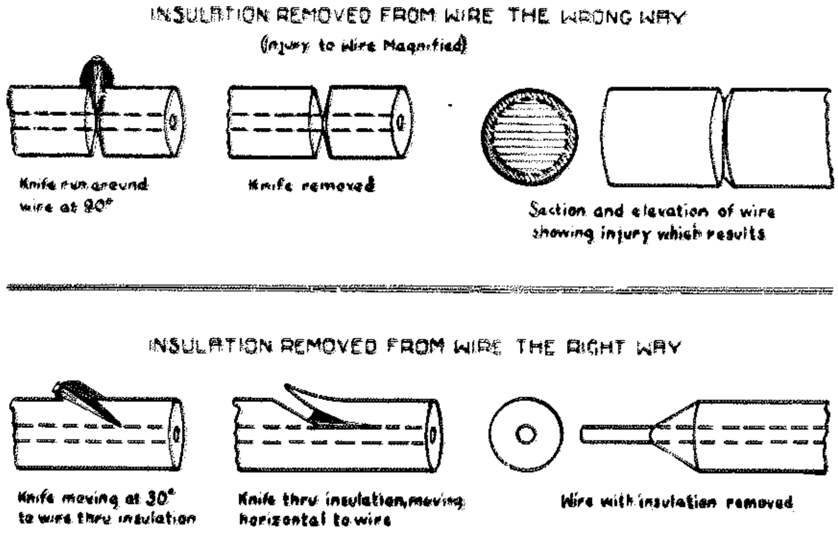


(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 38.5. A cable ripper.

Some of this equipment can also be used for other types of work in agriculture.

Splicing Wire—Care should be exercised in removing the insulation from wire to be spliced. A sharp knife should be used. Its blade should be held at a 30-degree angle to cut through the insulation, and then moved parallel to the wire. The knife should not be held at a 90-degree angle while the blade is run around the wire, because this may cause injury to the wire. Care must also be exercised not to nick the wire.



(Courtesy Committee on the Relations of Electricity to Agriculture)

Fig. 38.6. The correct and the incorrect methods of removing the insulation from wire.

The *end* splice is the most frequently used type of splice. It is made by removing the insulation approximately 3 inches from the end of each wire. The wires are crossed, as shown in Fig. 38.7, and each wire is bent to a 90-degree angle, thus hooking the wires together. The wires are then twisted together, as shown in Fig. 38.7. The joint should be covered with soldering paste or flux and securely soldered, using a soldering copper.

A *tap* or *branch* splice may be made by removing at least 2 inches of the insulation from the wire to which the tap is to be made and about 3 inches from the end of the tap wire. The tap wire is then tightly wound around the other wire, as shown in Fig. 38.8, after which the joint should be soldered and covered with electrician's tape.

A *rattail* splice may be used in joining wires when there is no strain on the wires, such as in a light fixture or in conduit wiring. It is made as illustrated in Fig. 38.9. It should be soldered and covered with electrician's tape. A solderless connector may also be used on a rattail splice. The use of such a connector eliminates the necessity of soldering the splice.

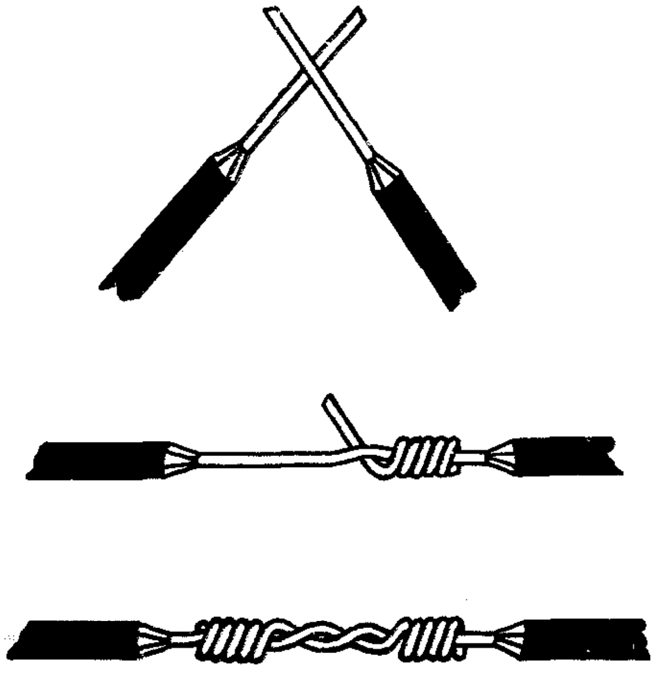


Fig. 38.7. Steps in making an end splice.

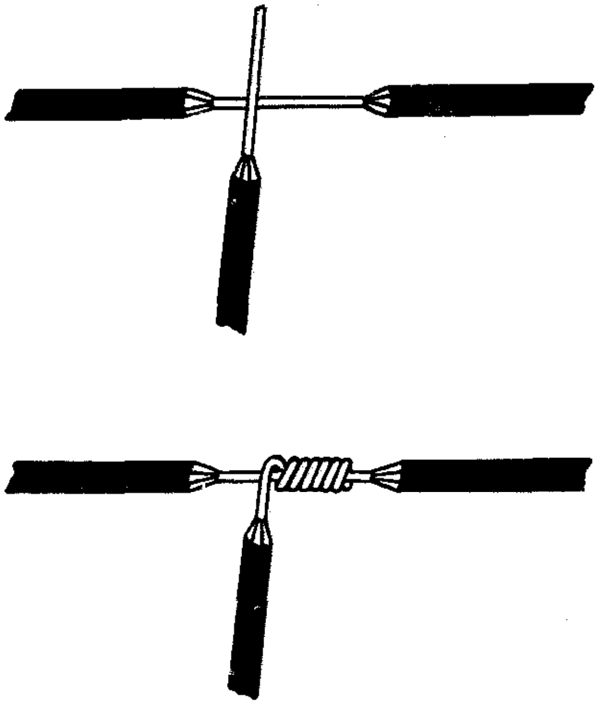


Fig. 38.8. Steps in making a tap or branch splice.

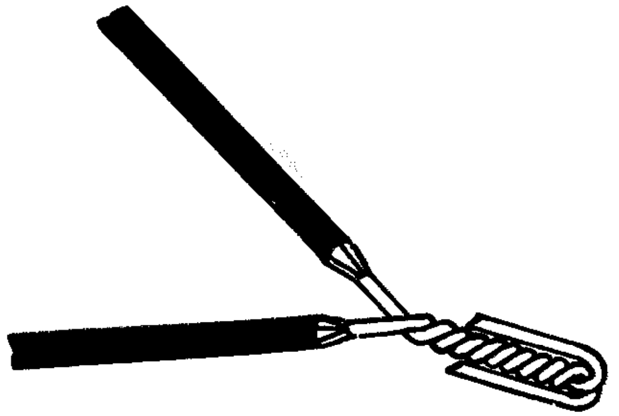
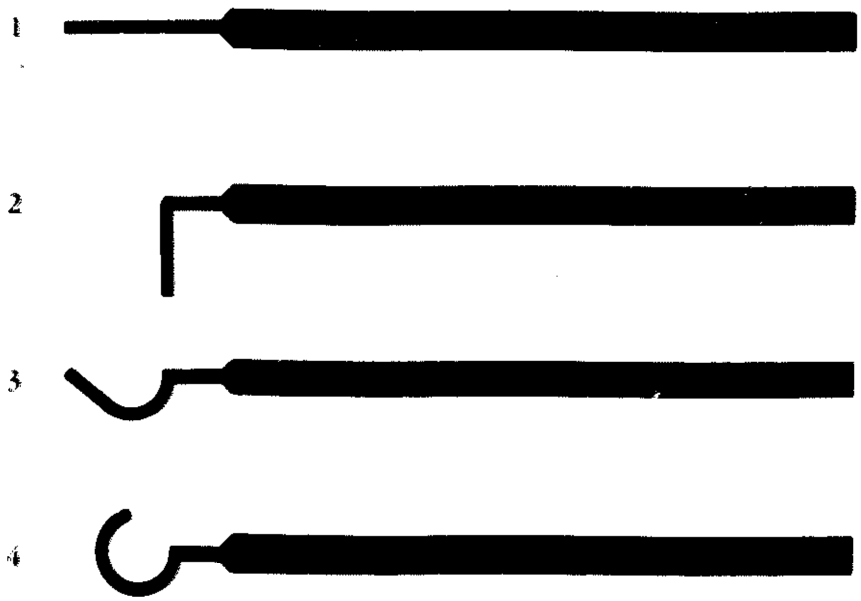


Fig. 38.9. A rattail splice.

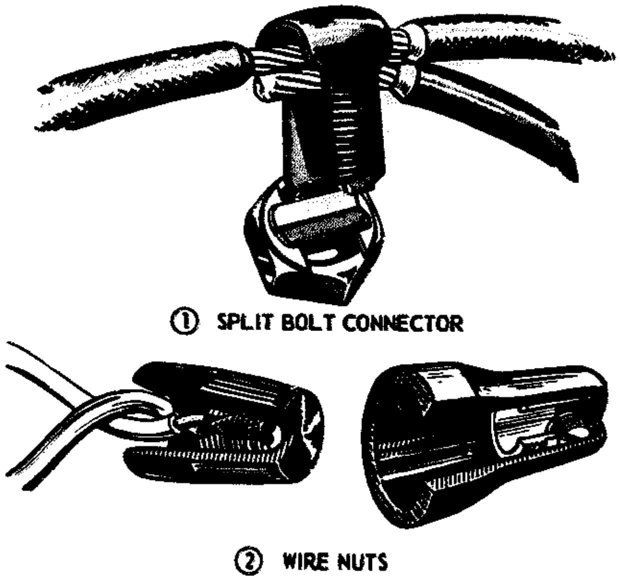


(Drawn by Ronald Ipsen)

Fig. 38.10. The successive steps involved in making an eye. First, remove the insulation as shown in No. 1. Second, bend the wire at a 90-degree angle as shown in No. 2. Third, shape the eye around electrician's pliers as shown in Nos. 3 and 4.

Solderless Connectors—Connectors have been developed to splice wires without soldering. Also, these connectors insulate the splice, thus eliminating the necessity of taping the splice. These connectors may be used when there is no strain on the splice.

Solderless connectors usually screw on or are crimped onto the ends of the wires. When this type of connector is used, the insulation should be stripped from the ends of the wires. They are then placed together, and the connector is screwed or crimped onto them. No bare wire should be visible when the connector is in



(Courtesy U.S. Department of the Army and the Air Force)

Fig. 38.11. Solderless connectors. Split bolt connectors are used to splice heavy outdoor wire such as No. 4 or No. 6.

place. If it is visible, too much insulation was removed. The shell of the connector insulates the splice and eliminates the need for taping the splice. Solderless connectors of this type are made for the different wire sizes. Connectors of the correct size for the wire being spliced should be used.

Following the National Electrical Code—The National Electrical Code is sponsored by the National Fire Protection Association (NFPA) under the auspices of the American National Standards Institute (ANSI). It includes the standards of quality which should be observed in wiring. It is not a law, but a guide to states and local governmental units in designing their laws regarding electrical wiring standards.

Before wiring, rural residents should consult their power supplier for a copy of the National Electrical Code and the local code which applies to them. A local code may establish standards which are somewhat different from the National Electrical Code.

A few of the important standards found in the National Electrical Code are as follows:

1. The grounded wire is always white. It should not be broken by a switch, and it should not be connected with the fuse.
2. The black wire is always connected to the brass terminal in the fixture, and the white wire should always be connected to the silver terminal.
3. Connectors and splices must be enclosed in a box.
4. All splices or connections must be soldered or fastened with a solderless connector. Splices with soldered connections must be wrapped with electrician's tape equivalent in an amount to the original insulation.

5. The smallest size wire permissible in interior wiring is No. 14. The fuse used for No. 14 wire must not be larger than 15 amperes. The fuse used for No. 12 wire must not be larger than 20 amperes.
6. A support or fastener must be used with nonmetallic sheathed cable every 4½ feet, and within 12 inches of each outlet or box.

Wiring "Hot" and "Neutral" Wires—"Hot" wires are the power-carrying wires, and they should always be black or otherwise designated. "Neutral" wires are the grounded wires, and they should always be white. To avoid short circuits, fasten black "hot" wires, with a few exceptions, to other black wires or to brass terminals. "Neutral" white wires should be spliced or fastened, with a few exceptions, to white wires or to silver terminals. Examples of two exceptions are shown in Figs. 38.20 and 38.21. In adding a switch to control a fixture in the middle or at the end of a run, it is necessary to violate the principle of wiring just given. These are known as switch loop situations.

Using a Test Lamp—A test lamp is needed to determine "hot" wires and also to determine when a circuit is "hot." A neon test lamp is the best type of test lamp to use, because it takes very little current to operate it. A test lamp can be homemade, as shown in Fig. 38.12. A test lamp may be made for a 240-volt circuit by using a 240-volt bulb.

When testing for a "hot" wire, place one wire of the test lamp on the wire being tested, and ground the other wire. When testing for a "hot" circuit, touch the wires of the test lamp to the terminals of an outlet.

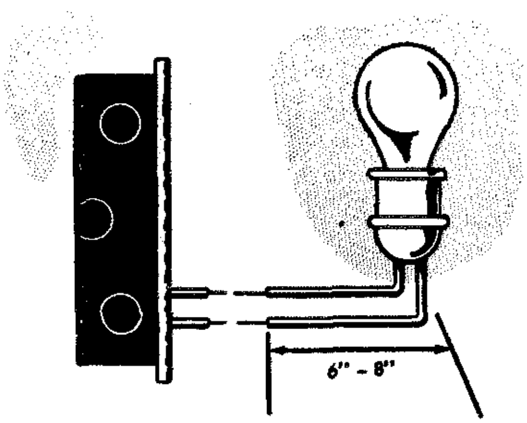
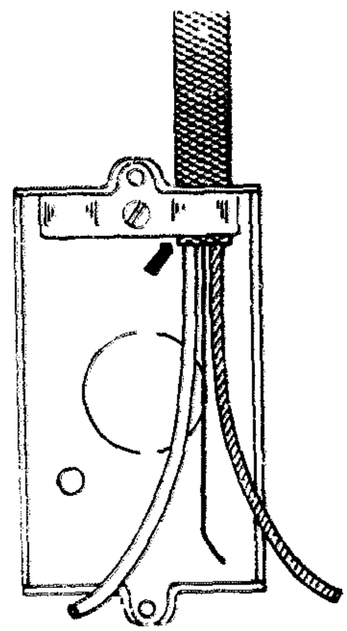


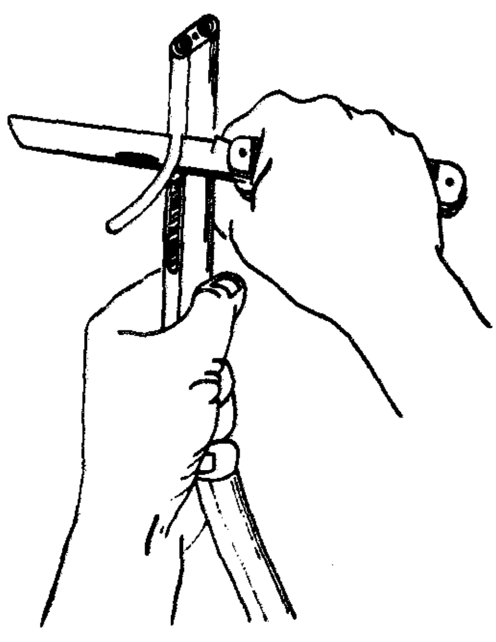
Fig. 38.12. A test lamp.

Wiring Boxes—All splices for switches and receptacles must be enclosed in boxes, unless the switches or receptacles are of the surface type. (See the National Electrical Code.) Boxes come in various sizes. The size to use depends on the size and number of wires being used. The National Electrical Code has established the maximum number of wires that can be placed in boxes of each size. Consult your local code for this information before wiring. Boxes may be enlarged by placing



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 38.13. When wiring nonmetallic cable, make certain that the outer sheath extends under the clamp in the box, as shown.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 38.14. A knife may be used to remove the covering over each conductor in UF cable.

two or more of them together. Sides of the boxes are removed when they are placed together or ganged.

The National Electrical Code specifies that 6 inches of each wire to be spliced must be left in a box so that adequate wire will be available to make connections and splices. After the splices and connections are made, push the excess wire into the box and put the cover, switch, or receptacle on the box.

Wiring Fixtures—The National Electrical Code specifies that only one wire be placed under a terminal screw. It is therefore necessary to splice two 6- or 8-inch pieces of wire to the proper wires carried in the box. These extra pieces of wire are called pigtails and are the wires attached to the fixtures. See Fig. 38.15 for an illustration of the use of pigtails.

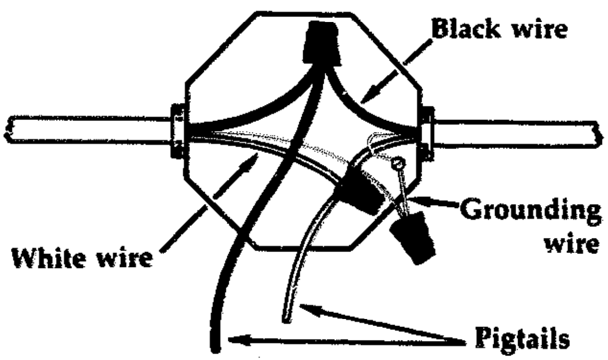


Fig. 38.15. Pigtails. Wires are added so that each of the terminal screws on a fixture will have to hold only one wire.

EXTENDING WIRING SYSTEMS

The efficiency of several activities on many farms and in many nonfarm agricultural businesses could be improved by extending their wiring systems. As stated in the section of this chapter on planning a wiring system, extensions should not be made haphazardly, but needed extensions should be carefully planned and made. Agricultural workers can develop the ability to make the less complex extensions needed.

Extending Electricity to a Building—The feeder wires to a building should not, if at all possible, go through another building. They should come directly from the meter pole. To make this possible, the meter pole should be located so that it is at the center of the load, that is, the point where the electricity demands, from the various points of use, balance.

The size of feeder wires to install depends on the amount of electricity that will be used in the building and the distance to the building. See Table 38.1 for information on the size of wire to use. If a 240-volt outlet is planned, a three-wire

Table 38.1—A Table That May Be Used to Estimate the Correct Size of Wire to Use Between Buildings[1]

Two-Wire Feeder Carrying 120 Volts[2]

Load in Watts																
3,000	10	8	6	6	4	4	4	2	2	2	1	1	1	1	0	0
2,500	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0
2,000	10	10	8	8	6	6	6	4	4	4	4	2	2	2	2	1
1,500	10	10	8	8	8	6	6	6	6	6	4	4	4	2	2	2
1,000	10	10	8	8	8	8	8	8	6	6	6	6	6	6	4	4
500	10	10	8	8	8	8	8	8	8	8	8	8	8	8	***8***	***8***
Distance in Feet	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400

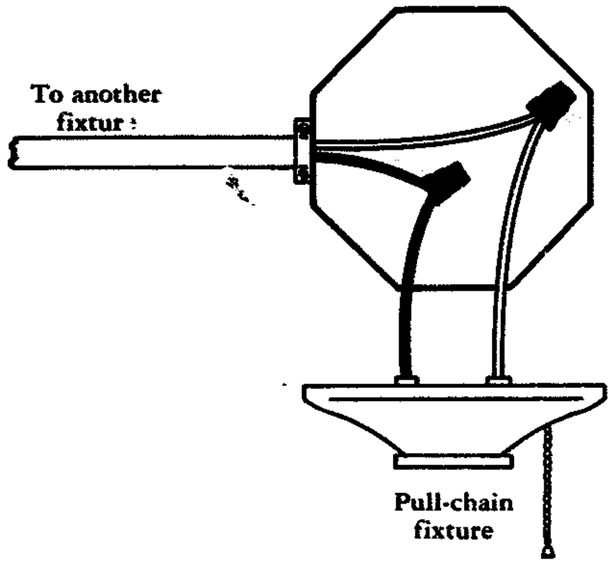
Three-Wire Feeder Carrying 120/240 Volts

Load in Watts																
9,000	10	10	8	8	6	6	4	4	4	4	2	2	2	2	1	1
8,000	10	10	8	8	6	6	6	4	4	4	2	2	2	2	2	2
7,000	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2
6,000	10	10	8	8	8	8	6	6	6	4	4	4	4	4	2	2
5,000	10	10	8	8	8	8	8	6	6	6	4	4	4	4	4	4
4,000	10	10	8	8	8	8	8	8	8	6	6	6	6	4	4	4
3,000	10	10	8	8	8	8	8	8	8	8	8	6	6	6	6	6
2,000	10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1,000	10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Distance in Feet	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400

[1]O. J. Trenary, "Wiring the Farmstead for Efficiency," Colorado A.&M., pp. 8–9.
[2]The figures in boldface italics indicate where a two-wire system becomes uneconomical and should be changed to a three-wire system.

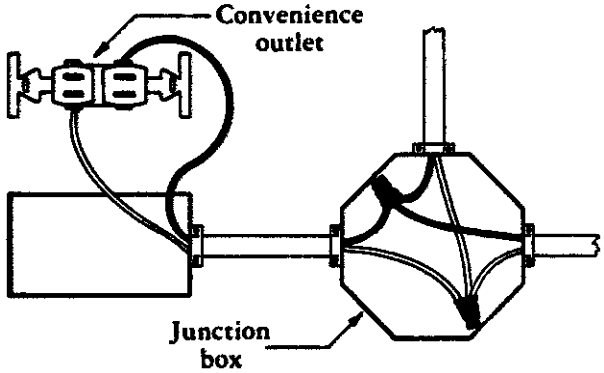
feeder line should be used. If there is a possibility that 240-volt motors will be used in the future, it is best to use a three-wire feeder line. A separate service entrance panel for each major building is usually advisable.

Adding Light Fixtures—An understanding of the information given in the previous section on wiring fundamentals should be sufficient for adding light fixtures in agricultural buildings. The task is more difficult in a house where the wiring is installed in the walls. Farmers or other agricultural workers should probably not attempt to add light fixtures in a house until they have developed some skill in wiring. See Fig. 38.16 for an illustration of how to add a pull-chain light fixture at the end of a run. See Figs. 38.19, 38.20, and 38.21 for other diagrams for wiring light fixtures. Be sure that the electricity has been disconnected for the circuit before starting to add an extension. Use a test lamp to test whether or not the correct circuit has been disconnected.



(Drawn by Ronald Ipsen)

Fig. 38.16. A pull-chain light fixture added to the end of a run. For clarity, the grounding wire is not shown.



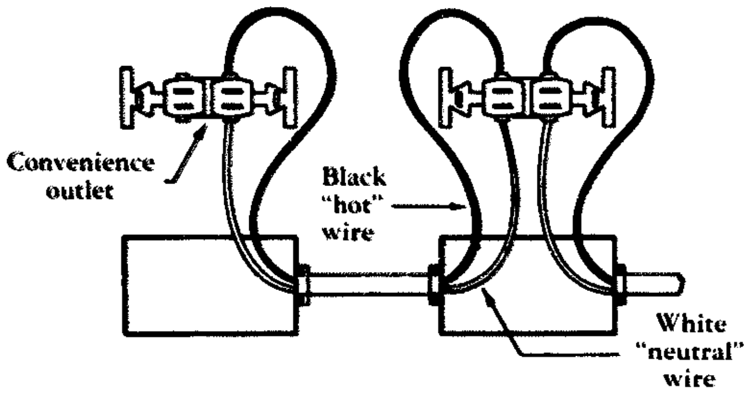
(Drawn by Ronald Ipsen)

Fig. 38.17. The addition of a convenience outlet beyond a junction box. For clarity, the grounding wire is not shown.

Adding Switches—The efficiency of a wiring system can often be improved by adding single-pole switches or by installing three-way switches. A three-way switch makes it possible to turn a light on or off at two locations.

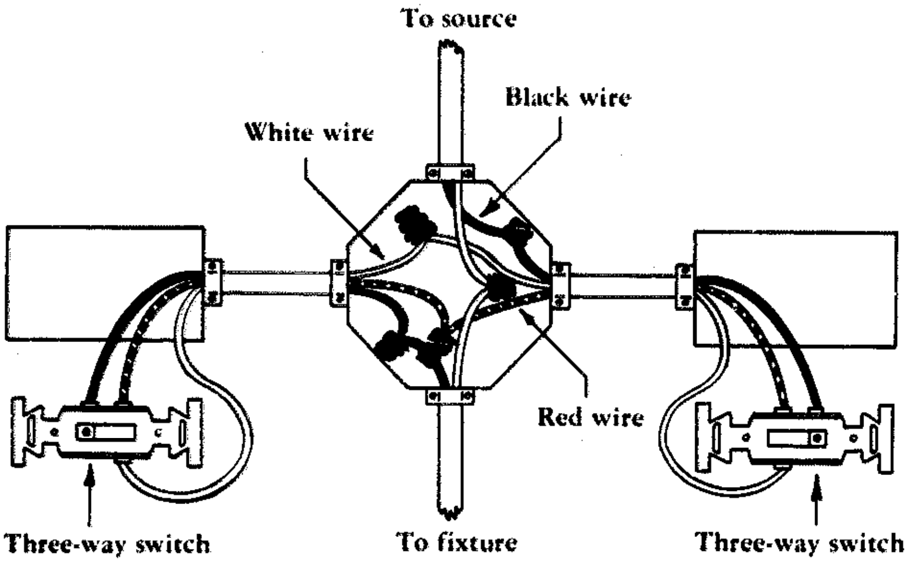
See Figs. 38.20 and 38.21 for a wiring diagram for the use of a single-pole switch at the end and in the middle of a run. See Fig. 38.19 for a wiring diagram for a three-way switch.

Adding Convenience Outlets—Original wiring systems often lack sufficient convenience outlets. See Fig. 38.18 for a wiring diagram for adding a convenience outlet beyond an existing convenience outlet. See Fig. 38.17 for a wiring diagram for a convenience outlet beyond a junction box.



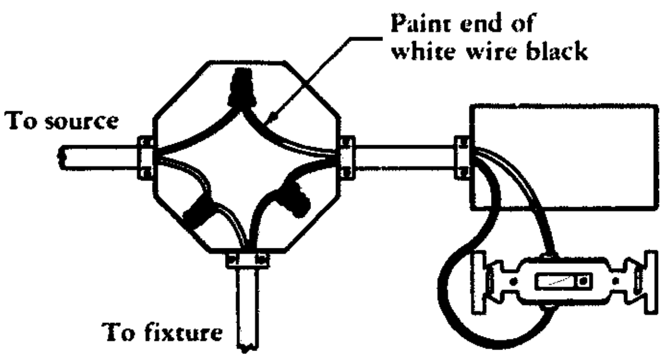
(Drawn by Ronald Ipsen)

Fig. 38.18. The addition of a convenience outlet beyond an existing outlet. For clarity, the grounding wire is not shown.



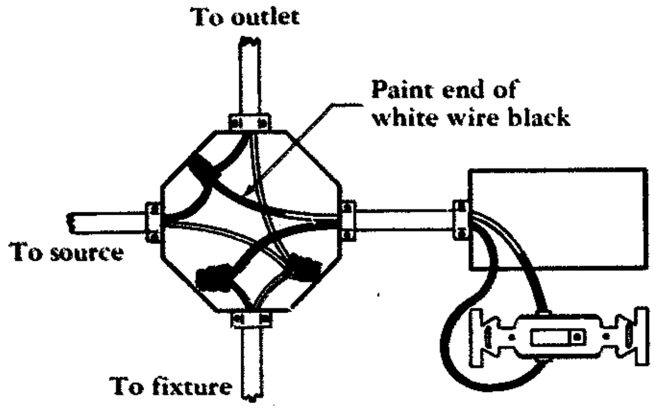
(Drawn by Ronald Ipsen)

Fig. 38.19. A three-way switch wiring diagram. For clarity, the grounding wire is not shown.



(Drawn by Ronald Ipsen)

Fig. 38.20. Switch used to control a fixture at the end of a run. For clarity, the grounding wire is not shown.



(Drawn by Ronald Ipsen)

Fig. 38.21. When a switch is used to control a fixture in the middle of a circuit, it is necessary to splice a white wire to a black wire. For clarity, the grounding wire is not shown.

MAINTAINING A WIRING SYSTEM

A wiring system ordinarily requires very little care. The following suggestions are offered:

1. An occasional checkup should be made to see that none of the switches, equipment, or appliances are damaged. This check is especially needed in buildings where animals are kept.
2. Fuses should be replaced with fuses of the proper size and not with pennies or other coins.
3. Electric cords should be removed from outlets by grasping the outlet plugs.

Repairing a Light Cord—If it is necessary to secure a new cord for a fixture, a cord should be selected that has the approval of the Underwriters' Laboratories. If a light cord is broken but good otherwise, it may be spliced and properly taped as previously discussed.

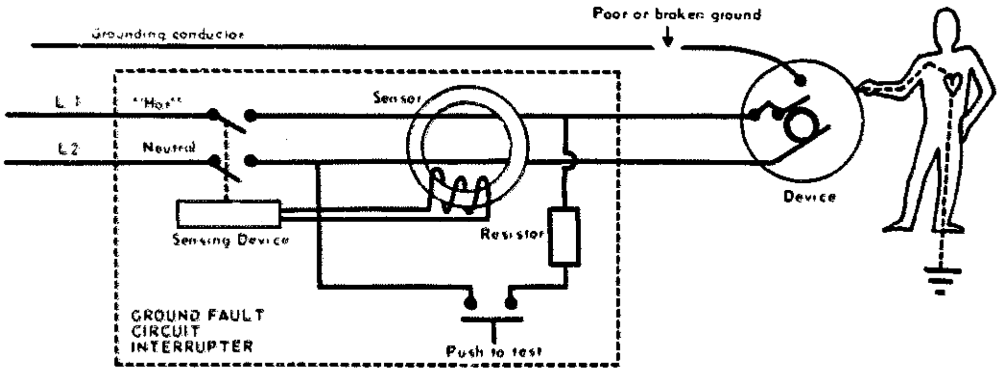
Replacing Fuses—If power or lights go off, check another circuit to determine whether or not the difficulty is a general power failure or a burnt fuse. If other circuits have power, locate the blown fuse or the open circuit in the service entrance panel. You may determine the blown fuse by inspecting the fuse. Before a new fuse is installed, check the cause of the trouble such as a short circuit, an overheated appliance, or too heavy a load.

If it can be done easily, pull the main switch on the entrance panel before unscrewing the burnt fuse. When removing the fuse, stand on a dry floor. If the floor is wet, stand on a dry board. Replace the burnt fuse with a fuse of the proper size. Connect the main switch.

Ground Fault Circuit Interrupter

When electrical equipment is used, the best and most positive protection from electrical shock disasters is the use of a ground fault circuit interrupter (GFCI). Electrical equipment should be properly insulated and grounded. But, sometimes insulation and grounding systems break down. If this occurs, a GFCI will protect the person operating the equipment.

A GFCI is a circuit breaker that is very sensitive to a small leakage of current to the ground. The operating principle is shown in Fig. 38.22. GFCI's that are designed for installation in the circuit breaker box are available. Another type of GFCI is designed to be placed in any receptacle. A GFCI of the correct type may be used on an extension cord. Some GFCI's are designed for ungrounded circuits, while other GFCI's are designec for use with grounded circuits.



(Courtesy Vocational Agriculture Service, University of Illinois)

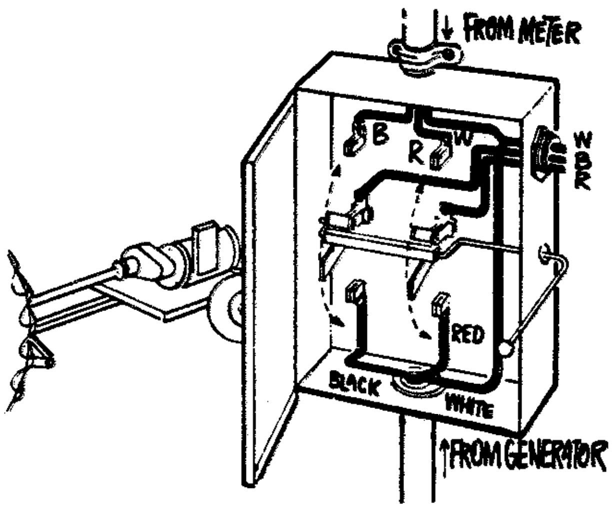
Fig. 38.22. The operating principle of a ground fault circuit interrupter (GFCI).

GFCI's should always be used in circuits where electrical equipment is used in wet or potentially wet locations outdoors or indoors in bathrooms, kitchens, laundry rooms, basements, dairy barns, milking parlors, shops, barns, machinery sheds, greenhouses, and so forth.

Wiring for Emergency Power

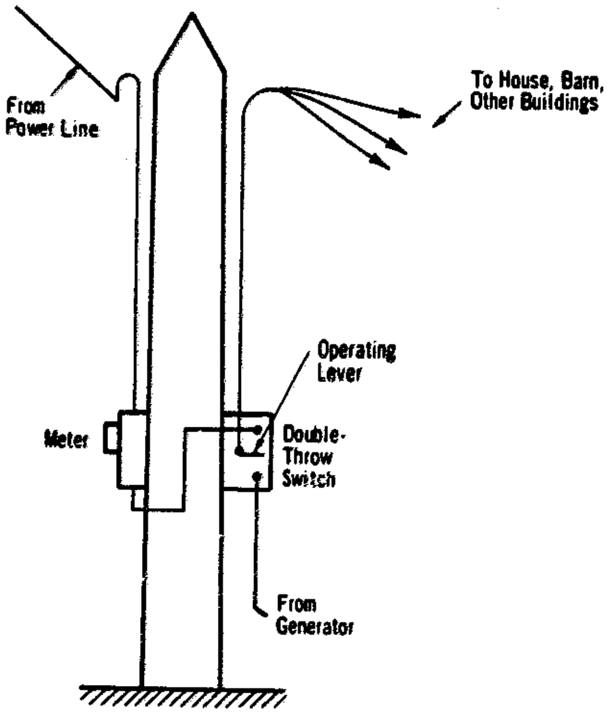
In farming or in an off-farm agricultural business, a power failure can be a disaster. In event of a power failure, it is important to have standby equipment to generate electricity. It is essential that this standby generator be attached to the wiring system correctly. A double-throw switch needs to be installed. A double-throw switch prevents the standby generator from feeding power back into the power supplier's line. The operating principle of a double-throw switch is illustrated in Fig. 38.23. With a double-throw switch, it is impossible for the standby generator and power supplier line to be connected to the farm or agricultural business wiring system at the same time.

It is important to have a double-throw switch, because it protects persons who repair the power supplier's line. It also prevents damage to the standby generator when the power comes back to the supplier's line. The capacity of the double-



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 38.23. The operating principle of a double-throw switch.



(Courtesy Food and Energy Council, Columbia, Mo.)

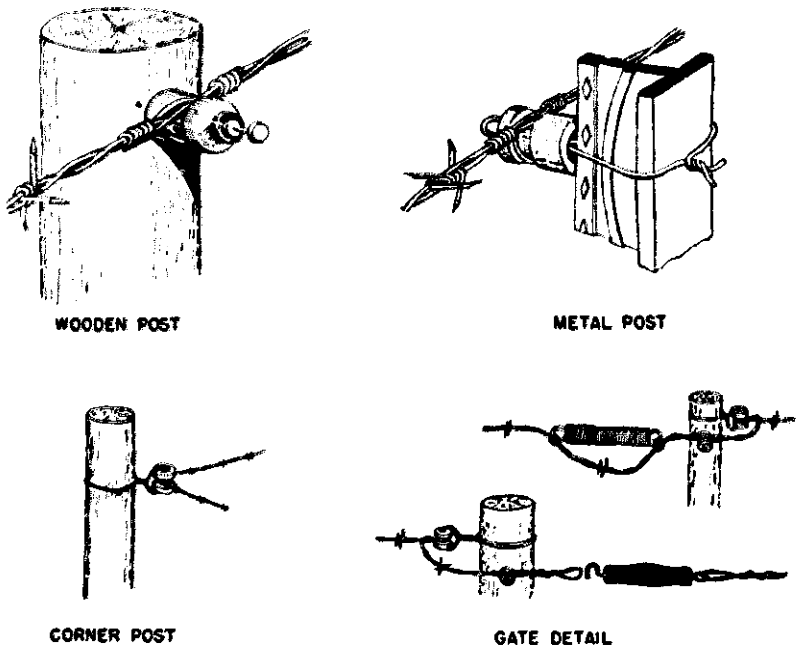
Fig. 38.24. A double-throw switch installed on a meter pole.

throw switch should be matched with the rating of the conductors for the load from the power supplier, instead of being matched to the operating load of the generator.

ELECTRICAL EQUIPMENT

Electric Fences—Electric fences are easily installed and quickly removed. Many farmers who have used electric fences have found them to be very successful, especially when a temporary fence is desired. Temporary fences require only one or two wires with posts placed 40 to 50 feet apart. At the present time several companies manufacture chargers or controllers for electric fences.

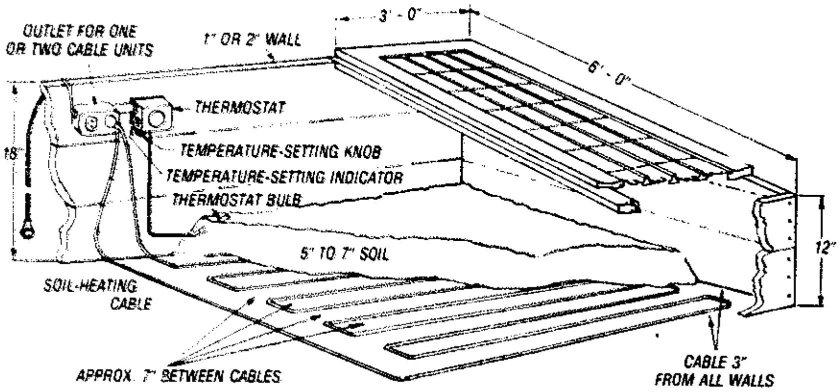
Some farmers have made electric fence chargers or controllers at home in order to save money. Persons and animals have been killed, however, when homemade units have been connected directly to circuits. An electric fence should be operated with a fence controller of proper design. Such controllers transform electricity into a form which will be sufficient to sting the animal but not sufficient to injure it.



(Courtesy College of Agriculture, University of Maine)

Fig. 38.25. Insulating fence wires on wooden and steel posts and constructing a gate for an electric fence.

Electric Soil Heaters—Electric soil heaters may be made to hasten the growth of plants early in the spring. The plan shown in Fig. 38.26 has been used by many rural residents.



(Courtesy Agricultural Extension Division, Michigan State University)

Fig. 38.26. An electric soil heater. This hot bed uses 400 watts of energy. Sixty feet of soil-heating cable, a lead-covered high resistant wire, is used. A layer of ¼-inch mesh hardware cloth may be placed over the heating cable to prevent damage to the cable from tools which are used to cultivate the plants.

CHAPTER 39

Selecting and Maintaining Electric Motors

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What determines the size of electric motor to use?
2. What are the three basic types of electric motors?
3. What are the distinguishing characteristics of each type?
4. What are the accessories frequently available for electric motors? Where and when should they be used?
5. What principles should be observed in the installation of electric motors?
6. What size of wire should be used for electric motors?
7. What precautions should be taken in the operation and maintenance of electric motors?
8. What repairs should an agricultural worker attempt in maintaining electric motors?
9. What electric motor troubles indicate the need for repairs by an electrical motor service person?

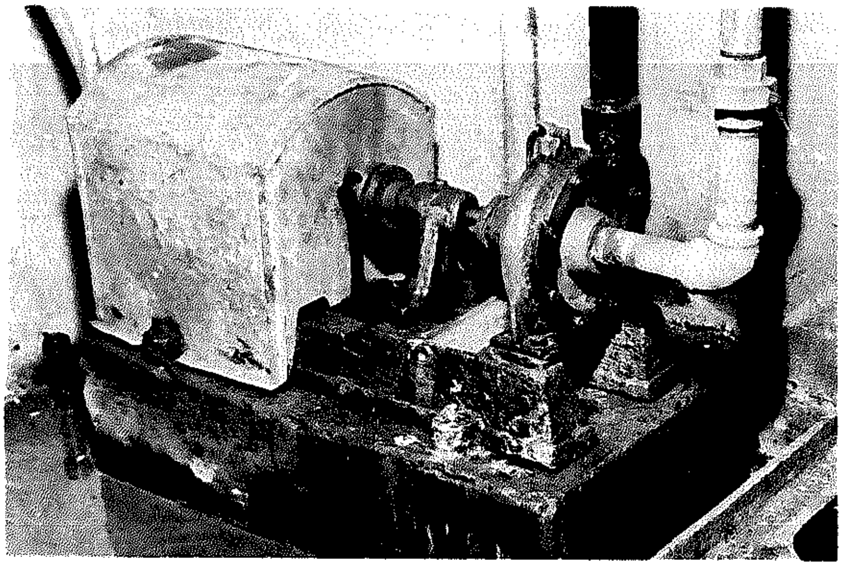
Electric motors are relatively cheap to purchase, and they are inexpensive to operate. If they are maintained properly, they have a long life. They are small in size and may be operated with automatic switches. They are not influenced adversely by hot or cold weather, and they operate quietly and safely.

Farmers and nonfarm agricultural businesspersons cannot afford *not* to make maximum use of electric motors. For a few cents of electricity, an electric motor will do as much work as a person working an eight-hour day.

SELECTING ELECTRIC MOTORS

Size—The size of electric motor to use depends on:

1. The equipment to be operated.
2. The speed of operating the equipment.
3. The wiring system available.
4. The regulations of the company supplying the electricity.



(Courtesy General Electric Co.)

Fig. 39.1. A homemade cover used to keep the motor clean and dry. This is important when motors are used in unprotected places where excessive moisture or dust is present.

It is usually advisable to consult the manufacturer of the equipment regarding the size of motor to use, but a general guide is that a 1/4-horsepower motor will be sufficient if the machine can be operated by hand. If a machine is operated by a small gasoline engine, a 2/3- to 3/4-horsepower electric motor should be used.[1]

If a machine may be operated at two or more speeds, it usually takes more power and may require a motor of larger size to operate the machine at the higher speed. So the speed of operating a machine should be considered in selecting a motor of the correct size.

An ammeter may be used to determine whether or not a motor is large enough to power a machine. If the motor is using more current than its rating on its nameplate, a larger motor is needed.

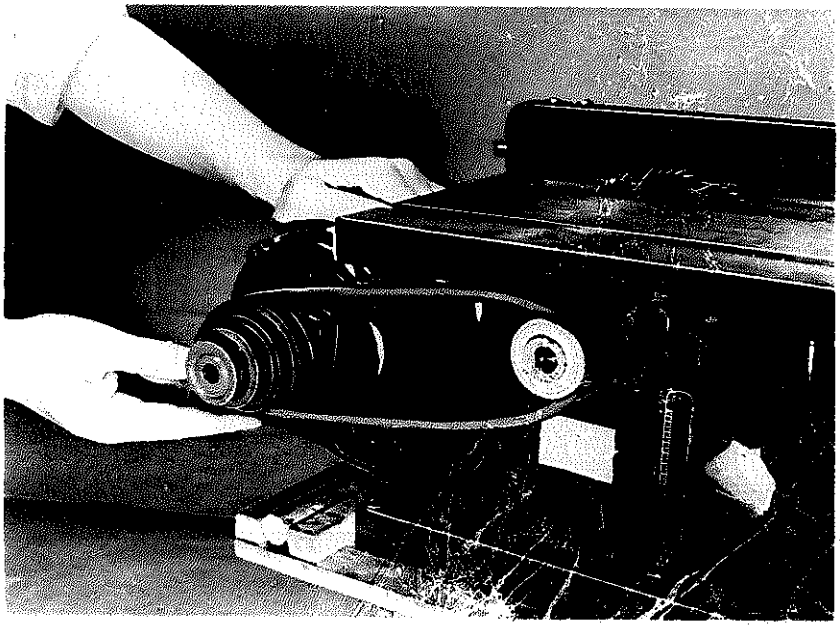
The wiring system must be considered in using electric motors. A two-wire, 120-volt wiring system will operate a 120-volt motor but will not operate a 240-volt motor. A three-wire system is needed for 240 volts.

The size of wire in a wiring system or the size of a service entrance panel may limit the size of motor that can be used.

An electric motor of 1/3 horsepower or less can be connected to any outlet, because a typical wiring system and service entrance panel will operate the motor. A motor up to 1 1/2 horsepower may be used on three-wire, 240-volt systems, even when relatively small wire and service entrance panels are used.

When a motor of over 1/3 horsepower on a 120-volt system or over one horsepower on a 240-volt system is needed, a check should be made to determine

[1]"Farm Electric, Electric Motors for Every Use," Southern Association of Agricultural Engineering and Vocational Agriculture, p. 2.



(Courtesy Westinghouse Electric and Mfg. Co.)

Fig. 39.2. Avoid overloading a motor. Heat caused by an excessive or continuous overload may destroy motor windings and bearings. Overload protective devices should be added if not built into motors. Often motor load may be reduced satisfactorily by changing pulleys.

whether or not the wiring system is adequate to operate the motor. Of course, whether a wiring system and service entrance are large enough is dependent also on the amount of other electrical equipment being served.

Before large motors are installed, the company supplying the electricity should be consulted. Most companies will serve motors as large as 5 to $7\frac{1}{2}$ horsepower. They may refuse to serve large motors, however, unless three-phase service[2] is available, because the motors may cause the lights to dim and brighten in the whole community.

Type—There are three basic types of single-phase, alternating-current electric motors frequently used on farms and in nonfarm agricultural businesses:

1. Split-phase
2. Capacitor
3. Repulsion-induction

The type of motor to select depends on the difficulty of starting the load. If the load is easy to start, the split-phase motor is probably the best type of motor to use. It is the cheapest of the three types usually used in agriculture. Split-phase motors are available in only the smaller sizes—1/3 horsepower being the largest. They are used for equipment such as bench saws, automatic washers, and tool

[2]Three-phase service supplies three currents of electricity, necessitating three or more "high-line" wires.

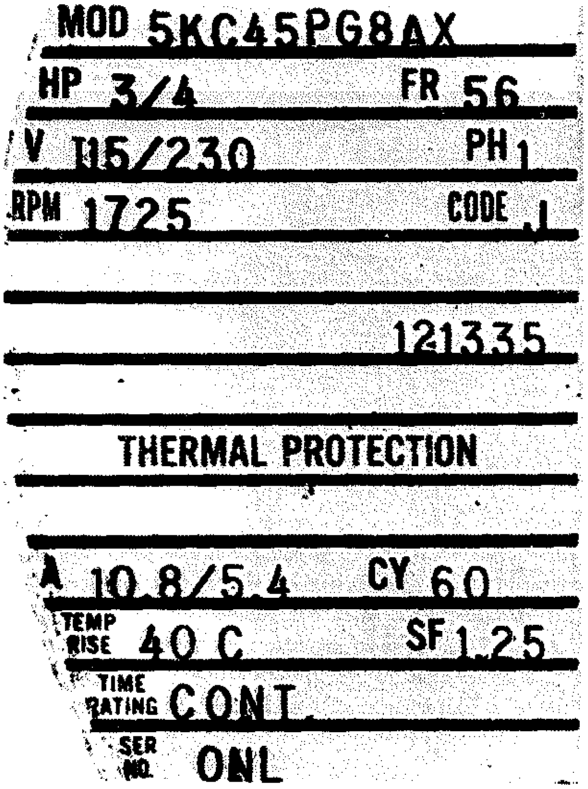


Fig. 39.3. A nameplate on an electric motor. Note that it gives the horsepower, voltage, R.P.M., temperature rise, and time rating. This motor is designed for continuous duty. With continuous operation the temperature rise will be only 40 degrees Celsius (74 degrees Fahrenheit). In selecting a motor, consider the information shown on the nameplate.

grinders. Split-phase motors require a large amount of current to start them. This may be a disadvantage, because it may cause the lights on the same wiring circuit to dim when the motor starts.

If the load is fairly difficult to start, a capacitor motor is probably the type to use. Some examples of equipment fairly difficult to start are feed mixers and air compressors. A capacitor motor produces about three times the starting force of a split-phase motor of the same size, and it uses about one-half to three-fourths as much current to start a load as a split-phase motor of the same size uses to start the load. Capacitor motors cost more than split-phase motors.

For loads that are difficult to start, such as grain elevators and hay elevators, repulsion-induction motors give good service. They are available in relatively large sizes, and voltage drops do not greatly influence them. Repulsion-induction motors cost more than capacitor motors. They have more mechanical parts than the other two types of motors and, therefore, may need more mechanical attention.

Accessories—Selecting a motor involves not only choosing the correct size and type of motor but also choosing the type of mounting, the type of bearings, the type of enclosures, and the type of protective devices.

Rigid or *adjustable mounts* are provided for motors. A mount is used to anchor a motor in position. An adjustable mount can also be used to tighten or loosen a belt. A *cushion* base can be obtained for some motors to reduce vibration or to lessen noise.

If a motor has a rigid mounting, a sliding base can be obtained which makes the motor mounting adjustable. For a discussion of a *portable* motor mount, see the section later in this chapter on making motors portable.

Motors are equipped with *sleeve bearings* and with *ball bearings*. The location and position of a motor are the determining factors in deciding which type of bearings to obtain. If a motor is located where it may be oiled and checked frequently, and if it is to be mounted with the shaft *parallel* to the floor, sleeve bearings are satisfactory. A motor equipped with sleeve bearings costs less than a motor equipped with ball bearings, but a ball-bearing motor can be mounted in any position.

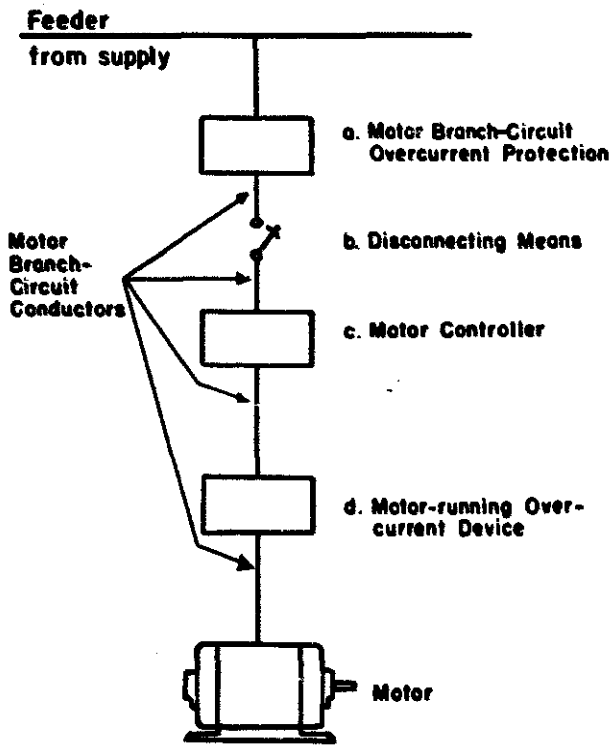
If a motor with sleeve bearings is mounted on a side wall, the shields on the ends must be rotated one-fourth turn to prevent the loss of the lubricating oil. If it is mounted on the ceiling, the shields must be rotated one-half turn.

Motors may be purchased that have open, splash-proof, dirt-proof, or explosion-proof enclosures. A splash-proof enclosure is needed when the motor is subjected to the splashing or spraying of water. A dirt-proof enclosure is needed when the motor is subjected to considerable dirt and dust, for example, a motor used to operate a feed grinder. An explosion-proof enclosure is needed for a motor operated in a location where explosions are a danger. Splash-proof, dirt-proof, and explosion-proof enclosures are more expensive than open-type enclosures, because the cheapest way to cool a motor is to leave openings in the cover or enclosure.

Motors need to be protected to prevent their "burning up" when they are overloaded. Ordinary circuit fuses or breakers do not protect a motor, because more current is required to start a motor than is required to operate it. If a fuse large enough to start a motor is used, it will allow the motor to become overheated while running. Overload may be caused by the use of too small a motor, by too tight a belt or one that is out of line, by low voltage on the line, or by the lack of motor lubrication.

Motors may be protected by *overload switches* or by time-delay fuses. Motors can be purchased with a built-in overload switch, or an overload switch may be combined with a starting switch. When an overload switch becomes heated to a point at which the windings of the motor are endangered, it opens and disconnects the motor. Some overload switches will reset or connect the motor automatically when the motor has cooled. Other overload switches are operated manually. A manual overload switch must be reset by hand when the motor has cooled. An overload switch increases the cost of a motor, but it may keep a motor from being destroyed by an overload.

A time-delay fuse may be used, instead of an ordinary fuse, to protect a motor. It has the advantage of also protecting the circuit as well as the motor. If a time-delay fuse, however, is destroyed by an overload, someone may inadvertently



(Courtesy Vocational Agriculture Service, University of Illinois)

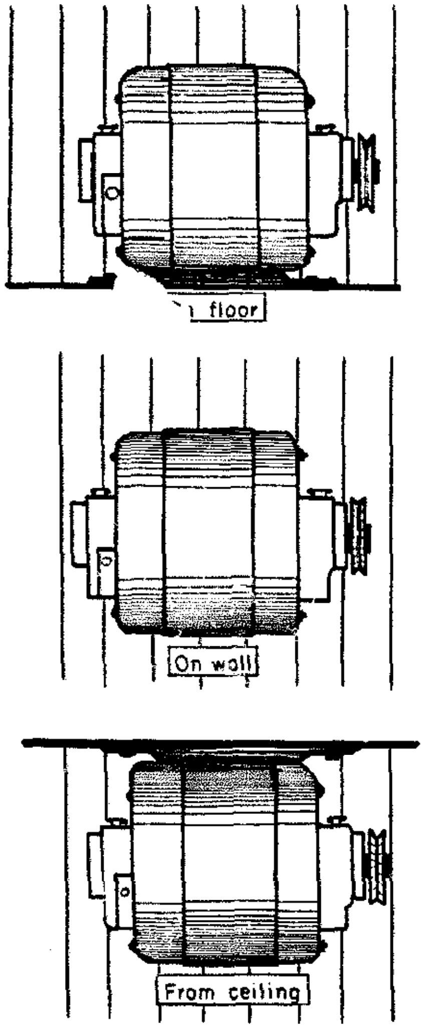
Fig. 39.4. An electric motor properly installed should have the following units to protect and control it: (a) circuit breaker for motor, (b) disconnect switch, (c) motor control device for turning motor on and off, (d) motor-running overcurrent device or overload device.

replace it with an ordinary fuse, thus leaving the motor unprotected. A time-delay fuse allows considerable current to flow for the brief period necessary to start a motor. The continuous use of an excessive current, however, will cause the fuse to "burn out."

INSTALLING MOTORS

Position—If a motor is to be mounted overhead, on a side wall, or vertically, the type of bearing should be checked. If it is a ball-bearing motor, it can be mounted in any position. Sleeve-bearing motors can only be mounted horizontally. By changing the end shields so that the oil holes are toward the top, most motors can be mounted overhead or on a side wall.

Wire Size—A motor cannot operate properly if the wires to which it is connected are too small. Small wire size decreases the voltage available for a motor, which may cause overheating. Motors, 120-volt, of less than 1 horsepower that are used within 30 feet of the service entrance can be operated on the wiring ordinarily used for lighting circuits. When larger 120-volt motors are used, or when in-



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 39.5. Most electric motors may be mounted overhead or on a side wall, in addition to on the floor, if the end shield is rotated so that the oil holes remain upright.

creased distances from the service entrance are used, the wiring available should be checked to determine whether or not it is of adequate size. Conductors (wire) for 240-volt motors do not need to be of as large a size as the conductors required by 120-volt motors of an equivalent size.

Belts and Pulleys—Connecting a motor to a load with belts and pulleys is discussed in Chapter 26.

Making Motors Portable—Equipment of many types may be operated with portable motors. Portable motors have been used on such equipment as post drills, tool grinders, meat grinders, feed grinders, and grain elevators. They are useful labor-saving devices and are often mounted on wheels so that they can be transported easily.

Table 39.1—Wire Sizes for Single-Phase Motors[1]

Volts	Full-Load Amperes	Nominal Horsepower of Motor	Distance in Feet from Service Entrance to Motor														
			0–20	30	40	50	60	80	100	120	160	200	250	300	350	400	500
			Wire Size[2]														
120	4		14	14	14	14	14	14	14	14	14	12	10	10	10	10	8
	6	¼	14	14	14	14	14	14	14	12	12	10	10	8	8	8	6
	8	⅓	14	14	14	14	14	14	12	12	10	10	8	8	6	6	6
	10	½	14	14	14	14	14	12	12	12	10	8	8	6	6	6	4
	12		14	14	14	14	12	12	10	10	8	8	6	6	4	4	4
	14	¾	12	12	12	12	12	10	10	8	8	6	6	4	4	4	2
	16	1	12	12	12	12	12	10	10	8	8	6	6	4	4	4	2
240	3	¼	14	14	14	14	14	14	14	14	14	14	14	12	12	12	10
	4	⅓	14	14	14	14	14	14	14	14	14	14	12	12	10	10	10
	5	½	14	14	14	14	14	14	14	14	14	12	12	10	10	10	8
	6		14	14	14	14	14	14	14	14	12	12	10	10	10	8	8
	7	¾	14	14	14	14	14	14	14	14	12	10	10	10	8	8	6
	8	1	14	14	14	14	14	14	14	12	12	10	10	8	8	8	6
	10	1½	14	14	14	14	14	14	12	12	10	10	8	8	6	6	6
	12	2	14	14	14	14	14	12	12	10	10	8	8	6	6	6	4
	16	3	12	12	12	12	12	12	10	10	8	8	6	6	4	4	4
	25	5	8	8	8	8	8	8	8	8	6	6	4	4	2	2	2
	40	7½	6	6	6	6	6	6	6	6	4	4	2	2	1	1	0
	50	10	4	4	4	4	4	4	4	4	4	2	2	1	1	0	0

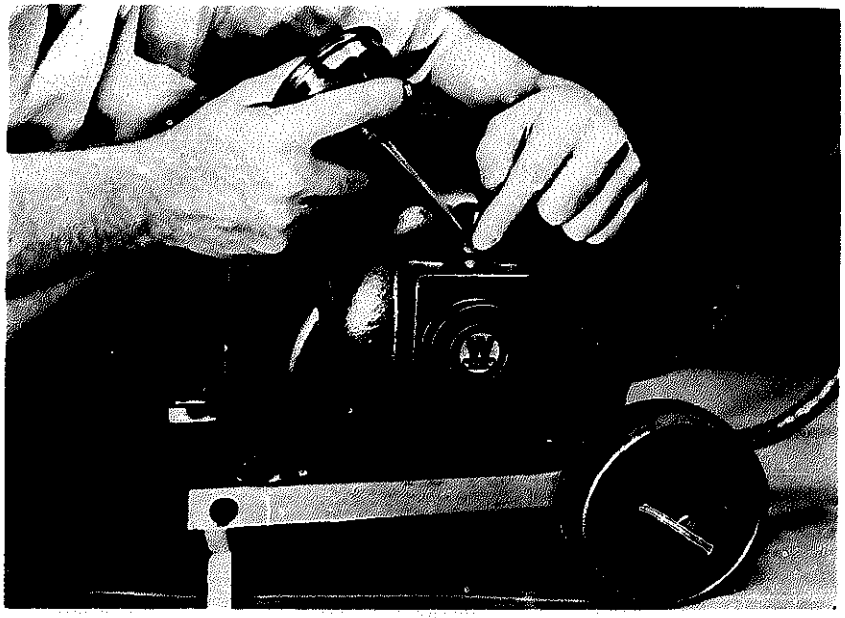
[1] *Single-Phase Electric Motors for Farm Use,* U.S.D.A. Farmers' Bulletin No. 2177, p. 14.

[2] Wire size is based on a 2 per cent maximum voltage drop at full-load motor current for wire temperatures up to 167° F. Minimum size wire for overhead in air is No. 10 for spans of 50 feet or less. Minimum size wire for conduit cable or direct burial is No. 14, types R, T, TW, and RH.

MAINTAINING MOTORS

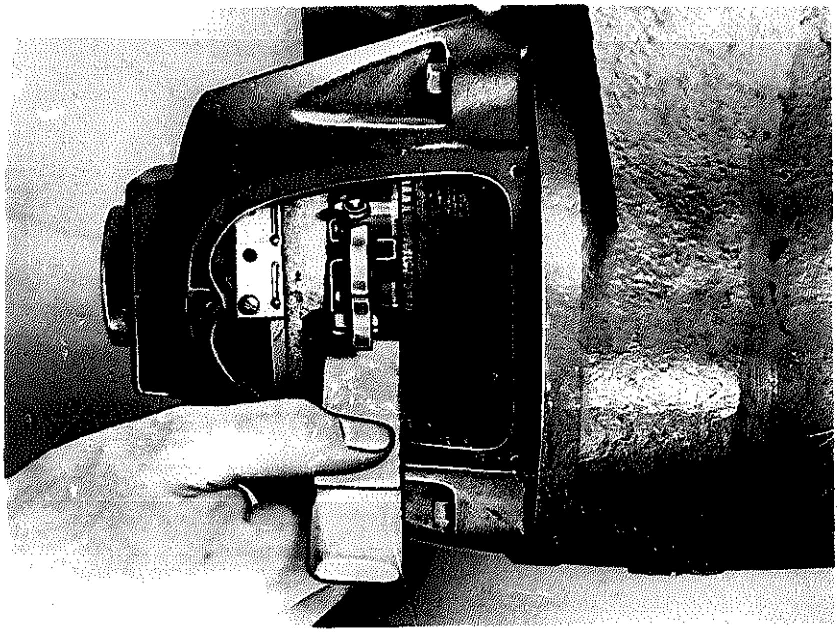
The proper care of motors is essential. In operating and maintaining motors, take the following precautions:

1. Turn off equipment before cleaning and oiling a motor.
2. Oil at regular intervals but use oil sparingly, as overoiling may injure the insulation. A few drops of oil is usually sufficient.
3. Wipe off any spilled oil. Keep the motor clean.
4. Use the grade of lubricant recommended by the manufacturer.
5. Check unsealed ball bearings at least once a year, and keep housing filled to the proper level with ball-bearing grease. If the ball bearings are sealed, do not disturb them. A sealed motor does not need to be lubricated after it leaves the factory.
6. Clean the commutator with a piece of 00 sandpaper placed over the end of a thin piece of wood. *Hold* the sandpaper against the commutator while the motor is running. *Never use emery cloth.*
7. Avoid letting the motor run hot, because it will eventually "burn out" if permitted to run too hot.
8. Be sure to use a cable on the motor of sufficient size to carry the power needed. If the cable is too small, it will cause a voltage drop, resulting in the motor's becoming too hot.
9. Clean the dust or other foreign matter from the motor occasionally. A vacuum cleaner can be used to clean the windings.
10. Avoid overloading the motor.
11. Enclose motors, when they are used where dust or excessive moisture is present, but make adequate provision for cooling.
12. Adjust the belt tension.
13. Align the motor.



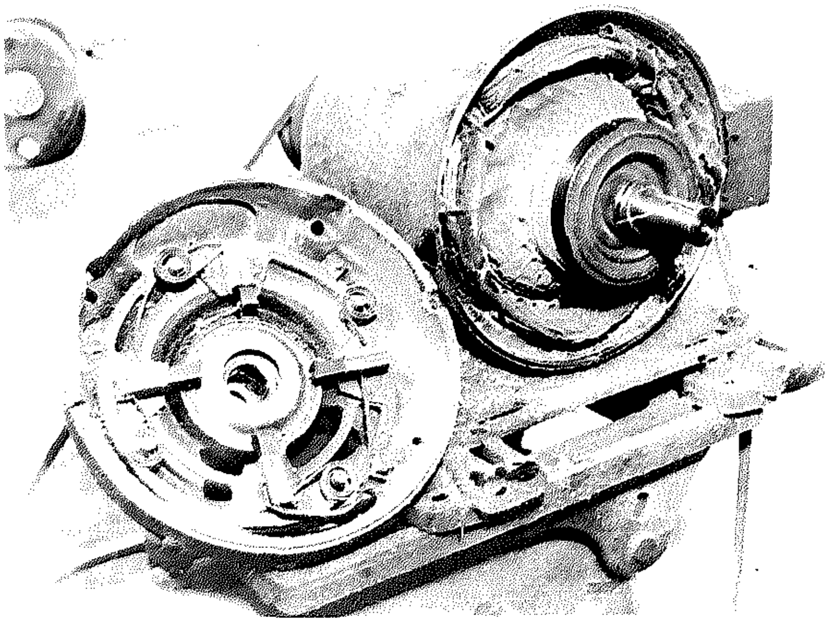
(Courtesy Westinghouse Electric and Mfg. Co.)

Fig. 39.6. Lubricate electric motors correctly. Use lubricants sparingly, and wipe away the excess oil.



(Courtesy Westinghouse Electric and Mfg. Co.)

Fig. 39.7. Keep the commutator clean. If the brushes spark, the commutator may be dirty or worn. Polish the commutator bars and improve the contact of the brushes by cleaning them with 00 sandpaper as illustrated. If the commutator is worn so that it is not round, have the armature removed and the commutator repaired by an experienced repair person.



(Courtesy General Electric Co.)

Fig. 39.8. The end shield has been removed so that the motor can be cleaned. Note the dirty commutator. Keep it clean.

REPAIRING MOTORS

If a motor sparks excessively or is slow in starting, it may need new brushes. In replacing brushes, be sure to obtain the correct type and to fit them to the contour of the commutator. The fitting of new brushes can be done by wrapping the commutator with 00 sandpaper and turning the motor by hand. If the springs holding the brushes against the commutator are weak or broken, they should be replaced.

Take the motor to an electrical motor service shop if any of the following troubles develop:

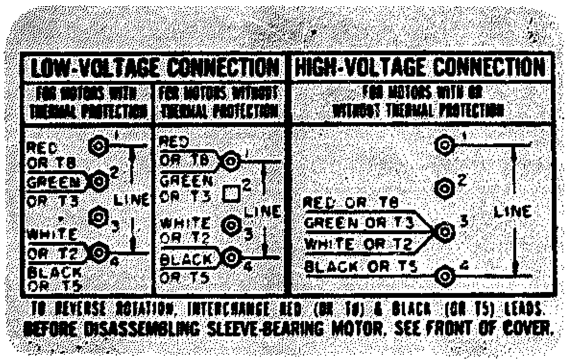
1. Rough or pitted commutator
2. Worn or frozen bearings
3. Failure of overload switch
4. Failure of starting mechanism
5. Burned-out windings

"Burned-out" windings may be detected by the odor coming from the motor or by the charring of the insulation of the wiring. If the starting mechanism on a motor has failed, the motor will hum when the switch is turned to "on." The motor will run when started by hand. If the overload mechanism has failed, the motor will not start after it has cooled. A worn or pitted commutator may be detected by inspection.

With the exception of replacing brushes and their springs, an agricultural worker should not attempt to repair an electric motor. An electric motor has a delicate structure and can be ruined easily.

REVERSING ELECTRIC MOTORS

The situation may occur that would make it desirable to change the direction of rotation of an electric motor. By rewiring, you may switch the direction of rotation of some motors.



(Courtesy U.S.D.A.)

Fig. 39.9. The wiring diagram for an electric motor, showing how to interchange leads to reverse the rotation of the motor.

Single-voltage split-phase and capacitor motors with only two leads cannot be reversed. Split-phase and capacitor motors that can be reversed have four line leads. Two of these line leads are for the running winding on the motor, and two are for the starting winding on the motor. Dual-voltage capacitor motors that can be reversed will have at least six line leads.

A split-phase or capacitor motor may be reversed by reversing the connections of the starting winding or by reversing the connections of the running winding. Do not reverse the connections of both the starting and running windings. In reversing an electric motor, follow the wiring diagram for the motor. See Fig. 39.9 for an illustration of how to reverse a split-phase or capacitor motor. The terminals for an electric motor may be in a terminal box on the outside of the motor box, or they may be located on a terminal board on the motor.

Most repulsion-type electric motors may be reversed by rotating the brush ring to the alternate position. To move the brush ring to the alternate position, first release the locking screw or spring clip that holds the ring.

PART VI

Soil and Water Management

SOIL AND WATER MANAGEMENT

Student Abilities to Be Developed

1. Ability to recognize soil conservation and water management problems and to plan a satisfactory method of solving them.
2. Ability to plan a terrace system.
3. Ability to analyze a farm, draw a map of it, and plan a suitable crop rotation system for it.
4. Ability to lay out terrace lines.
5. Ability to construct and maintain terraces.
6. Ability to lay out and run contour lines.
7. Ability to lay out contour strips.
8. Ability to control gullies.
9. Ability to determine the need for drainage or irrigation and to plan a satisfactory drainage or irrigation system.
10. Ability to establish a system of drainage or irrigation.
11. Ability to maintain a drainage or irrigation system satisfactorily.
12. Ability to use an irrigation or drainage system intelligently.

CHAPTER 40

Using Contour Farming, Strip Cropping, and Grassed Waterways

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. How serious a problem is soil erosion?
2. What is contour farming?
3. What is the purpose of contour farming?
4. What is meant by a contour line?
5. What is meant by strip cropping?
6. What are buffer strips?
7. How should contour strips be laid out?
8. How should contour strips be established?
9. What tillage practices may be followed in contour strip cropping?
10. How may gullies be controlled?
11. What are the characteristics of good waterways?

In some communities, erosion has rapidly depleted the soil. Many persons live in communities where soil erosion is a serious problem.

"Unless controlled, the undermining action of erosion will ultimately, and at no distant date, render large areas of cultivated land in the United States valueless for agricultural use. Millions of acres of once fertile farm land have already been eroded beyond immediate repair. It has been estimated that the rate of plant-food removal by erosion is about 21 times greater than the rate of removal by agricultural crops. This loss by erosion does not include losses incurred through silt damage to bottom lands, water reservoirs and irrigation channels.

"In general, soil erosion may be defined as the loosening and removal of soil from its resting place by the action of wind or water. The two main classes of erosion from the action of water are sheet erosion and gully erosion. Sheet erosion is the removal of soil in fairly uniform layers or sheets; gully erosion is the removal of soil at points of excessive concentration where relatively deep ditches are cut into the surface slopes."[1]

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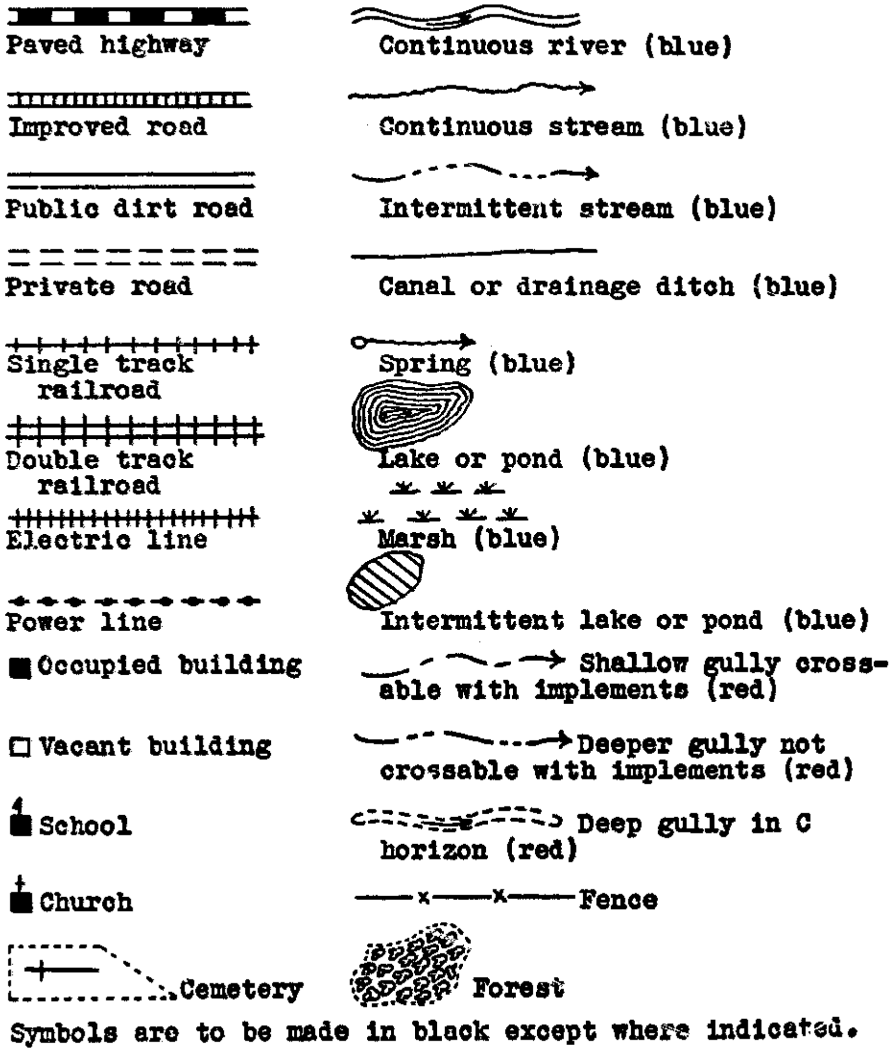
[1] C. L. Hamilton, "Terracing for Soil and Water Conservation," U.S.D.A., Farmers' Bulletin 1789, p. 5.



(Courtesy College of Agriculture, Clemson University)

Fig. 40.1. The symbols for use in mapping rural areas.

CONTOURING

Contour Farming—"Contour farming is the carrying out of all farming operations on the level on rolling land by operating parallel to reference lines laid out on the contour. It is farming around the hills rather than up and down them. All farming practices carried out on the contour, such as strip cropping, contour tillage, terracing, and the use of correction strips may be considered types or phases of contour farming."[2]

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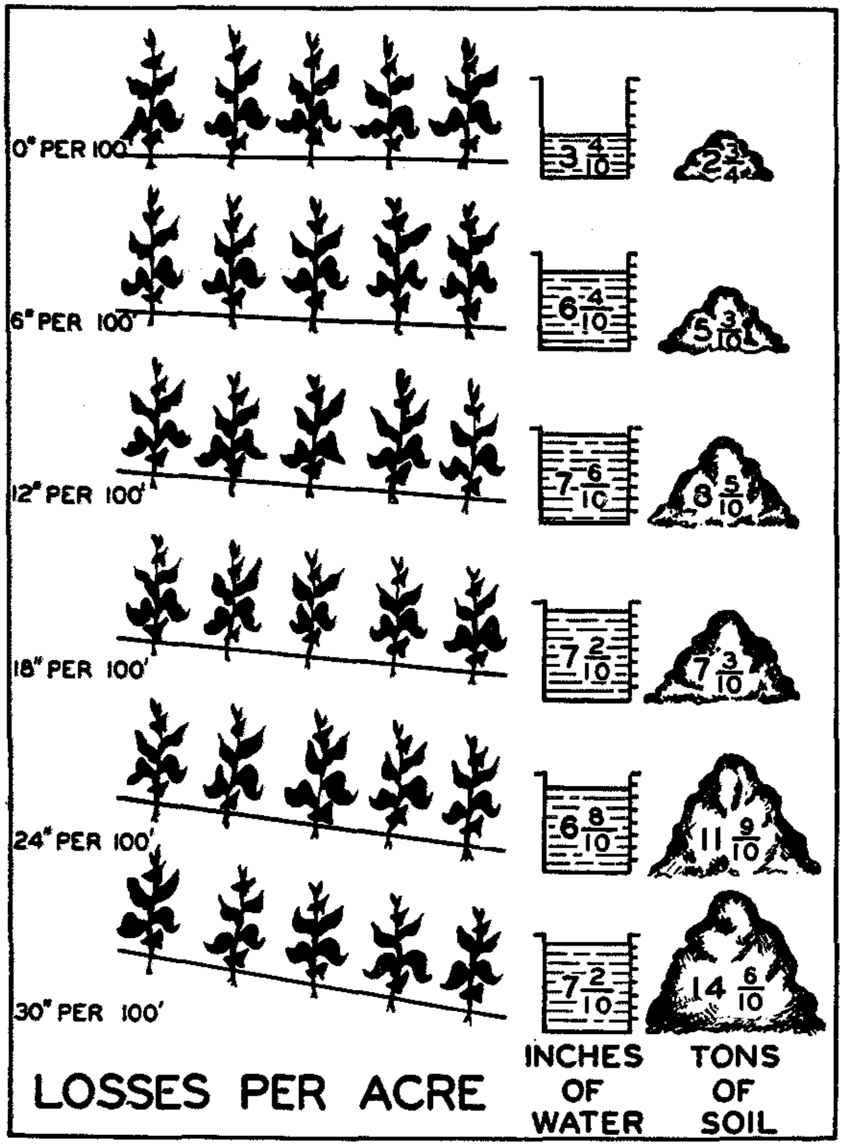
[2] J. B. Peterson and L. E. Clapp, "Following the Contour," Agricultural Experimental Station, Iowa State University Bulletin, P53, p. 733.

Purpose of Contour Farming—The main purpose of contour farming is to conserve soil and water. Some other advantages of contour farming are:

1. It increases yields.
2. It saves time.
3. It conserves fuel, power, and machinery.
4. It is easier to farm across a slope than it is to farm up and down it.

Contour farming reduces soil loss and water loss, because every row running



(Courtesy North Carolina Extension Service)

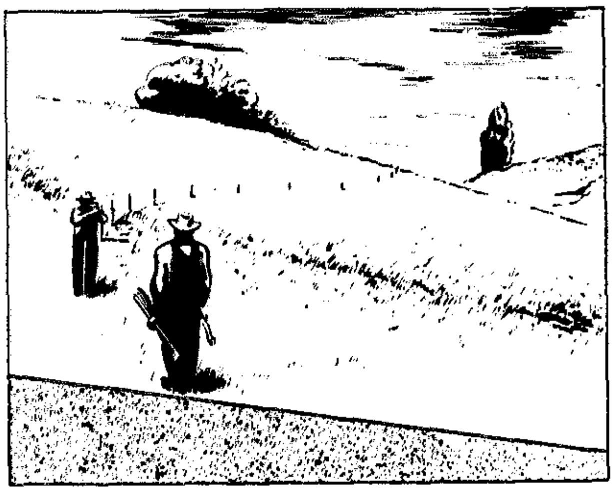
Fig. 40.2. The illustration indicates why contour farming, strip cropping, and grass waterways are necessary. These results were obtained in an experiment conducted in North Carolina.

around a hill forms a barrier which checks the rate of the surface run-off. The water flows more slowly, and more of it soaks into the soil.

Contour Line—A line connecting points of equal elevation is called a contour line. Contour lines are parallel to each other on a uniform slope, but on an irregular slope the distance they are apart varies.

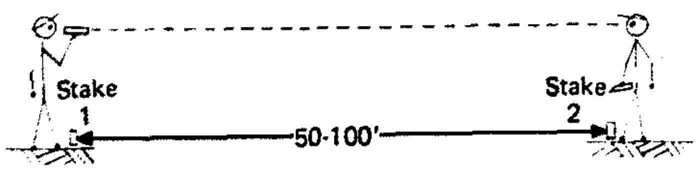
Determining Contour Lines—The following procedure is suggested for laying out contour lines with a hand level:

1. One person carries the hand level and another person acts as the target person.
2. The person with the hand level sights at the target person's eyes if both are the same height; otherwise, sights are made at the target person's hat or collar, or at some other part of the person which is the same height as the eyes of the person using the hand level. Both persons stand at attention when taking sights.
3. The target person walks 100 feet ahead. The target person is then motioned up or down the slope until standing on a point that is level with the point where the person operating the level is standing.
4. A stake is driven at the spot where the sight was taken, and the person with the hand level moves to a point 100 feet beyond the target person.



(Courtesy University of Minnesota)

Fig. 40.3. Laying out contour lines.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 40.4. The person with the hand level motions the second person up or down the slope until both are on the same level. A stake is driven into the ground at this point.

5. The person with the hand level sights back at the target person, moving up or down the slope until at the same level as the target person.

This procedure is continued the full length of the field.

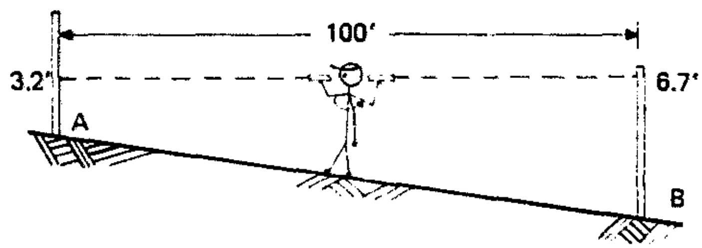
STRIP CROPPING

There are three types of strip cropping, namely, (1) contour, (2) field, and (3) wind.

In *contour strip cropping* the crops are grown in strips across the slope of the land and on the contour. Densely growing crops such as grass and hay are alternated with clean-tilled row crops such as corn. The strips of the densely growing crops are approximately the same width as the strips of row crops. This is also known as *rotation strip cropping*.

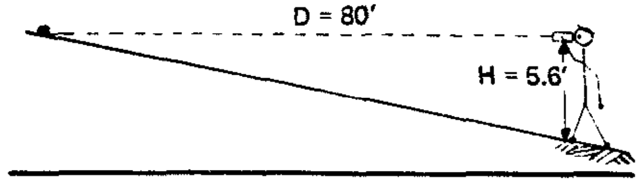
In *field strip cropping* the row and densely growing crops are alternated and planted in narrow strips of uniform width across the slope of the land, but they are not planted parallel to the true contour of the land. This method of strip cropping can be used on land with a uniform slope.

In *wind strip cropping* the primary objective is to prevent the loss of soil by wind. The crops are grown in narrow parallel strips crosswise to the direction of the prevailing winds.



(Courtesy Vocational Agriculture Service, University of Illinois)

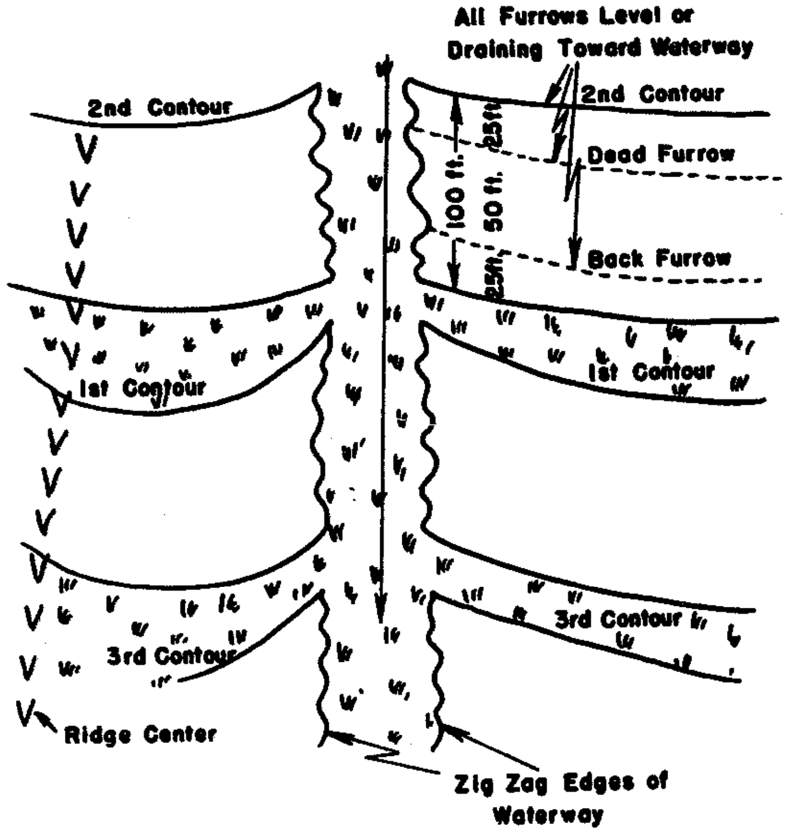
Fig. 40.5. A hand level may be used to determine percentage of slope. A second person is needed to hold the rod.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 40.6. With a hand level, one person can determine percentage of slope. Determine your eye height. Select an object such as a stone or a stake. Move down the slope until the object is level with your eye. Measure the distance to the object and calculate the percentage of slope. Percentage of slope equals height of the eye divided by distance to the object.

Iowa State University Bulletin P53 states that "when the narrower correction areas lying between the larger even-width strips of intertilled crops are planted to close-growing, soil-conserving crops they are called *correction strips* or *buffer strips*."[3] See Fig. 40.7.



(Courtesy College of Agriculture, Iowa State University)

Fig. 40.7. Buffer strips absorb the irregularities caused by variations in slope.

In developing a strip cropping system, the planner should devise a soil conservation program for the entire farm. The following steps should be taken:

1. Study the farm to determine what land is suitable for cropping and what land should be used for pasture, hay, and woodlot.
2. Study the field layouts, keeping in mind their possible rearrangement and the possibility of shifting fences to fit the contour of the land.
3. Select a suitable rotation system to fit the farm.
4. Plan contour strips to fit the rotation.
5. Determine the number and width of strips.
6. Build fences on the contour to separate the crop land from the pasture land. The fences may be used as guides in planning the contour strips.

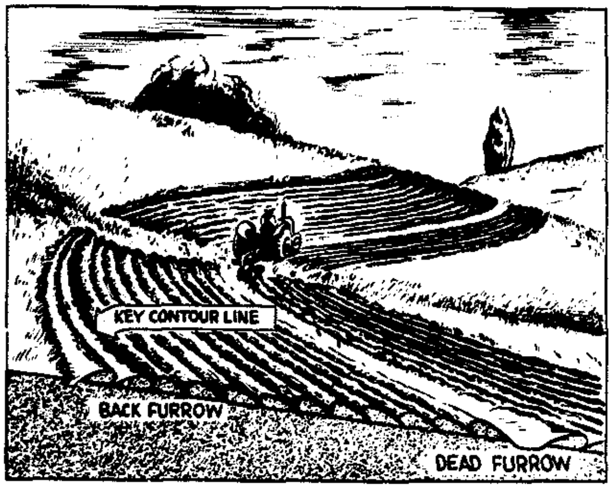
[3]Ibid., p. 734.

Laying Out Contour Strips—The following procedure for laying out contour strips is suggested in the University of Minnesota Extension Folder 108:

1. Determine width of contour strips. Take soil, slope, and degree of erosion into consideration. If field is severely eroded, lay out strips 15 feet narrower than listed except for slopes of 15 to 20 per cent, which should be seeded to permanent hay for pasture. See Table 40.1.
2. Locate first contour line far enough down the slope to leave one strip above it. This strip should be below the contour pasture fence if the field is in a valley, or below the ridge if the field is on ridge land.
3. Lay out a second strip below the contour line and then check the lower side of the strip to see how far it is off the contour.
4. Lay out a third strip if the lower side of the second strip is not off the contour more than 2 per cent for a distance of 50 feet. Again check lower side of the strip to determine whether or not it is on the contour.
5. Run a new contour line whenever the lower side of a strip is too far off the contour. The new contour line should run below the last even strip so that an even-width strip can be laid out above it and a correction strip can be left between the new even strip and the previous even-width strip.
6. Plow a back furrow on the stake line as soon as one side of a strip is definitely located.
7. Leave the back furrows as guides to the strip boundaries.[4]

Table 40.1—Width of Contour Strips

Amount of Slope (Per Cent)	Width of Strips (Feet) Good Soil	Fair Soil	Poor Soil
4–10	125	100	75
10–15	100	75	60
15–20	60	60	60



(Courtesy University of Minnesota)

Fig. 40.8. Plowing a contour strip. The back furrow was used as the key contour line.

[4] "Contour Strip Cropping," University of Minnesota Extension Folder 108.

Establishing Contour Strips—It is desirable to start a strip cropping system in fields established with grass so that well sodded meadow strips and waterways will be available to hold the soil and to protect it. If strip cropping is started on land not in meadow or hay, every other strip should be seeded to some meadow mixture. If necessary, a quick-growing crop such as Sudan grass may be seeded in the waterways and on the buffer strips for temporary protection. A meadow mixture is then drilled in these areas in the fall.

Cultivating on the Contour—It is desirable to cultivate and perform all other tillage operations on the level or on the contour. Such operations are easier on a farmer and less wearing on farm machinery, and they require less fuel.

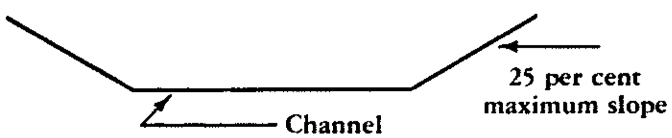
GRASSED WATERWAY

Even though strip cropping and contour farming are used, there is still danger of gullies being formed if proper precautions are not taken. The following are a few of the methods used to control or prevent gullies:

1. Close-growing crops may be seeded in the natural depressions or other waterways to form a sod.
2. Straw may be placed in small gullies and dirt plowed over the straw. The area is then seeded to some quick-growing dense grass or legume.
3. Fast-growing trees may be planted in dense rows across or along the sides of gullies.
4. Diversion ditches may be used to carry the water slowly to a suitable outlet.
5. Various types of dams may be used.
6. Grassed waterways may be constructed.

The use of scientifically shaped waterways seeded to grass is probably the most desirable way to stabilize outlets for run-off water. A grassed waterway may be used as a terrace outlet (see Chapter 41) or as a means of stabilizing gullies. A waterway must be shaped so that the running water is slowed to a walk. If water can be slowed enough, grass growing in the waterway will prevent the erosion of the soil.

Water can be slowed by providing waterways with channel widths that will spread the water sufficiently to prevent erosion. The most desirable width for a waterway is determined by the percentage of slope of the channel and by the area drained. If the percentage of slope and the drainage area make a waterway of over



(Drawn by Ronald Ipsen)

Fig. 40.9. The channel of a waterway should be level, smooth, and packed. The sides of the channel should have a slope of 25 per cent or less. The sides and the channel should be fertilized so that they will support an excellent stand of grass.

35 feet necessary, two waterways at different locations should be provided. If the division of the water into two waterways is not possible, dividers should be provided so that the waterway has multiple channels. Dividers are usually mounds of earth 4 feet wide and 5 inches high.

The channel of a grassed waterway should be level and smooth. Leveling is often done with a blade. The sides of the channel should not have a slope greater than 25 per cent. It is better, however, if the slopes of the sides are less than 25 per cent. See Table 40.2 for the recommended width and depth of waterways for various slopes and drainage areas.

In the construction of waterways, two dangers must be avoided—erosion and silting. A channel that has sufficient width and is level, smooth, and grassed will

Table 40.2—Grassed Waterway Channel Dimensions[1]

Channel Slope in Per Cent[2]	Dimensions in Feet	Dimensions Required for Drainage Area in Acres									
		5	10	15	20	25	30	35	40	45	50
10	Width	21	37								
	Depth	1	1.5								
9	Width	20	34								
	Depth	1	1.5								
8	Width	18	30								
	Depth	1	1.5								
7	Width	16	28								
	Depth	1	1.5								
6	Width	14	27	35							
	Depth	1	1	1.5							
5	Width	12	23	29	38						
	Depth	1	1	1.5	1.5						
4	Width	9	18	22	32	36					
	Depth	1	1	1.5	1.5	1.5					
3	Width	7	15	22	23	29	35	41			
	Depth	1	1	1	1.5	1.5	1.5	1.5			
2[3]	Width	4	10	15	20	19	23	28	33	38	44
	Depth	1	1	1	1	1.5	1.5	1.5	1.5	1.5	1.5

[1]Walter E. Selby, "Grassed Waterways and Terrace Outlets for Kansas," Eng. Ext. Dept., Kansas State University, Land Reclamation Bulletin 4, p. 4.

[2]Maximum average velocity—4 feet per second.

[3]For slopes of 1 per cent or less use depth indicated for 2 per cent slope; width requirements may be decreased by one-third.

not erode. Silting, which is caused by a decrease in the velocity of the water, may be caused by a change in the percentage of slope, by a widening of the channel when the slope remains the same, or by a lack of smoothness of the channel. If silting occurs, check the smoothness of the channel. If this is not the cause, check the change in the percentage of slope. It may be necessary to narrow the width of the channel at the point of silting. Of course, care in constructing a channel will avoid changes in grade without changes in the width of the channel and changes in width of the channel when there is no change in the grade.

The sides and channels of waterways should be well sodded before they are used. Dikes or diversion ditches are often provided around waterways until the seeding in them has a good start. Waterways should be constructed and seeded a year before strip cropping, contouring, and terracing are started.

CHAPTER 41

Terracing to Control Soil Erosion

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. How may terracing help control erosion?
2. What equipment is necessary for terracing?
3. What are some factors to consider in terracing?
4. What are the steps in planning a terracing system?
5. What procedure may be used in laying out terrace lines?
6. What procedure may be followed in the construction of terraces?

How Terracing Helps to Control Erosion—The terracing of farm land is a process whereby artificial obstructions of soil are created on sloping land to prevent erosion. Terracing is only one of the methods used in the control of erosion. A variety of methods should be used for the most effective control. Some of the methods to use are as follows:

1. Using well planned cropping systems that will improve the productivity of the soil and protect the land.
2. Planting row crops across the slope instead of with the slope.
3. Stopping gullies through the use of dams, sod strips, and strip cropping.
4. Building broad-base terraces which tend to slow the water. The slowing of the water permits more of it to be absorbed by the soil.

Some types of terraces are almost as old as agriculture.

Equipment for Terracing—A tripod farm level[1] and target rod are needed to determine terrace lines. A plow is needed for marking a terrace line before the construction of the terrace is started. A variety of equipment may be used for moving earth for terraces. The elevator grader is one of the best tools to use in moving earth. Small blade terracers, heavy-duty tractors with blades, road graders, scrapers, V-drags, and plows may also be used. To lay out terrace lines, several stakes and a 100-foot tape are also necessary.

Factors to Consider in Terracing—There are a number of factors to con-

[1]A tripod farm level is a commercial level which has a telescope and bubble tube attached to a tripod. Tripod farm levels have been manufactured so that they are accurate enough for soil and water management work.

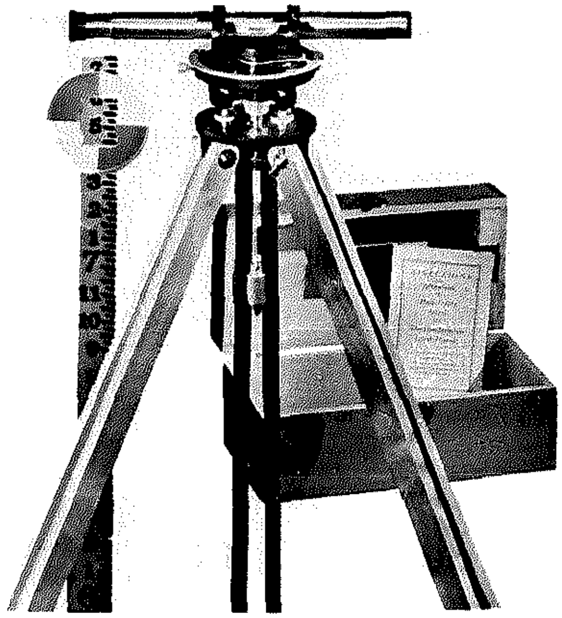


Fig. 41.1. A tripod, farm level, and rod. A low priced instrument that may be used in terracing, contouring, drainage, and irrigation work.

sider in deciding whether or not to terrace to prevent soil erosion. Some of these factors are as follows:

1. The cropping practices that can be used to supplement the terraces.
2. The cost of terracing and the equipment available.
3. The slope of the land. "Generally it is unwise to rely upon terraces for protection of fields devoted to cultivated crops, where the slopes are more than 12 per cent (a 12-foot drop for each 100 feet in distance)."[2]
4. The amount of grade necessary. "The grade should seldom exceed 5 inches in each 100 feet. Starting with a zero grade at the upper end, the grade is generally increased one-tenth inch per 100 feet, at 300 to 400 feet intervals throughout the length of the terrace toward the outlet."[3]

Planning a Terrace System—A high degree of technical training is not essential in planning a terrace system if the underlying principles of soil erosion and their methods of control are understood and if good judgment is used. Farmers who have not had training, however, in using surveying equipment and in planning a terrace system should have this work done by someone who has had sufficient training and experience to do the job properly.

Following is the information needed to plan intelligently a terrace system:

1. The spacing of the terraces. (See Table 41.1.)
2. The length of the terrace (usually not over 1,200 to 1,800 feet).
3. The area benefited.

[2]Glenn K. Rule, "Soil Defense in the Northeast," U.S.D.A., Farmers' Bulletin 1810, p. 23.
[3]Ibid.

4. The soil type, the amount of rainfall, and the amount of erosion.
5. The value of the land and the long-time farming program.

Following are some of the essential steps in planning a terrace system:

1. Make a thorough inspection of the area to be terraced.
2. Prepare a sketch map, using graph paper, indicating location of hills, ridges, slopes, drains, gullies, boundaries, buildings, railroads, streams, marshes, lakes, and fences.
3. Determine the type of soil and amount of precipitation, and the type of farming to be followed.
4. Consider the farm as a whole in order that any terracing that is done in one area will fit into a long-time farming program.
5. Locate desirable outlets. A natural outlet with a dense growth of permanent sod is desirable.

Outlet waterways will have to be used if sod outlets are not available. They should be constructed near the edges of fields. Outlet waterways should be made wide enough to carry the water at a shallow depth, not to exceed 12 inches. These waterways should be seeded to adapted pasture grasses which will form a dense sod. It is a good plan to build waterways with the natural slope of the land. See Chapter 40 for a discussion of the principles of constructing grass waterways.

A beginner should probably terrace only a small acreage until some experience has been obtained with this system of farming.

Using a Tripod Level and a Rod—A tripod level is used in determining terrace lines. In getting a tripod level ready for use, follow these steps:

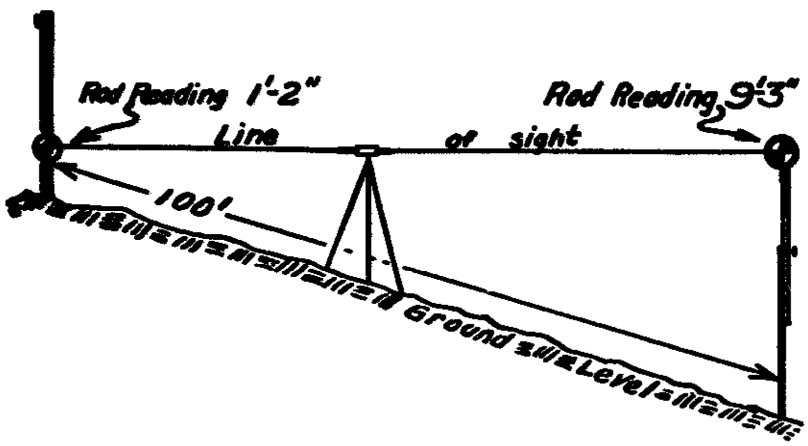
1. The first step is to spread the legs of the tripod. To do this, loosen the thumbscrews which fasten the head and legs together. The legs should be adjusted so that the tripod head is approximately level in all directions.
2. The second step is to tighten the thumbscrews previously loosened.
3. The third step is to use the four leveling screws found under the telescope and bubble tube to finish leveling the bubble tube. The telescope is aligned over an opposite pair of leveling screws. The screws work against each other and must be moved simultaneously. In turning them, either move the thumbs toward each other or away from each other. When the bubble has been leveled, align the telescope with the other pair of leveling screws and repeat the leveling process. Continue to level over the opposite pairs of leveling screws until the bubble is level when it is turned in all directions.
4. The fourth step is to focus on the rod by changing the focusing adjustment. In focusing on the cross hairs, adjust the eyepiece.

The tripod level is ready to use after these four steps have been taken. However, the level of the bubble should be checked before and after each reading, and the adjustments needed should be made.

Leveling rods are made so that the distance in feet is measured from the bottom of the rod. The person handling the rod must hold it in a vertical position. If the rod is allowed to lean in any direction, the reading obtained will be too large. Figure 41.4 shows the hand motions used by the instrument person in signaling the person handling the rod.

Determining Terrace Lines—After the preliminary plans for terracing are completed, determining the terrace lines is the next step. Two persons are needed, one to operate the rod and the other to operate the level. Ordinarily the upper terrace is staked first, followed by each succeeding terrace. In determining the line of the upper terrace, proceed as follows:

1. Figure the slope of the land. This is done by averaging several readings of the type shown in Fig. 41.2. Remember, the slope desired is the average slope of the land that will drain into the top terrace. The percentage of slope in Fig. 41.2 is figured by subtracting 1 foot 2 inches from 9 feet 3 inches. The difference is 8 feet 1 inch. Since the distance between the two readings is 100 feet, the fall is 8 feet 1 inch, or 8.1 per cent. In making readings to determine slope, take a reading on the rod with the level located at the top of the area that will drain into the terrace. The rod person should then take 33 steps, 100 feet, directly down the slope. The second reading is made at this point. The rod person should, however, check the number of steps required for 100 feet. The usual number is 33.
2. Determine the vertical interval for the terrace. The vertical interval or fall between terraces or between the top of a slope and the first terrace may be determined by consulting Table 41.1. This table is based on carefully obtained experimental data and should be followed. If the average slope is 8 per cent, the vertical interval derived from Table 41.1 would be 5.2 feet.
3. Locate the center of the terrace line. The level remains near the outlet end of the terrace where it was placed for the slope readings. The rod person adds the 5 feet 2 inches to the 1 foot 2 inches (see Fig. 41.3) obtained at the top or high point of the slope and sets the target on the rod at 6 feet 4 inches. The person with the rod then walks approximately one-half the distance to the other end of the first terrace. The person operating the level motions the person with the rod up or down the slope



(Courtesy North Carolina Extension Service)

Fig. 41.2. Measuring the slope of the land. Rod readings are taken at two points on the slope located so that one point is 100 feet from the other point. The smaller reading is subtracted from the larger reading. The land being measured has a slope of approximately 8.1 per cent. (Taken from "Mapping and Measuring Farms," *Agricultural Education*, Vol. 13, Nos. 5 and 6, Clemson Agricultural College, Clemson, S.C., by permission of the Department of Agricultural Education.)

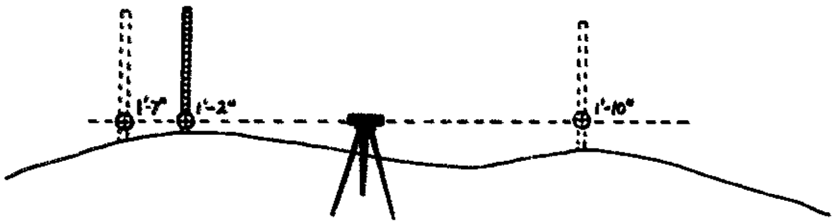


Fig. 41.3. In locating the top or high point of a slope, move the rod up and down the slope until the point with the lowest reading is found. This is the high point.

until the target is level with the instrument. At this point the rod person drives a stake which becomes the center stake of the terrace.

4. Locate a level terrace line. It is not necessary for persons experienced in determining terrace lines to locate a level terrace line, but for persons lacking experience it helps them visualize the location of a terrace. In locating a level line, the person with the rod leaves the target on the rod set at the same point. The points level with the instrument are located at 50-foot intervals from the center stake.
5. Locate the graded terrace line. A level terrace will not lead water to an outlet. A terrace must have a grade or fall to make running water walk to a grassed waterway, and this grade must be determined with care. The distance from the upper end of a terrace determines the grade used. If a terrace is 1,000 feet long, the first 300 feet from its upper end would have a grade of 1½ inches per 100 feet. The grade of the next 300 feet would be 2 inches per 100 feet, and the grade of the next 300 feet would be 2½ inches per 100 feet. The grade of the last 100 feet would be 3 inches. (See Table 41.2.) If the target is set at 6 feet 4 inches at the center stake, the target person, on a 1,000-foot terrace, sets the target at 6 feet 5 inches and moves 50 feet or 16 steps toward the outlet. The instrument person then motions the target person up or down the slope until the target is level with the instrument. The point is then marked with the stake used to mark the level line of the terrace. The target is raised 1 inch for each 50 feet until the distance is 600 feet from the upper end of the terrace. It is then raised 1¼ inches for each 50 feet until the distance is 900 feet from the upper end of the terrace. For the last 100 feet the target is raised 1½ inches each 50 feet. The upper end of the terrace is then staked, starting again at the center stake. The target is lowered according to the recommendations in Table 41.2 in staking the upper end of a terrace.
6. Check the terrace line. The top terrace must be correct or a terrace system for a field will not be successful. If there is excessive washing, sheet or rivulet, above the terrace line, the terrace should be moved up the hill.

When the upper terrace is staked and checked, the location of the second terrace may be staked. In determining the location of the second terrace, proceed as follows:

1. Measure the percentage of slope from the line for the first terrace. An average slope is used.
2. Consult Table 41.1 to determine the vertical interval for the terrace.
3. Move the instrument to a point between the first and second terrace and take a backsight at the center stake of the first terrace. Add this reading to the vertical interval and place the target on the rod on this number.
4. Locate the center of the second terrace. With the target placed on the rod at a height equal to the backsight reading plus the vertical interval, the

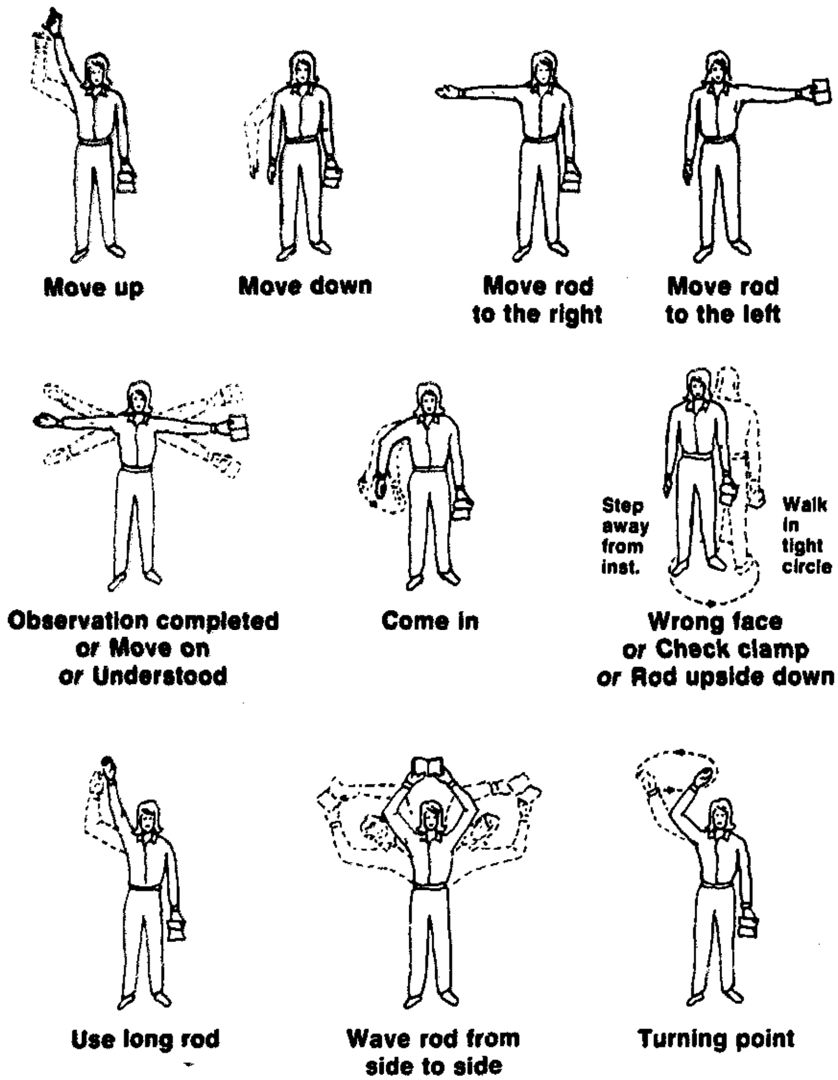
person with the rod moves down the slope until the instrument person provides the level motion.

5. Stake the second terrace from the center stake in the same way the first terrace line was determined.

All succeeding terrace lines are determined the same way. If a terrace is over 1,600 feet long, it should be divided so that the run-off will empty into waterways placed at the opposite ends of the terrace.

After the terrace lines are staked, sharp irregularities may be corrected.

After the stakes are in their proper places the terrace line may be marked with a plow.



(Courtesy Vocational Agriculture Service, University of Illinois)

Fig. 41.4. The hand motions used by the person operating the instrument to guide the person with the target rod.

Table 41.1—Guide for Terrace Spacings[1, 2]

Slope of Area Draining into Terraces (%)	Vertical Interval Between Terraces: For Rod Graduated in Ft. and 10ths	Vertical Interval Between Terraces: For Rod Graduated in Ft. and In.	Surface Distance Between Terrace Centers (Ft.)
1	1.3	1:4	130
2	2.1	2:1	105
3	2.8	2:10	93
4	3.4	3:5	85
5	4.0	4:0	80
6	4.4	4:5	74
7	4.8	4:10	70
8	5.2	5:2	66
9	5.6	5:7	63
10	6.0	6:0	60
11	6.2	6:2	57
12	6.4	6:5	54
15	8.0	8:0	54
20	10.5	10:7	54

[1]Marion Clark and J. C. Wooley, "Terracing for Erosion Control," College of Agriculture and Agricultural Experiment Station, University of Missouri, Bul. 507, pp. 21–22.

[2]Variations from the table are to be discouraged, but when special soil conditions and a known future cropping plan warrant the change, spacings may be varied from the table as much as 20 per cent.

Table 41.2—Grade in Terrace Lines per Station[1]

Length of Terrace	Grade Recommended on Soil Having Medium to Tight Subsoils: *Inches*	Grade Recommended on Soil Having Medium to Tight Subsoils: *Hundredths of a Foot*	Grade Recommended on Soil Having Very Porous Subsoil: *Inches*	Grade Recommended on Soil Having Very Porous Subsoil: *Hundredths of a Foot*
00–100′[2]	1½	0.13	0	0
100–200′	1½	0.13	0	0
200–300′	1½	0.13	1	0.09
300–400′	2	0.17	1	0.09
400–500′	2	0.17	1½	0.13
500–600′	2	0.17	1½	0.13
600–700′	2½	0.20	1½	0.13
700–800′	2½	0.20	2	0.17
800–900′	2½	0.20	2	0.17
900–1000′	3	0.25	2	0.17
1000–1100′	3	0.25	3	0.25
1100–1200′	3	0.25	3	0.25
1200–1300′[3]	4	0.33	3	0.25
1300–1400′	4	0.33	4	0.33
1400–1500′	4	0.33	4	0.33
1500–1600′	4	0.33	4	0.33

[1]Marion Clark and J. C. Wooley, "Terracing for Erosion Control," College of Agriculture and Agricultural Experiment Station, University of Missouri, Bul. 507, pp. 21–22.

[2]Station 00 is at the upper end of the terrace.

[3]On slopes over 14 per cent, the grade may be increased to 4½ inches per 100 feet if the terrace length exceeds 1,200 feet and the ridge height is no more than 20 inches.

Terrace Outlets—Terrace outlets should be constructed prior to the construction of the terraces. See the discussion in Chapter 40 on grassed waterways for the principles of constructing outlets when a natural drainageway, or a meadow with a good sod, is not available as an outlet.

If a meadow strip is used as an outlet, it should be twice as wide as the outlet channels recommended in Table 40.1 in Chapter 40. Meadow strips should be leveled or smoothed. Dividers of the type described in the section on grassed waterways in Chapter 40 may be necessary for strips wider than 40 feet. The use of dividers keeps the water spread more uniformly and reduces the possibility of erosion. A dike may be necessary along the side of the meadow next to the terraced field to prevent the water from flowing back into the field.

If a meadow strip is not available and if space for a channel for an outlet is limited, it may be possible to use structures of concrete to reduce the width of the channel required.

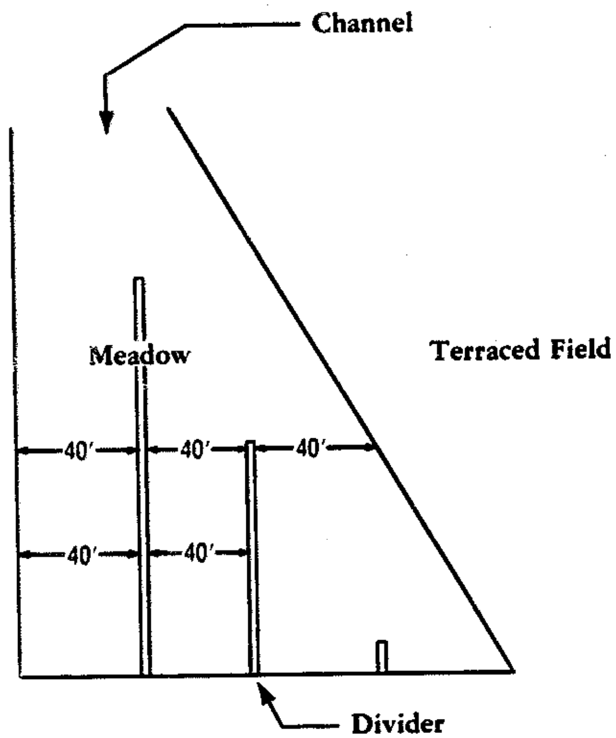


Fig. 41.5. A meadow strip used as an outlet for a terrace. The use of dividers to produce multiple channels is shown.

Constructing Terraces—The upper terrace should be constructed first. The following are a few of the more important principles to be observed in the operation of terracing equipment:[4]

[4]C. L. Hamilton, "Terracing for Soil and Water Conservation," U.S.D.A., Farmers' Bulletin 1789, pp. 42–43.

1. Do not, unless necessary, remove soil from areas that later will require filling.
2. Move the soil as few times as possible.
3. Move the soil down the slope whenever possible.
4. Avoid, whenever possible, moving loose earth over loose earth with a blade terracer. Earth can be moved most efficiently if the blade is cutting some undisturbed earth at all times.
5. Move as much earth each trip as the power will permit.
6. Regulate the blade so that uniform cuts will be secured. This is particularly important on curves.
7. Do not disturb the topsoil from a wider area than is necessary.
8. Secure the necessary terrace height as early during construction of the terrace as possible.
9. Adjust the angle of the blade so that satisfactory scouring will be secured.

A wide-base terrace is often 15 to 20 feet wide at the base.

It is often necessary to fill low places in the terrace ridges to prevent future trouble from gullying. Any other correctional work needed should be done to make the terraces complete in every detail.

CHAPTER 42

Providing Drainage and Irrigation

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. How important is farm drainage?
2. How will drainage improve the soil?
3. What are some of the systems of tile drainage?
4. How deep should drainage lines be laid? How far apart?
5. What slope is needed for a drainage line?
6. Why is it necessary to survey for drainage lines?
7. How are drainage trenches established, the plastic pipe or tile laid, and the trenches backfilled?
8. Why and how should a drainage outlet be protected?
9. When is a surface inlet used? How should it be constructed?
10. What work is needed to maintain a drainage system?
11. How important is crop irrigation?
12. What are the sources of irrigation water? What is a water right?
13. Why is the amount of irrigation water required important?
14. How is water measured? What is an acre-inch of water?
15. What are the methods of applying water to the soil?
16. When should ditches be established? How should they be constructed?
17. What size ditch should be built to carry 500 gallons per minute?
18. How is irrigation water conducted over a low place in a field? Over a drainage ditch?
19. How should crops be irrigated?
20. What are some of the common structures used in irrigation?
21. What are some of the common pieces of irrigation equipment? How are they used?
22. Why does an irrigation system need to be maintained?

DRAINAGE

Importance of Drainage—The removal of excess water from wet land by drainage is an important land reclamation process, because wet land hinders farm operations and endangers public health. Every state in the union contains land in need of drainage. The amount varies from small acreages in some of the states to large areas of land in other states. There is also a vast area of marsh land in the United States which could be reclaimed by drainage and by the control of inundating water.

Many rural areas have drainage problems. The solution of these problems would make these areas more productive by increasing the acreage, the yield, and the quality of the produce. In addition, drainage improves sanitary and health conditions. It may eliminate stagnant water, mosquito breeding areas, and wallowing holes for livestock.

Soil Improvement by Drainage—A primary purpose of drainage is to increase the productive capacity of the soil. When excess water is removed, the water table is lowered and the soil becomes firmer. As water percolates through the drained soil, it divides the soil into finer particles which contain more pore space for capillary water and for the passage of air. This enables plants to root more easily and to penetrate more deeply. Such a soil cultivates more easily, and, as the improvement process continues, the fertility of the soil is increased.

Since humus can be increased in a well drained soil, such a soil will retain more usable soil moisture for plant growth and will withstand drought better than a wet soil. Organic matter also tends to prevent water and wind erosion. A drained soil will absorb more rain water and thus decrease run-off and the removal of fertile topsoil through erosion.

Excess water in the soil tends to make it cold. A drained soil is a warmer soil. It will become warm more quickly in the spring and remain warm longer in the fall, resulting in a longer growing season.

Kinds of Drainage—Where soil does not drain naturally, it is necessary to provide artificial drainage either by *under drains* or *open drains*. Open drains or ditches are open channels established to carry large quantities of water or to drain soils when a system of underdrainage is not practical. Under drains are drains under the surface of the ground such as tile, open pipes, or other types of conduits. Often land is drained by both an underdrainage system and open ditches, the tile or pipe drains discharging into the open ditches or channels.

Systems of Underdrainage Lines—There are several systems for arranging lines, each of which is adapted to certain drainage conditions. Nearly every drainage installation involves a combination of several systems.

The simplest drainage system is the *natural system*, sometimes called the *random system*, which consists of placing lines in natural depressions in an attempt to drain wet spots and ponds. The natural system is particularly adapted to undulating or rolling land and to land of moderate value. It may also be used to remove the nuisance of a pond or a slough. Following are other more systematic ways of establishing lines:

1. The *gridiron* system is used to supply complete drainage on very flat fields.
2. The *herringbone* system, as the name implies, resembles a fish skeleton.

(See Fig. 42.2.) This system will provide satisfactory drainage where there are two slopes which form a valley in which a main line can be laid.

3. The *single line* system is composed of lines independent of one another, each line having its own outlet, usually an open ditch or a stream.
4. The *interceptor* system locates drains to intercept seepage and surface water and thus prevents the water from seeping onto lower land. This system is sometimes called a cut-off system and is often used along the edge of bluffs, hills, or other places where water has a tendency to seep or drain onto the lower land.

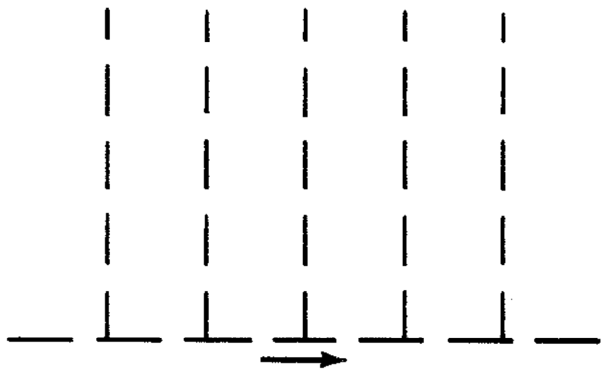


Fig. 42.1. The gridiron system of laying underground drainage lines.

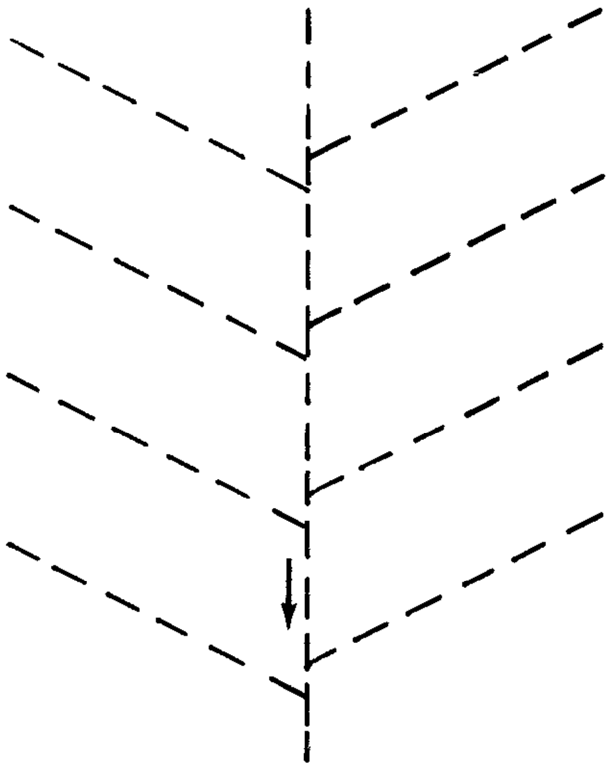


Fig. 42.2. The herringbone system of laying underground drainage lines.

5. The *vertical drainage* system consists of a column of tile or pipe; or it is a column of open or coarse material which extends vertically to an underground outlet. This system is used to drain land with a tight subsoil which has a layer of sand, gravel, or other coarse material underneath the subsoil. The porous material serves as an outlet through which the water can pass.

Depth and Frequency of Underdrainage Lines—In most cases the water table should be lowered to 3½ to 4 feet below the surface. In some tight clay soils, it may, however, be impossible to place the lines more than 3 feet deep.

The distance between drains is closely related to the depth of the drains; shallow drains in heavy soils need to be close together, while deeply placed drains in light soils can be farther apart. In most soils, drains tend to lower the water table in an arch, the lower ends of the arch being located at the plastic pipe or clay tile lines. In light, porous soils, lines may be 6 to 8 rods apart, while in tight soils they may have to be spaced as close as 3 to 4 rods apart.

Establishing Slope for a Drain—The slope, grade, or fall given a line influences the amount of water that will flow through the line. A line should have as much slope as conditions will permit because the steeper the slope, the faster the water will flow and the greater will be the discharge of water from the plastic pipe or clay tile. The difference in elevation between the land at the outlet and at the upper end of the line determines the fall which a line can be given.

Ordinarily a fall of 2 to 8 inches per 100 feet is the desirable range for farm drains. It is possible to place large tile or plastic pipe on too steep a slope. If the fall is too steep, the water's high velocity may break the line. If the slope is 12 inches or more in 100 feet, the line should have risers or breathers opening to the surface.

Determining the Size of Drain—Table 42.1 shows the size of plastic pipe or clay tile required to drain a given number of acres, at a rate of ⅜ inch of water in 24 hours, for a line laid on a given slope (⅜ inch in 24 hours is a satisfactory rate for most parts of the United States).

Assume that a grade of 0.25 foot per 100 feet can be obtained for a line that would drain 20 acres of land. To find the size of plastic pipe or clay tile required, use the column "0.25" and follow down this column until "20" (or more) is en-

Table 42.1—Acreages Drained with Various Sizes of Plastic Pipe or Clay Tile with Various Line Grades[1]

Diameter in Inches	Fall or Slope—Feet per 100-Foot Station									
	0.08	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.75	1.00
5	5	6	7	9	9	10	12	13	16	19
6	9	10	12	14	15	18	20	22	27	31
7	13	15	19	22	24	27	31	34	42	48
8	20	22	27	32	36	39	45	50	61	71
10	37	41	50	58	65	71	82	92	112	130

[1]Extension Bulletin No. 269, Purdue University and U.S.D.A.

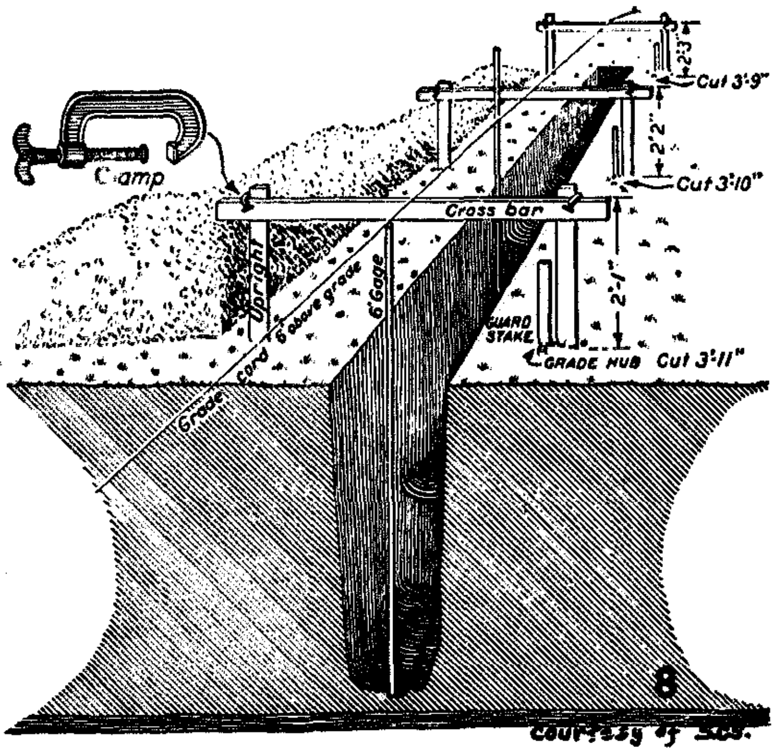
countered. In this case the size recommended in the left-hand column would be between 6 and 7 inches, so the 7-inch plastic pipe or clay tile would be selected.

Surveying for Land Drainage—Land should be surveyed before a drainage system is established. If difficult drainage problems are encountered, consult a reliable drainage engineer.

The relative elevations of various parts of a farm must be known in order to determine the direction of lines, the fall or slope that can be supplied in the lines, the line system that should be used, and the locations of the outlets.

Staking Underdrainage Lines—Lines should be marked by setting stakes or establishing stations every 50 feet, 1 foot to the left (as the outlet is faced) of the center line of the ditch for the plastic pipe or clay tile. Two stakes are required. The grade stake should be driven nearly flush with the ground surface. The guide stake should be driven to the left of the grade stake. It should extend above the ground surface so that information such as the station number can be recorded on it. Depths of the ditch are computed from the tops of the grade stakes. The stakes should not be set too far in advance of the installation of the drain, and they should remain in place until the job has been completed and has been checked as acceptable.

To obtain the right grade for a line, use the accurate and simple method of measuring and checking shown in Fig. 42.3. Set the uprights and crossbar at every



(Courtesy Purdue University)

Fig. 42.3. The target method of laying plastic pipe or clay tile.

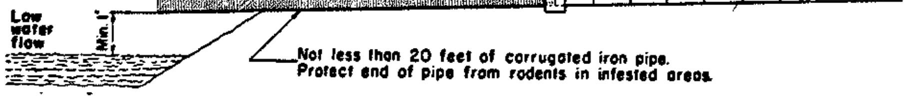
station, with the crossbar a selected distance above the flow lines of the tile. For example, the depth of the ditch or the cut at the first station is given as 3 feet 11 inches. Then, 3 feet 11 inches plus 2 feet 1 inch equals 6 feet, which should be the distance to the top of the crossbar. By subtracting the cuts from 6 feet, you can determine the height of the crossbar. Remember that the grade or slope of the tile line is established when the cut is determined for each station. With the grade cord method, grades may be checked at intermediate points along the line. When good slopes are used, such as 6 inches or more per 100 feet, stations may be 100 feet apart, and grade checks may be made to the grade cord at intermediate station points. Lines should be as straight as possible. When bends are necessary, use long, sweeping curves.

Trenching, Laying Plastic Pipe or Clay Tile, and Backfilling Trenches—Trenches may be dug with a machine. Plastic pipe or clay tile laying should start at the outlet end and progress toward the head end of the line. Straw, sod, or burlap is often used to cover clay tile or plastic pipe laid in unstable soil or in soil which tends to seal. When straw is used, the clay tile or plastic pipe should be covered to a depth of about 4 inches. The straw will last a long time, and even after it has decayed it will form a layer of humus which will allow water to enter the line and will help to hold sand or fine soil out of the line.

Protecting the Outlet—A drainage system must have a good outlet. The outlet of a drain should be constructed and protected so that it will continue to function and not become damaged.

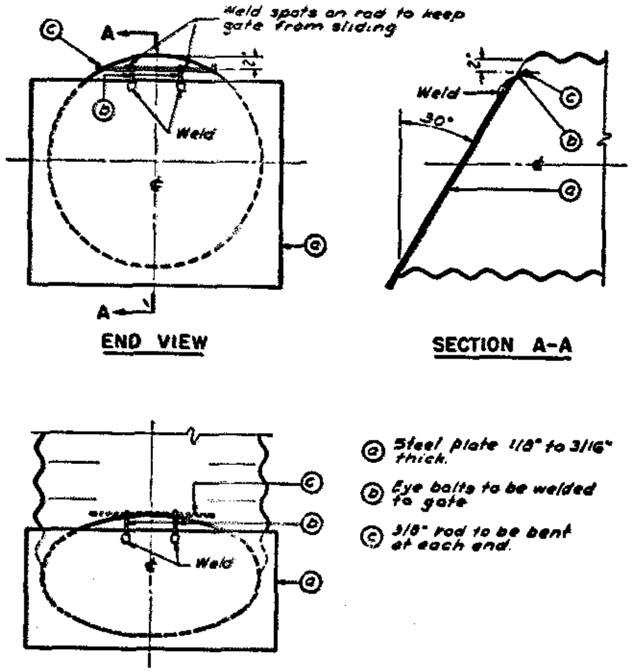
A bulkhead should be provided at the outlet to protect the end of the drain from erosion and trampling by livestock. Vitrified tile, or preferably a piece of corrugated culvert, should be used as the outlet pipe to prevent damage by freezing, trampling by livestock, or crushing by machinery. A concrete collar should be placed around the junction of the plastic pipe or clay tile and the outlet pipe. The end of the outlet should be covered with a screen or a gate, made of small rods spaced about an inch apart, to keep rodents and small animals out of the line.

An apron should be supplied to receive the water discharged from the line and to transfer it quietly to the drainage channel. Concrete is a very desirable construction material for headwalls and aprons. When a line is in a draw so that surface water will probably run over the line, the headwall should have ample wing walls and a weir or notch for the surface water overflow. The apron should extend far enough to receive the overflow of surface water. Reinforced concrete should be used for large structures.



(Courtesy Soil Conservation Service, U.S.D.A.)

Fig. 42.4. A drain pipe used as an outlet.



(Courtesy Soil Conservation Service, U.S.D.A.)

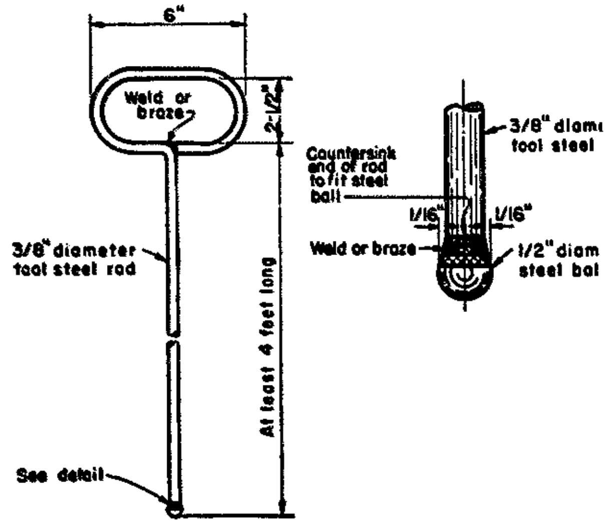
Fig. 42.5. The plans for a flap gate on a drain pipe outlet. The flap gate is to keep small animals out of the line.

Installing Surface Inlets—Under some conditions, such as the presence of surface water which needs to escape rapidly, a surface inlet to a line may be used. Care should be exercised in using such a device, because trash and silt may clog the line if the line is not designed for the use of a surface inlet.

Usually surface inlet drains are built like catch basins—cistern-like receptacles with grated tops—into which storm water can flow and enter a line. Sometimes a pit filled with broken rock is used to drain away surface water. Surface drains extending to the surface of the ground are not desirable in cultivated fields. If they can be located along roadways, lanes, or fence rows, they are not often objectionable.

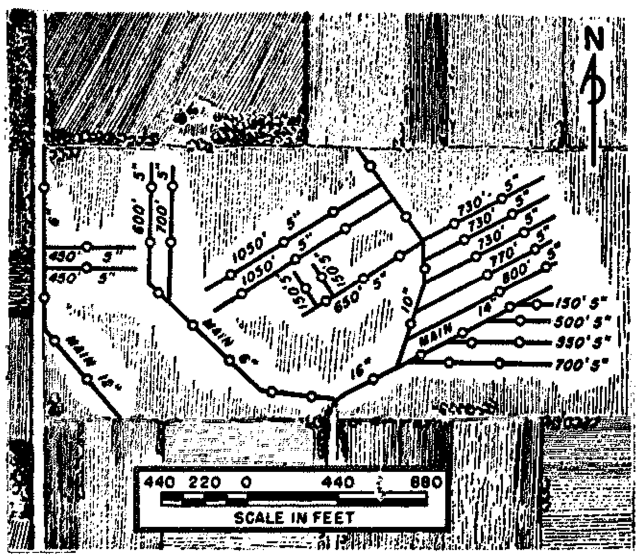
Maintaining a Drainage System—An underground drainage system costs a considerable amount of money to install. Even though it may be constructed to last a lifetime, it will not continue to operate properly unless it is carefully maintained. In maintaining an underground drainage system, take the following precautions:

1. The system should be inspected for small sink holes which may indicate silt leakage into the line or breaks in the line.
2. Outlets and outlet structures should also be examined. Headwalls should not have water, which soon washes them away, cutting around them. Discharge water should not undercut the front of the apron.
3. Any settling of the backfill should be repaired by the addition of more soil.
4. Small sink holes should be sealed with soil. If they form again, dig to the line and see whether there is a break in the line.
5. The waterway over a main line should be kept sodded to prevent erosion.



(Courtesy Soil Conservation Service, U.S.D.A.)

Fig. 42.6. A plan for a probe used in locating underground drainage lines.



(Courtesy Soil Conservation Service, U.S.D.A.)

Fig. 42.7. A record of underground drainage lines should be kept. This line map uses an aerial photograph as a base map.

IRRIGATION

Importance of Irrigation—Irrigation is the artificial application of water to the soil to make it possible to grow crops or to increase crop production. A permanently profitable agriculture is of vital importance to the prosperity and economic security of a nation. Irrigation makes agriculture profitable in those areas where rainfall is not adequate.

It is estimated that about one-third of the earth's surface receives less than 10 inches of water annually, and an additional one-third receives 10 to 20 inches of water annually. There is also a large area which receives over 20 inches but under 30 inches of precipitation. It requires around 30 inches of water to secure a good yield of most crops. Thus, a considerable portion of the earth's surface does not receive enough water to obtain maximum crop yields.

Sources of Irrigation Water—The most common way of obtaining irrigation water is to divert water from streams into canals leading to the land to be irrigated. Reservoirs, either natural or obtained by the use of dams, are another common source of water supply. Water from reservoirs is often released into the channel of a stream as it is needed for irrigation purposes. Pumps are often employed to lift water from streams and sometimes from reservoirs onto land. Underground water is obtained in many areas with irrigation wells and pumps. Small tracts of land such as gardens are sometimes irrigated with water from farmstead wells powered by small motors.

Irrigation Water Requirements—It is important to know the amount of irrigation water required in order to determine the size of pumps, wells, reservoirs, canals, ditches, and other structures needed for the irrigation system. Also the quantity of water available is often a limiting factor in the establishment of an irrigation system.

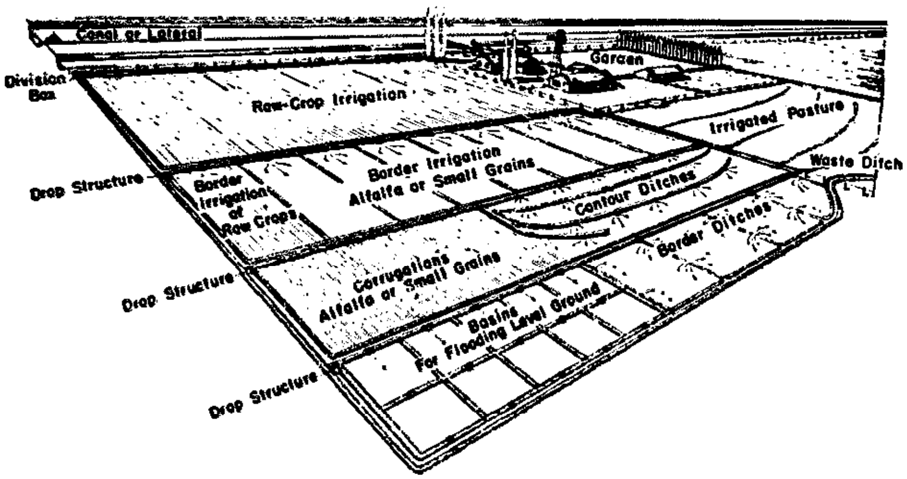
There are two ways of measuring water: (1) by *volume* and (2) by *rate of flow*. Water at rest is measured by volume. Some measures of water by volume are the gallon, the cubic foot, the acre-inch, and the acre-foot. Flowing water is measured by gallons per minute, cubic feet per second, acre-inches per hour, or acre-feet per day. A cubic foot of water is approximately 7½ gallons; an acre-inch is equivalent to 1 inch of water over 1 acre and is, therefore, equal to 3,630 cubic feet; and an acre-foot will cover 1 acre 1 foot deep and is equal to 43,560 cubic feet. A cubic foot per second is equal to approximately 450 gallons per minute and will provide almost 1 acre-inch of water in an hour.

Two to 5 inches of water per acre is usually applied each time a field is irrigated. Applications are usually repeated every 10 days to 3 weeks during an irrigating season. To irrigate 1 acre with 3 inches of water requires 3 acre-inches. If supplied at the rate of 450 gallons per minute or 1 cubic foot per second, it would require three hours to irrigate 1 acre with 3 inches of water. In general, a continuous flow of water at the rate of 1 cubic foot per second would irrigate 80 acres. A 50-gallon-per-minute pump operated every day for 12 hours per day should irrigate about 4½ acres.

Methods of Applying Water to the Soil—Water may be applied to the soil as follows:

1. By flooding which may be done in different ways
2. By using furrows and corrugations
3. By sprinkling
4. By subirrigating

The best method to use depends upon many factors such as topography of the ground, character of the soil, size of the irrigation stream, kind of crop, and ability of the irrigator. Methods of irrigation whereby water is allowed to flow onto the land are termed gravity methods. Sprinklers require the use of pipes and a certain amount of pressure. Figure 42.8 illustrates the various gravity methods of applying water.



(Courtesy U.S.D.A.)

Fig. 42.8. Various gravity methods of applying irrigation water to field crops.

Flooding from field laterals is a frequently used system of irrigation, although it is not the most economical system in the use of water and labor. The system is used on rolling land, on land with shallow soil that cannot be leveled, or on reclaimed land not prepared for irrigation. The field laterals are constructed approximately on the contour (called contour ditches) or on the top of small, flat ridges. These small ditches are usually from 50 to 100 feet or more apart. This method does not give a farmer very good control of the water because it flows into the low places. With this system much water is wasted. The irrigator also has to do considerable shovel work.

Furrows or corrugations between the rows are often used to irrigate cultivated crops. They are used on land that has considerable slope and for soil that bakes, crusts, or erodes easily. Furrows and corrugations run down the slope, and water is supplied to them from a head ditch running across the upper edge of the field. Corrugations are also frequently used for alfalfa, small grain, pasture grasses, and other crops that are seeded on steep slopes. Corrugations are spaced, according to soil characteristics, 16 to 18 inches apart for sandy soils, 20 to 36 inches for loam soils, and more than 36 inches for soils with a tight subsoil. The spacing of the furrows is often regulated by the spacing of the row crop. For crops with very wide rows such as trees, several furrows may be used. In general, furrows and corrugations should be spaced so that the soil at a point halfway between the trenches becomes moist when the moisture near the furrow or corrugation reaches the soil depth from which crops absorb moisture.

The distance water can or should be carried over the surface of the ground to the soil to be irrigated is called the *length of run*. The variations in the texture of the soil, in the size of the furrow, in the slope of the ground, and in the type of crop grown should influence the length of run. The soil near the source of the water will receive too much water when the water is transported too far over the soil. Lighter soils require shorter runs than heavy soils because water penetrates them more readily. Generally, the length of run for sandy soils ranges from 200 to 500 feet, for loams from 300 to 880 feet, and for clays from 440 to 1,320 feet.

The *border method* of irrigation consists of land laid out in strips that slope gently from the head or supply ditch to the lower edge of the strips. The water moves slowly in a thin, uniform sheet over the strips. (See Fig. 42.8.) Borders or small dikes of soil are formed along the edges of these strips to retain the water in the desired area. The amount of water available, the soil type, the slope of the border, and the change in topography between the borders will influence the spacing of the borders. Generally the width of border strips will range from 25 to 50 or more feet. Border strips must be level from side to side, or the water will flow into a low area and leave a portion of the strip dry. Water is usually turned into a border strip from one opening in the head ditch. The border method of irrigation is a very satisfactory method to use when the soil is deep; when the soil can be leveled properly; when water, labor, and land are expensive; and when a controlled irrigation system is preferred.

Level contour basins are used where the land is nearly level and the basins, constructed by diking on all four sides, can be laid out on one or both sides of an irrigation ditch. (See Fig. 42.8.) The first basin is then filled with water to the depth desired, then the next basin is filled, and so on.

Establishing Ditches—The location of the laterals and head ditches should be established after the method of irrigation has been determined. A level and rod are the most accurate and convenient instruments for laying out ditches.

When the line of a ditch is located, avoiding sharp bends if possible, a furrow should be plowed along the line throwing the soil to the low side, a V-ditcher can then be used. If larger ditches are to be constructed or if the ground is very hard, it may be necessary to plow the soil to the depth of the ditch before the ditcher is used.

When it is necessary to cross low areas, drainageways, or other depressions, a

Table 42.2—Rate of Discharge of Irrigation Ditches of Various Sizes and Slopes

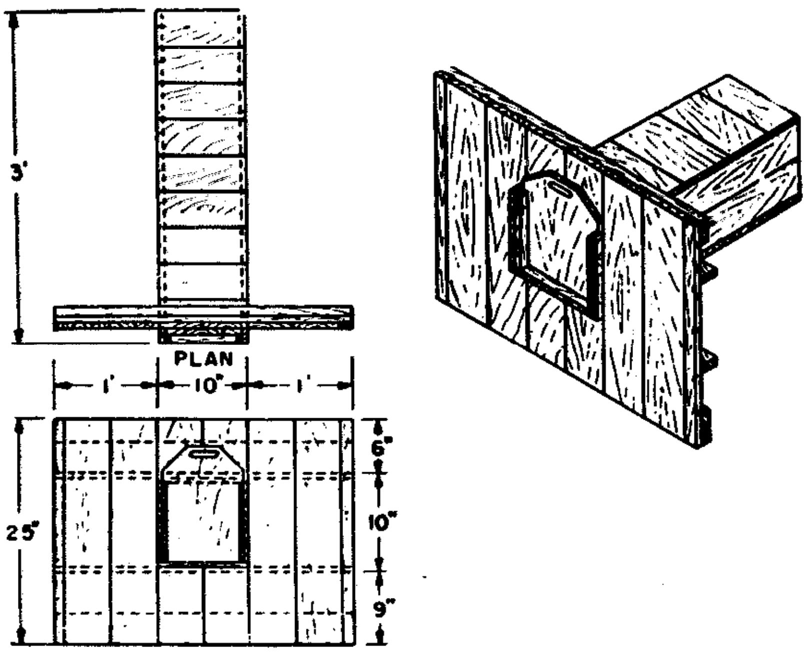
Form of Ditch				Slope		Discharge	
Total Depth	Water Depth	Bottom Width	Top Width	In. per Rod	Ft. per 100 Ft.	Cu. Ft. per Sec.	Gal. per Min.
12 in.	6 in.	14 in.	28 in.	5/16	0.15	0.8	360
12 in.	6 in.	14 in.	28 in.	1/2	0.25	1.1	500
14 in.	8 in.	16 in.	32 in.	3/16	0.10	1.5	675
14 in.	8 in.	16 in.	32 in.	5/16	0.15	1.9	850

flume or pipe should be used. Precautions should be taken to prevent the water from cutting around the ends of the flume or pipe. Sometimes an earth fill can be used to cross low places. The irrigation ditch is built on the top of this fill.

The quantity of water that a given ditch will carry depends upon its slope or grade, its smoothness, and its form. Table 42.2 indicates the rate of discharge of ditches of various sizes.

Irrigation Structures and Equipment—There are numerous structures and pieces of equipment necessary to control and measure irrigation water and to prepare the land and ditches for irrigation water. Numerous pieces of useful equipment that will make irrigation easier and more profitable can be made in a home shop. Some of the irrigation structures frequently used are as follows:

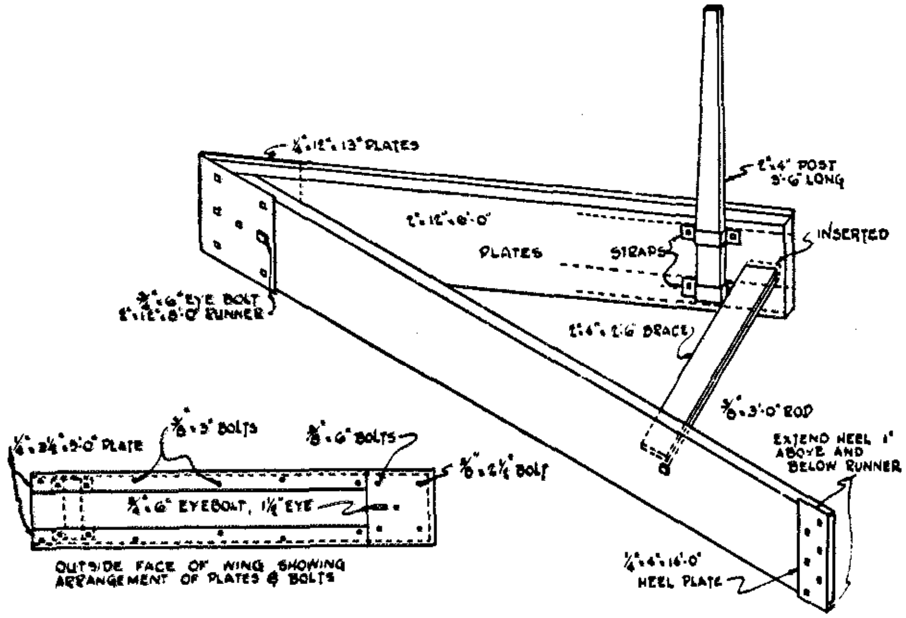
1. *Division boxes* are used to direct a portion of the water from a supply lateral into one or more head or field ditches.
2. *Turnouts, takeouts,* or *outlet boxes* are used to divert water from a field ditch into the upper end of border strips or are used to service a group of furrows or corrugations. One type of turnout is shown in Fig. 42.9.
3. *Checks* of various types, including canvas dams and gated devices, are utilized in ditches to block the water to a higher level so that it will more readily push through the turnouts or outlets.
4. *Spiles* made of small pipes, lath boxes, or tubes are used to supply water to furrows, corrugations, or rows. They provide a regulated supply of water.
5. *Flumes* are used to conduct water over draws or drain pipes.
6. *Siphons* of the inverted type are used to conduct water under roadways, ditches, or drain pipes.



(Courtesy College of Agriculture, Montana State University)

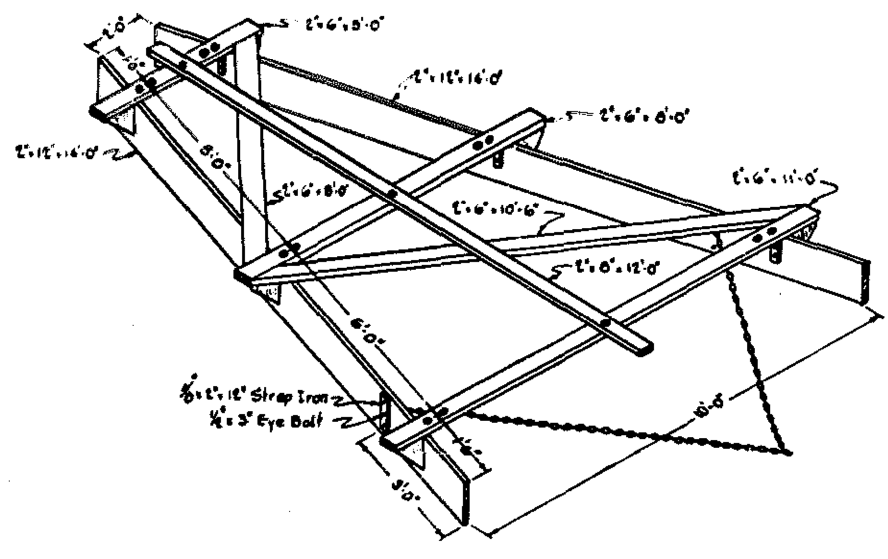
Fig. 42.9. A wooden turnout for use in irrigation ditches.

7. *Weirs* are used to measure the quantity of water flowing in ditches.
8. *Measuring flumes* are used for measuring the water flowing in ditches.
9. *Levelers* are used to level and smooth the land.
10. *Floats* are used before each crop is seeded to obtain a desirable soil condition for irrigation.
11. *V-ditchers* (Fig. 42.10) are used to construct field ditches after they have been filled with soil by harvesting, tilling, seeding, or other farming op-



(Courtesy College of Agriculture, North Dakota State University)

Fig. 42.10. A homemade V-ditcher.



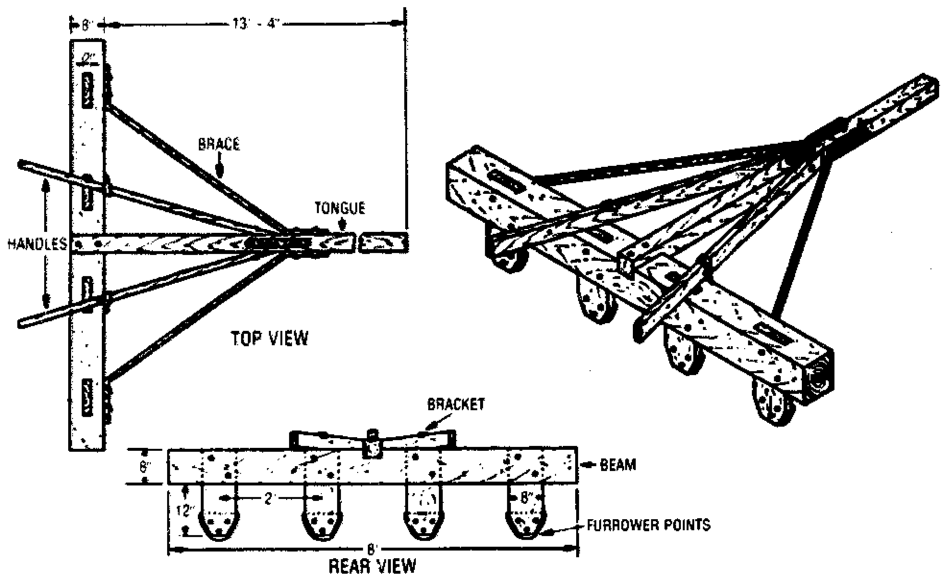
(Courtesy College of Agriculture, North Dakota State University)

Fig. 42.11. A border drag.

erations. To obtain penetration it is best to use a plow ahead of the ditcher.

12. A *border drag* (Fig. 42.11) is used to pull a ridge of soil together at each side of a border strip. It resembles, somewhat, an A-frame, but it is usually pulled with the wide end forward.
13. A *corrugator* (Fig. 42.12) consists of several furrow points or other small trenching devices to open small furrows in the soil.

The two-way plow should always be used on irrigated fields so that the levelness of the field will be maintained. Ordinary moldboard plows with their characteristic dead furrows and back furrows have no legitimate place on irrigated land.



(Courtesy College of Agriculture, Montana State University)

Fig. 42.12. A homemade corrugator used to open small furrows in the soil for the flow of the irrigation water.

Leveling Land for Irrigation—If soil characteristics permit, land should be graded for best irrigation results. Small hummocks and hollows should be eliminated. The type of irrigation system to be used will influence the amount of land leveling necessary. If conditions permit, the land should be prepared so that a crop rotation system can be used; if borders are eventually to be used, the land should be leveled so that borders can be constructed and so that the border strip system can be used successfully. If heavy cuts are necessary in the process of leveling the land, scrapers will have to be used.

A topographic map is absolutely necessary before land leveling is attempted. Hummocks and hollows usually can be removed without the aid of surveying instruments, but do not attempt major land leveling without first surveying the land, because the soil might be removed and placed in the wrong location, resulting in conditions that are more undesirable than before leveling was attempted. The eye cannot be relied upon for determining cuts and fills necessary for land leveling. Competent engineers and soils technicians should be sought to assist with land development problems.

Maintaining an Irrigation System—An irrigation system requires maintenance. Ditches will fill with silt and become fouled with weeds. They will render better service if a ditcher is slipped through them occasionally. Ditches can easily become a harboring place for insects and vermin, and a source of noxious weeds. Ditches in fields should be plowed every year, if possible, then reconstructed for use the following year.

Diversion structures should be kept in good condition. Since most diversions in streams are small dam-like structures, they require frequent repairs. Some of the smaller structures of wood should be removed from the ditch banks and carefully stored, or they will soon decay or break apart.

A properly maintained irrigation system should be ready to deliver water when crops need water. An irrigation system failure when a crop needs water can materially reduce the yield of the crop.

SPRINKLER IRRIGATION

Sprinkler irrigation is often used on soils that have high intake rates, on fields with steep slopes or irregular slopes, and on shallow soils that cannot be leveled. Sprinkler irrigation imitates rainfall.

In installing a sprinkler irrigation system, consider the supply of water available. To put 1 inch of water on 1 acre of land requires 27,000 gallons of water. As much as 800,000 gallons of water may be required to sprinkle irrigate an acre of land.

Farm wells are often inadequate for a sprinkler irrigation system. Ponds are also usually inadequate as a source of water. If a pond is used, it must contain 1½ to 2 acre-feet of water for each acre to be irrigated. Streams or lakes are often used as sources of water.

The equipment for a sprinkler irrigation system follows:

1. Pumping plant.
2. Debris removal equipment. This equipment is needed when water is obtained from streams and ponds.
3. Pipelines.
4. Sprinklers.

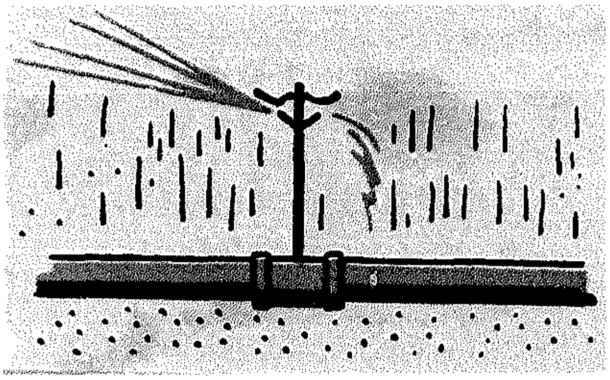
Operating the System—In operating a sprinkler irrigation system, observe the following points:

1. Locate the centrifugal pump so that the suction lift does not exceed 12 to 15 feet.
2. Check the pressure in the laterals with a pressure gauge periodically. The pressure in laterals should not exceed the pressure in the main line by more than 20 per cent.
3. Locate laterals across the slope, and place the main line up and down the slope.

4. Use safety switches on the power unit. The safety switches should shut off the power unit if (1) it overheats, (2) the oil pressure is low, or (3) the pump loses its prime.
5. Check whether or not parts purchased meet minimum requirements of the Sprinkler Irrigation Association and the American Society of Agricultural Engineers.

Maintaining the System—All parts of a sprinkler irrigation system should be checked periodically for wear. The sprinkler heads, pump, and power unit wear rapidly when operated 24 hours a day. All worn, bent, and damaged parts should be replaced at the end of the irrigation season.

Sprinkler irrigation equipment should be stored in a dry location when not in use.



(Courtesy Wyoming Agricultural Extension Service)

Fig. 42.13. Check sprinkler heads periodically to determine whether or not they are revolving. A plugged head will quit revolving.

If the system begins to operate at a reduced pressure, check for (1) an air leak in the suction line, (2) a clogged pump, or (3) a drop in the water level at the water source. These difficulties may also cause the power unit to overheat. Overheating of the power unit may also be caused by a worn pump bearing.

PART VII

The Metric System

THE METRIC SYSTEM

Student Abilities to Be Developed

1. Ability to understand metric system terminology.
2. Ability to convert present units of measurement to metric measurements.
3. Ability to apply the metric system to agricultural mechanics.
4. Ability to appreciate the advantages of using the metric system.

CHAPTER 43

Using the Metric System in Agricultural Mechanics

TYPICAL PROBLEMS AND CONCERNS OF STUDENTS

1. What is the metric system?
2. Why is learning the metric system important?
3. What is the principle involved in the metric system?
4. Where and when is the metric system now used?
5. When will the use of the metric system be universal?
6. What is the metric terminology for length, area, mass, volume, and temperature?
7. How can conventional units of measuring be converted to the metric system?

INTRODUCTION

The metric system is a system of measuring in which all units of measure are divisible by ones, tens, hundreds, thousands, and so forth. For example, the units of money in the United States are divisible by ones, tens, hundreds, thousands, and so forth.

The metric system of measuring is now being used in many areas of agricultural mechanics. Small engines manufactured in Japan and several other countries are built using the metric system. Ford and General Motors have switched to the metric system. Mechanics in agriculture have had to purchase wrenches sized by the metric system in order to repair many machines.

The United States is rapidly converting to the metric system; if the United States is to trade internationally, its people must learn *how* to use and *then* use the metric system. Soon the common units of measure for length, area, mass, volume, and temperature will be metric.

The metric system, with its base of 10, is an easier measuring system to learn and use than the conventional system. The metric system is the universal language of scientific measurement. It is a decimal system like the U.S. monetary system. It has consistent relationships among the units of length, weight, and volume.

DEFINITION OF TERMS

Length—The metre is used for measuring length. The metre is approximately 39 inches in length.

In the measurement of length, mass, and volume, certain prefixes are consistently used to indicate the division or the multiple of 10. They are:

Prefix		*Meaning*
micro	$^1/_{1,000,000}$	00.000001
milli	$^1/_{1,000}$	00.001
centi	$^1/_{100}$	00.01
deci	$^1/_{10}$	00.1
deka	× 10	10
hecto	× 100	100
kilo	× 1,000	1,000
mega	× 1,000,000	1,000,000

For example, 1,000 millimetres is equal to 1 metre. One hundred centimetres is equal to 1 metre. Ten decimetres is equal to 1 metre. One dekametre is equal to 10 metres. One hectometre is equal to 100 metres, and 1 kilometre is equal to 1,000 metres.

Certain symbols have been adopted for the metre and the various units based on the metre. They are as follows:

Unit of Measure	*Symbol*
metre	m
millimetre	mm
centimetre	cm
decimetre	dm
dekametre	dam
hectometre	hm
kilometre	km

Traditionally, length is measured in inches, feet, yards, rods, and miles. In the metric system, length is measured in centimetres, decimetres, metres, kilometres, and so forth.

Mass—In the conventional measuring system, mass (weight with sea-level gravity, heaviness) is measured in tons, pounds, ounces, drams, and grains. In the metric system, mass, or weight, is measured in grams, kilograms, tonnes, and so forth. A kilogram is approximately 2.2 pounds. A gram is approximately $^{3.5}/_{100}$ ounce, or 0.035 ounce. A tonne is 1.1 tons, or 2,200 pounds.

In the measurement of mass in the metric system, the same prefixes are used to indicate the division or multiple of 10 for the basic unit (the gram) as are used in measuring length. For example, they are as follows:

Symbol	*Unit of Measure for Mass*	*Meaning*
mg	milligram	$^1/_{1,000}$ or 0.001 gram
g	gram	= 1
kg	kilogram	× 1,000 grams

A kilogram is 1,000 grams. A milligram is $^1/_{1,000}$ gram.

In the measurement of mass and weight, there is a relationship between the gram (mass unit of measure), the metre (length unit of measure), and the litre (volume unit of measure). The mass or weight varies with the density of the material. For material with the density of water, 1,000 grams or 1 kilogram is approximately equal to 1 litre. One cubic decimetre (1 dm^3) or 1 decimetre × 1 decimetre × 1 decimetre = 1 litre. Remember that 1 decimetre is $^1/_{10}$ (0.1) metre. Thus, 1 cubic decimetre of water would weigh 1,000 grams or 1 kilogram.

Volume—In the conventional system of measuring, volume is measured by the barrel, gallon, quart, pint, cup, fluid ounce, and so forth. In the metric system, the basic unit of volume is the litre. A litre is approximately equal to 2.1 pints, or 1.06 quarts. A millilitre, which is $^1/_{1,000}$ litre, is equal to $^3/_{100}$ fluid ounce, or 30 millilitres is approximately equal to 1 fluid ounce. Volume is a measure of space occupied, such as the size or volume of a grain bin or a tank of water. Length has one dimension, area has two dimensions, and volume has three dimensions. For example, a litre, a volume unit of measure, is 1 decimetre × 1 decimetre × 1 decimetre = 1 $decimetre^3$ (1 dm^3) = 1 litre. Remember that 1 decimetre is 0.1 or $^1/_{10}$ metre. Also notice the relationship in the metric system between the measurement of length and the measurement of volume. This relationship is a characteristic of the metric system which is not a characteristic of the conventional system. It is one of the factors that makes the metric system more versatile and easier to use than the conventional system of measuring length, mass (weight), and volume.

The common units of volume measure are as follows:

Symbol	*Unit of Measure for Volume*	*Meaning*
ml	millilitre	$^1/_{1,000}$ or 0.001 litre
l	litre	= 1
m^3	cubic metre	1 metre × 1 metre × 1 metre or 1,000 fluid litres

In the measurement of volume, there is a relationship between the metre and the litre.

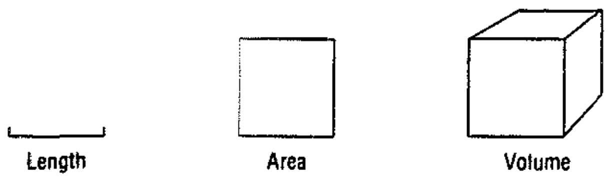


Fig. 43.1. Length has one dimension, area has two dimensions, and volume has three dimensions.

Area—In the conventional measuring system, area is calculated in square inches, square feet, square yards, acres, square miles, and so forth. In the metric system, area is calculated in square centimetres, square decimetres, square metres, ares, hectares, and square kilometres.

The common units of area measure are as follows:

Symbol	*Unit of Measure for Area*	*Meaning*
cm^2	square centimetre	1 centimetre × 1 centimetre
dm^2	square decimetre	1 decimetre × 1 decimetre
m^2	square metre	1 metre × 1 metre
a	are	100 square metres
ha	hectare	10,000 square metres
km^2	square kilometre	100 hectares

There is a relationship among all of the area units of measurement in the metric system. For example, 1 square centimetre is 100 square millimetres. An are is 100 square metres, which is equal to approximately 120 square yards. A hectare, which is equal to approximately 2.5 acres, is equal to 10,000 square metres or 100 ares. A square kilometre is equal to 100 hectares or 1,000,000 square metres.

Area is used to measure the floor space in an agricultural building, the size of the farm, and so forth.

Temperature—The Fahrenheit scale is the conventional scale for measuring temperature. In the metric system the Celsius scale is used. Celsius is the name of the man who developed the centigrade scale. On this scale there are 100 points or degrees between the melting point of ice and the boiling point of water. Specifically, ice melts at 0 degrees Celsius and water boils at 100 degrees Celsius.

In converting Fahrenheit temperature to Celsius temperature, subtract 32 from the Fahrenheit temperature and then multiply by $^5/_9$ or 0.555. In converting Celsius degrees to Fahrenheit, multiply Celsius degrees by $^9/_5$ or 1.8 and add 32 degrees.

APPROXIMATE CONVERSIONS

Length—When you know the metric length and want to convert the length to conventional inches, feet, and yards, use the following procedure:

Symbol	*Metric Length*	*Multiply by*	*to Find*	*Symbol*
mm	millimetres	0.04	inches	in.
cm	centimetres	0.4	inches	in.
m	metres	3.3	feet	ft
m	metres	1.1	yards	yd
km	kilometres	0.6	miles	mi

When you know the length in inches, feet, yards, and miles and want to convert the length to metric measures, use the following procedure:

Symbol	*Conventional Length*	*Multiply by*	*to Find*	*Symbol*
in.	inches	2.5	centimetres	cm
ft	feet	30	centimetres	cm
yd	yards	0.9	metres	m
mi	miles	1.6	kilometres	km

Area—When you know the metric area and want to convert the area to conventional square inches, square yards, square miles, and acres, use the following procedure:

Symbol	*Metric Length*	*Multiply by*	*to Find*	*Symbol*
cm^2	square centimetres	0.16	square inches	$in.^2$
m^2	square metres	1.2	square yards	yd^2
km^2	square kilometres	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	a

When you know the area in conventional measures such as square inches, square feet, square yards, square miles, and acres and want to obtain the equivalent metric measures, use the following procedure:

Symbol	*Conventional Area Measure*	*Multiply by*	*to Find*	*Symbol*
$in.^2$	square inches	6.5	square centimetres	cm^2
ft^2	square feet	0.09	square metres	m^2
yd^2	square yards	0.8	square metres	m^2
mi^2	square miles	2.6	square kilometres	km^2
a	acres	0.4	hectares	ha

Mass (Weight)—When you know the metric mass and want to convert to conventional mass measures of ounces, pounds, and tons, use the following procedure:

Symbol	*Metric Mass Measure*	*Multiply by*	*to Find*	*Symbol*
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	s t

When you know the mass in conventional terms such as ounces and pounds, and you want to convert to metric measures such as grams and kilograms, use the following procedure:

Symbol	*Conventional Mass Measure*	*Multiply by*	*to Find*	*Symbol*
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
s t	short tons (2,000 lb)	0.9	tonnes	t

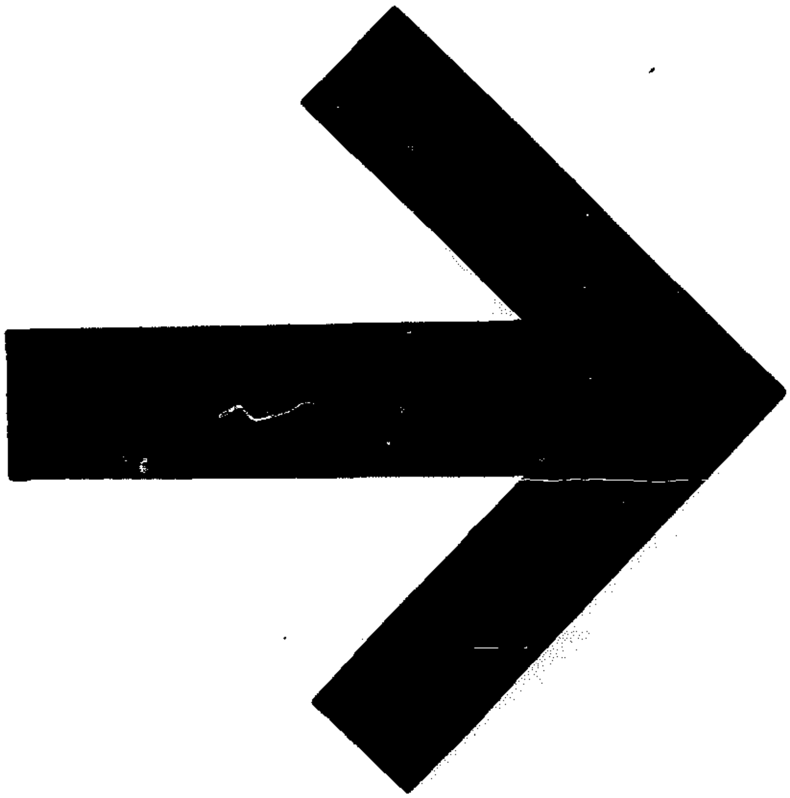
Volume—When you know the metric volume such as millilitres, litres, and cubic metres and want to convert to the conventional measures of fluid ounces, pints, quarts, gallons, and cubic feet, use the following procedure:

Symbol	Metric Volume Measure	Multiply by	to Find	Symbol
ml	millilitres	0.03	fluid ounces	fl oz
l	litres	2.1	pints	pt
l	litres	1.06	quarts	qt
l	litres	0.26	gallons	gal
m^3	cubic metres	3.5	cubic feet	ft^3
m^3	cubic metres	1.3	cubic yards	yd^3

When you know the conventional volume such as teaspoons, ounces, pints, quarts, gallons, and cubic feet, and you want to convert to metric measures such as millilitres, litres, and cubic metres, use the following procedure:

Symbol	Conventional Volume Measure	Multiply by	to Find	Symbol
tsp	teaspoons	5	millilitres	ml
tbsp	tablespoons	15	millilitres	ml
fl oz	fluid ounces	30	millilitres	ml
c	cups	0.24	litres	l
pt	pints	0.47	litres	l
qt	quarts	0.95	litres	l
gal	gallons	3.8	litres	l
ft^3	cubic feet	0.03	cubic metres	m^3
yd^3	cubic yards	0.76	cubic metres	m^3

The agricultural mechanic will increasingly use metric measures. At present some jobs require an understanding of metric measures and an ability to use them. Eventually, mechanics in agriculture will use metric measures exclusively. In this book, most measures are presented in conventional terms. There will be occasions when the measures will need to be converted to metric terms in order to do some mechanical activity on a farm or in an agricultural business. When this occurs, review this chapter. Learn to use the metric system of measuring length, area, mass (weight), volume, and temperature. If you learn to use it, you will find that it is an easier and more efficient measuring system to use than the conventional measuring system.



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