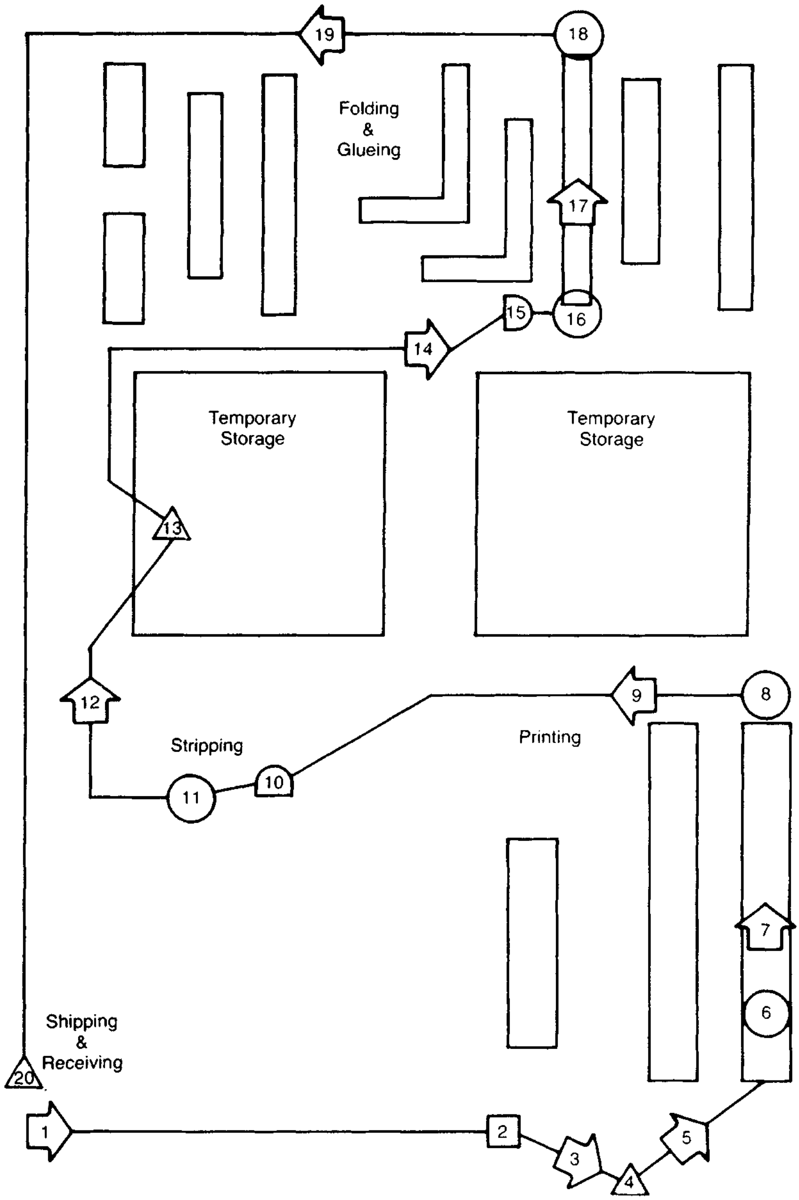


Fig. 38.16 Flow diagram.

These handling methods are implemented individually, or in combination, by commercially available material-handling equipment types.

38.5 MATERIAL-HANDLING EQUIPMENT CONSIDERATIONS AND EXAMPLES

38.5.1 Developing the Plan

Once the material-handling problem has been identified and the relevant data have been collected and analyzed, the next step in the design process is to develop a plan for solving the problem. This usually involves the design and/or selection of appropriate types, sizes, and capacities of material-handling equipment. In order to properly select material handling equipment, it must be realized that in most cases, the solution to the problem does not consist merely of selecting a particular piece of

To / From	A	B	C	D	E	F	G
A		13	37	69	85	57	33
B	13		21	53	69	41	17
C	37	21		29	45	17	41
D	69	53	29		13	33	57
E	85	69	45	13		49	73
F	57	41	17	33	49		21
G	33	17	41	57	73	21	

A

Fig. 38.17 "From–to" chart.

hardware, such as a section of conveyor. Rather, handling should be viewed as part of an overall system, with all activities interrelated and meshing together. Only on this basis can the best overall type of equipment or system be planned.

This section provides examples of some of the more common types of unit load material handling and storage equipment used in production facilities.

38.5.2 Conveyors

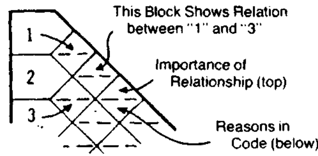
Conveyors are generally used to transport materials long distances over fixed paths. Their function may be solely the movement of items from one location in a process or facility to another point, or they may move items through various stages of receiving, processing, assembly, finishing, inspection, packaging, sortation, and shipping.

Conveyors used in material handing are of two basic types:

1. *Gravity conveyors,* including chutes, slides, and gravity wheel or roller conveyors that essentially exploit the use of gravity to move items from a point at a relatively high elevation to another point at a lower elevation. As listed in Fig. 38.12, MHI Principle 5 indicates that one should maximize the use of gravity in designing material-handling systems.
2. *Powered conveyors,* which generally use electric motors to drive belts, chains, or rollers in a variety of in-floor, floor-mounted, or overhead configurations.

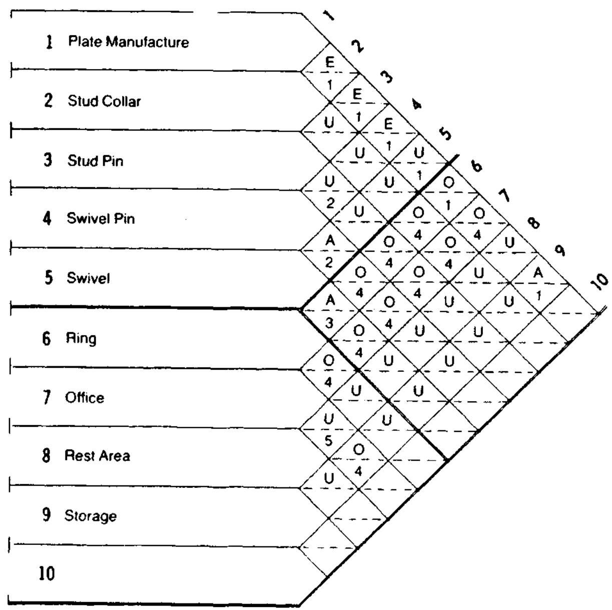
In general, conveyors are employed in unit material handling when

1. Loads are uniform.
2. Materials move continuously.
3. Routes do not vary.
4. Load is constant.
5. Movement rate is relatively fixed.
6. Cross traffic can be bypassed.



CLOSENESS RATING

VALUE	CLOSENESS
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary proximity OK
U	Unimportant
X	Not desirable



Reasons behind the "Closeness" Value

Code	REASON
1	Material Flow
2	Share Equipment
3	Parts Subassembly
4	Ease of Supervision
5	Noise Avoidance
6	
7	
8	
9	

Fig. 38.18 Activity relationship chart.

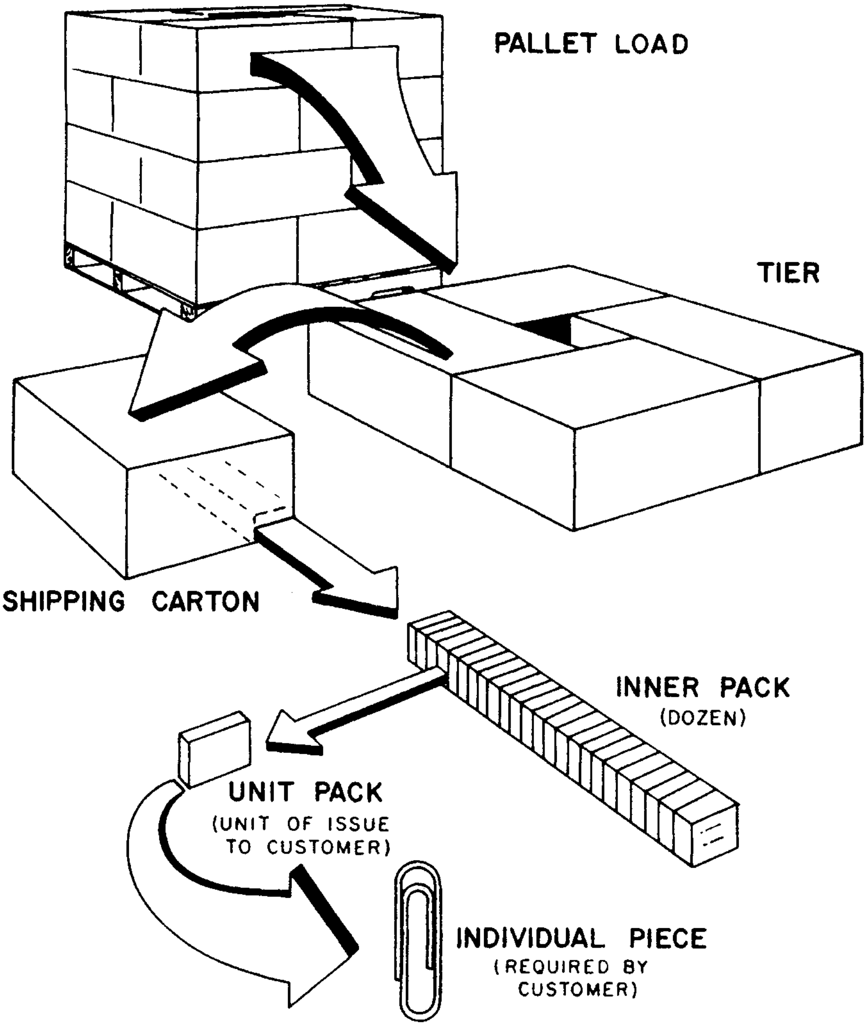


Fig. 38.19 Unit load design.

7. Path is relatively fixed.
8. Movement is point-to-point.
9. Automatic counting, sorting, weighing, or dispatching is needed.
10. In-process storage is required.
11. In-process inspection is required.
12. Production pacing is necessary.
13. Process control is required.
14. Controlled flow is needed.
15. Materials are handled at extreme temperatures, or other adverse conditions.
16. Handling is required in a hazardous area.
17. Hazardous materials are handled.
18. Machines are integrated into a system.
19. Robots are integrated into a system.
20. Materials are moved between workplaces.
21. Manual handling and/or lifting is undesirable.

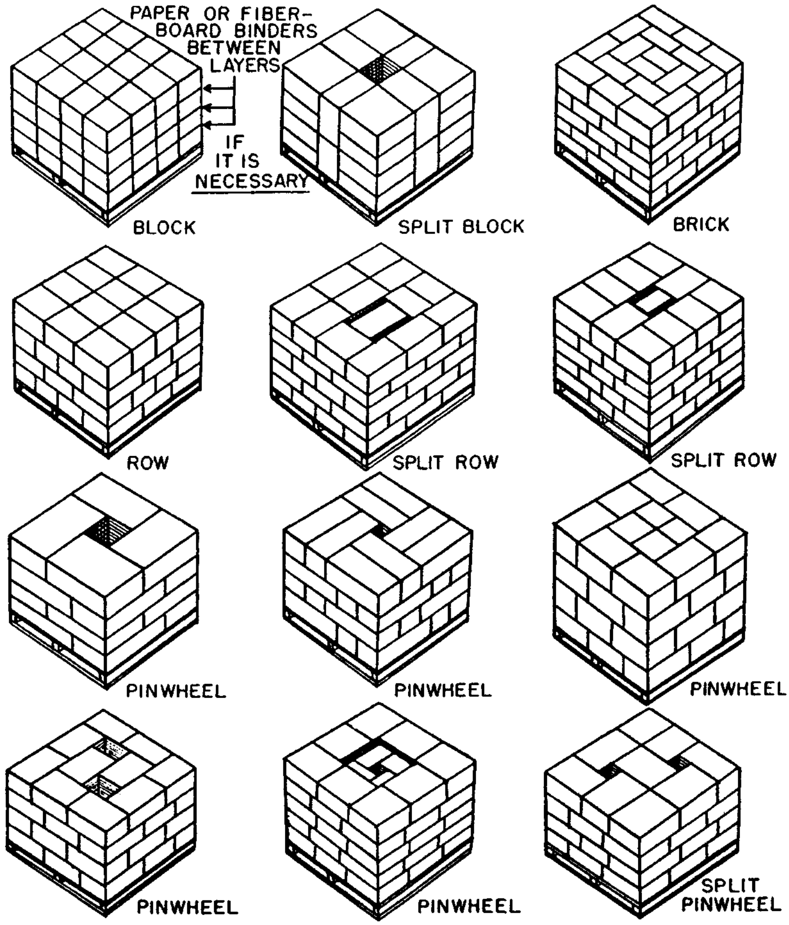


Fig. 38.20 Example pallet-loading patterns.

22. Changes in production volume or pace are needed.
23. Visual surveillance of a production process is required.
24. Floor space can be saved by utilizing overhead space.
25. Flexibility is required to meet changes in production processes.
26. Integration between computer-aided design and computer-aided manufacturing is required.

This section further details essential information on four main classes of conveyors used in unit material handling:

1. Gravity conveyors
2. Powered conveyors
3. Chain-driven conveyors
4. Power-and-free conveyors

Gravity Conveyors

Gravity conveyors exploit gravity to move material without the use of other forms of energy. Chutes, skate wheel conveyors, and roller conveyors are the most common forms of gravity conveyors. Figure 38.23 illustrates wheel and roller conveyors. Advantages of gravity conveyors are low cost, relatively low maintenance, and negligible breakdown rate. The main requirement for using gravity conveyors is the ability to provide the necessary gradient in the system configuration at the point at which gravity units are placed.

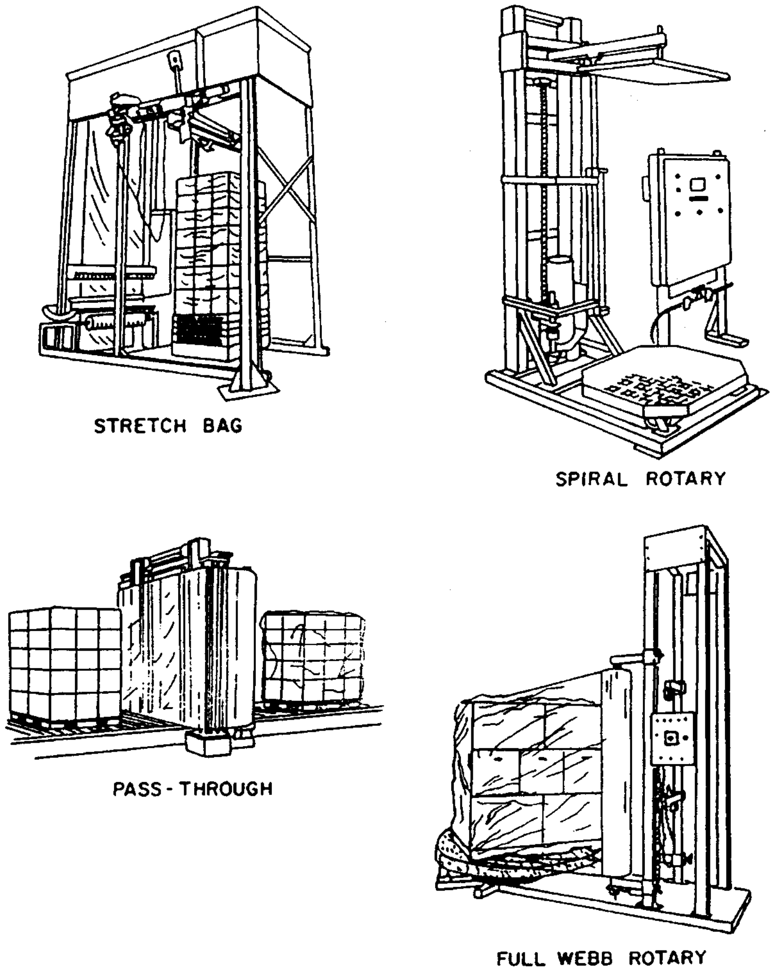


Fig. 38.21 Stretch wrap equipment.

Powered Conveyors

The two principal types of powered conveyors are belt conveyors and roller conveyors, as shown in Fig. 38.24. Electric motors provide the energy to drive the belt or rollers on these conveyors.

Belt conveyors are used either in the horizontal plane or with inclines up to 30°. They can range in length from a few feet to hundreds of feet, and are usually unidirectional. Changes in direction must be managed through the use of connecting chutes or diverters to conveyors running in another direction.

Roller conveyors are used for heavier loads than can be moved with belt conveyors, and are generally of sturdier construction. When used as accumulating conveyors, roller conveyors can also be used to provide spacing between items. Inclines are possible to about 10°; declines of about 15° are possible.

Powered conveyors should be operated at about 65 ft/min (about 1 mile/hr).

Chain-Driven Conveyors

Chain conveyors are those in which closed-loop systems of chain, usually driven by electric motors, are used to pull items or carts along a specified path. The three principal types of chain-driven conveyors used in unit material handling are flight conveyors, overhead towlines and monorails, and in-floor towlines. Figure 38.25 illustrates an overhead towline type of chain-driven conveyor.

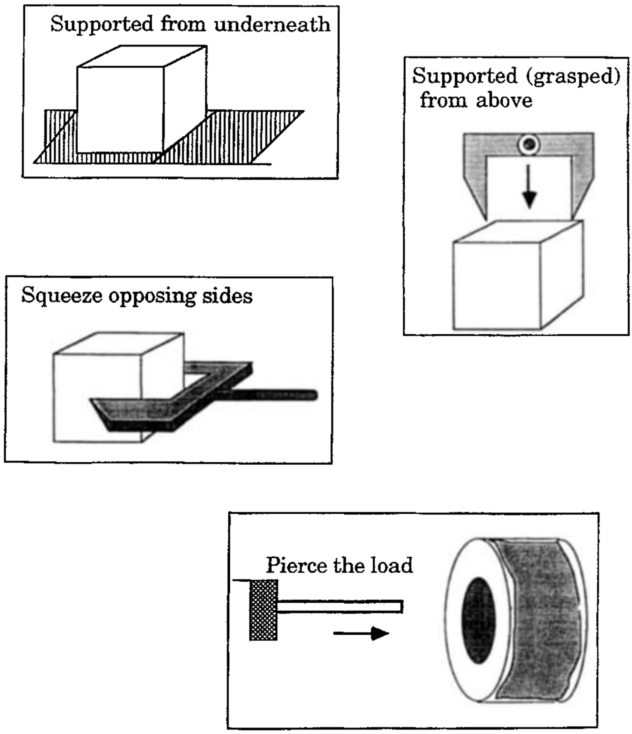


Fig. 38.22 Ways to handle a load.

Flight conveyors consist of one or more endless strands of chain with spaced transverse flights or scrapers attached, which push the material along through a trough. Used primarily in bulk material handling, its primary function in unit material handling includes movement of cans or bottles in food canning and bottling. A flight conveyor is generally limited to speeds of up to 120 ft/min.

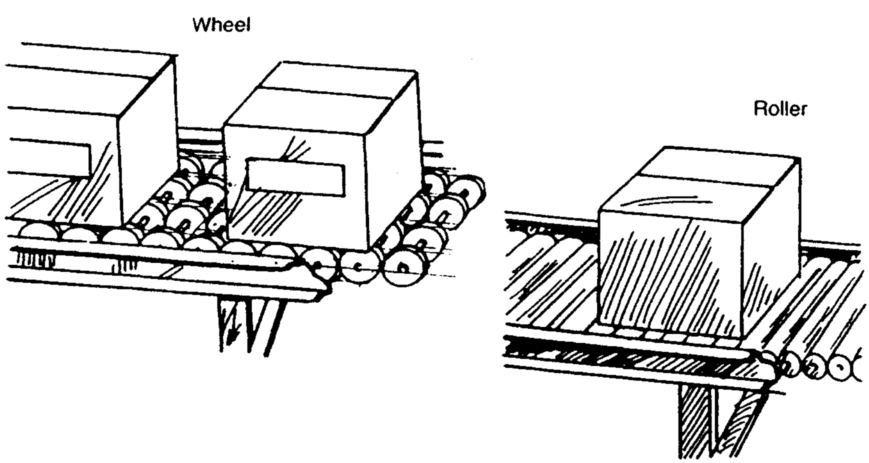


Fig. 38.23 Gravity conveyors.

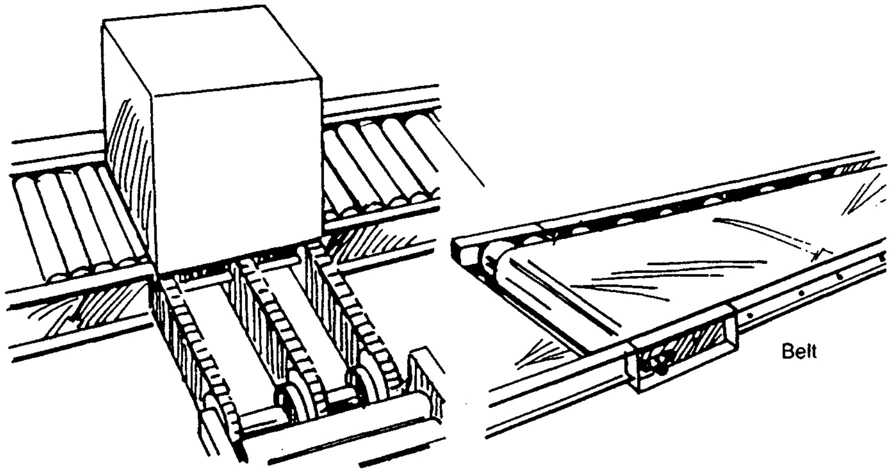


Fig. 38.24 Belt and roller conveyors.

In-floor towlines consist of chain tracks mounted in the floor. A cart is pulled along the track by attaching a pin-type handle to the chain. In-floor towlines are capable of greater speeds than overhead towlines and have a smoother pickup action. They are difficult to maintain and lack flexibility for rerouting.

Overhead towlines consists of a track mounted 8–9 ft above the floor. Carts on the floor are attached to the chain, which moves through the overhead track. Overhead towlines free the floor for other uses, and are less expensive and more flexible than in-floor towlines.

Power-and-Free Conveyors

Power-and-free conveyors are a combination of powered trolley conveyors and unpowered monorail-type conveyors. Two sets of tracks are used, one positioned above the other. The upper track carries the powered trolley or monorail-type conveyor, which is chain-driven. The lower track is the free,

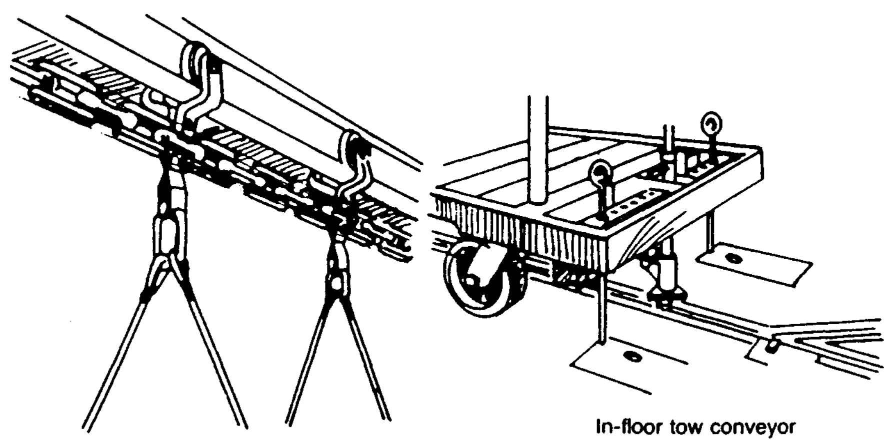


Fig. 38.25 Chain-driven conveyors.

unpowered monorail. Load-carrying free trolleys are engaged by pushers attached to the powered trolley conveyors. Load trolleys can be switched to and from adjacent unpowered free tracks.

Interconnections on power-and-free conveyors may be manually or automatically controlled. Track switches may divert trolleys from "power" to "free" tracks. Speeds may vary from one "power" section to another, and programmable logic controllers (PLC) or computers can be used to control power-and-free conveyors.

Power-and-free conveyors, shown in Fig. 38.26, are relatively expensive and are costly to relocate.

38.5.3 Hoists, Cranes, and Monorails

Overhead material handling system components (e.g., tracks, carriers/trolleys, hoists, monorails, and cranes), can make effective use of otherwise unused overhead space to move materials in a facility. This can free up valuable floor space for other uses than material handling, reduce floor-based traffic, and reduce handling time by employing "crow-fly" paths between activities or departments.

Hoists, cranes, and monorails are used for a variety of overhead handling tasks. A hoist is a device for lifting and/or lowering a load and typically consists of an electric or pneumatically powered motor; a lifting medium, such as a chain, cable, or rope; a drum for reeling the chain, cable, or rope; and a handling device at the end of the lifting medium, such as a hook, scissor clamp mechanism, grapple, and so on. Hoists may be manually operated or automatically controlled by PLC or computer.

A monorail is a single-beam overhead track that provides a horizontal single path or route for a load as it is moved through a facility. The lower flange of the rail serves as a runway for a trolley-mounted hoist. A monorail system is used to move, store, and queue material overhead.

Through the use of switches, turntables, and other path-changing devices, an overhead monorail can be made to follow multiple predetermined paths, carrying a series of trolleys through various

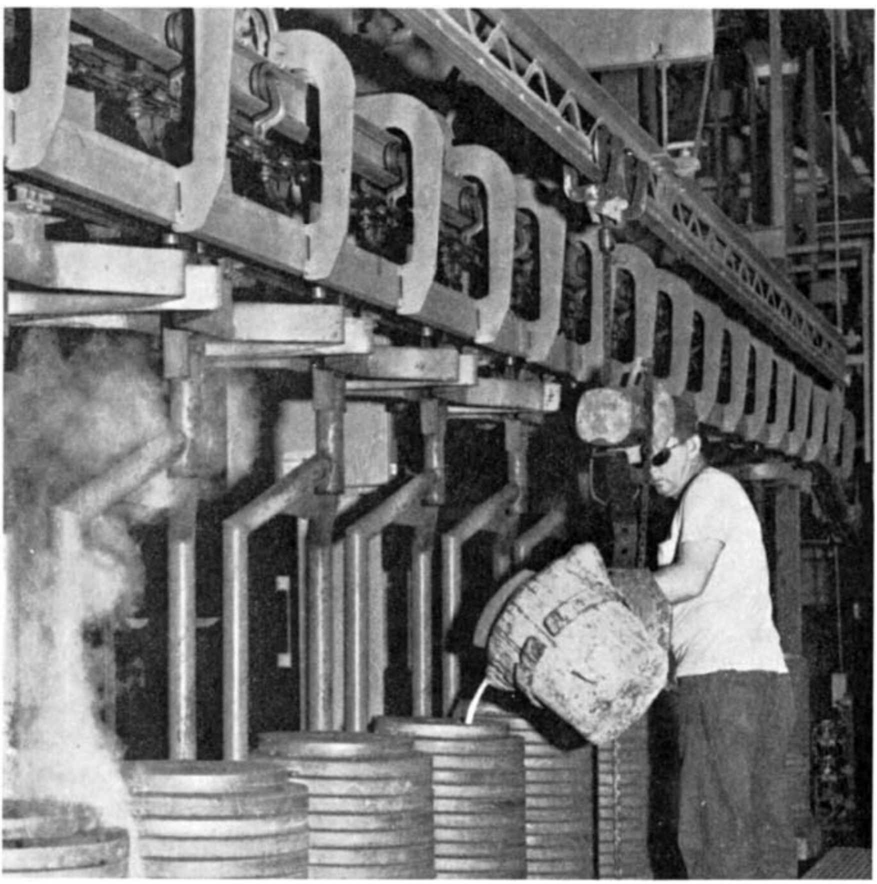


Fig. 38.26 Power-and-free conveyor.

stations in processing or assembly. A chain-driver overhead monorail is very similar to the overhead towline in its configuration, except that it generally carries uniformly spaced trolleys overhead instead of pulling carts along the floor.

However, newer monorail technology has led to the development of individually powered and controllable trolleys that travel on the monorail (see Fig. 38.27). These devices are termed *automated electrified monorails* (AEM). The speed of the individually powered AEM vehicles can be changed en route and can function in nonsynchronous or flexible production environments.

Monorails can be made to dip down at specific points to deliver items to machines or other processing stations.

A crane also involves a hoist mounted on a trolley. Frequently, the trolley may be transported, as in the case of the bridge cranes shown in Fig. 38.28. Cranes may be manually, electrically, or pneumatically powered.

A jib crane has a horizontal beam on which a hoist trolley rides. The beam is cantilevered from a vertical support mast about which the beam can rotate or pivot (see the wall bracket-type jib crane in Fig. 38.28). This rotation permits the jib crane a broad range of coverage within the cylindrical work envelope described by the degrees of freedom of the beam, hoist, and mast.

38.5.4 Industrial Trucks

Industrial trucks provide flexible handling of materials along variable (or random) flow paths. The two main categories of industrial trucks are hand trucks and powered trucks, illustrated by the examples in Fig. 38.29.

Four-wheeled and multiple-wheeled carts and trucks include dollies, platform trucks, and skid platforms equipped with jacks. Hand-operated lift trucks include types equipped with hand-actuated hydraulic cylinders, and others having mechanical-lever systems.

Perhaps the most familiar type of powered truck is the forklift, which uses a pair of forks—capable of variable spacing—riding on a vertical mast to engage, lift, lower, and move loads. Lift trucks may be manually propelled or powered by electric motors, gasoline, liquified propane, or diesel-fueled engines. With some models, the operator walks behind the truck. On others, he or she rides on the truck, in either a standing or sitting position. Figure 38.30 depicts several types of forklift trucks.

Lift trucks are very effective in lifting, stacking, and unloading materials from storage racks, highway vehicles, railroad cars, and other equipment. Some lift trucks are designed for general-purpose use, while others are designed for specific tasks, such as narrow-aisle or high-rack handling.

38.5.5 Automated Guided Vehicle Systems

An automated guided vehicle system (AGVS) has similar uses as an industrial truck-based material-handling system. However, as implied by their name, the vehicles in an AGVS are under automatic control and do not require operators to guide them. In general, the vehicles in an AGVS are battery-powered, driverless, and capable of being automatically routed between, and positioned at, selected pickup or dropoff stations strategically located within a facility. Most of the vehicles in industrial use today are transporters of unit loads. However, when properly equipped, AGVs can provide a number of other functions, such as serving as automated storage devices or assembly platforms.

The four commonly recognized operating environments for AGVSs are distribution warehouses, manufacturing storerooms and delivery systems, flexible manufacturing systems, and assembly systems. Vehicles are guided by inductive-loop wires embedded in the floor of a facility, a chemical stripe painted on the floor, or laser-based navigation systems. All vehicular motion, as well as load pickup and delivery interfaces, are under computer control.

Examples of typical unit load AGVs are shown in Fig. 38.31 equipped with various types of load-handling decks that can be used.

38.5.6 Automated Storage and Retrieval Systems

An automated storage and retrieval system (AS/RS) consists of a set of racks or shelves arrayed along either side of an aisle through which a machine travels that is equipped with devices for storing or retrieving unit loads from the rack or shelf locations. As illustrated in Fig. 38.32, the AS/RS machine resembles a vertically oriented bridge crane (mast) with one end riding on a rail mounted on the floor and the other end physically connected to a rail or channel at the top of the rack structure. The shuttle mechanism travels vertically along the mast as it, in turn, travels horizontally through the aisle. In this manner, it carries a unit load from an input station to the storage location in the rack structure, then extends into the rack to place the load. The procedure is reversed for a retrieval operation; that is, the empty shuttle is positioned at the correct rack location by the mast, then it is extended to withdraw the load from storage and transport it to the output station, usually located at the end of the aisle.

The AS/RS machines can have people on board to control the storage/retrieval operations, or they can be completely controlled by a computer. The objective in using AS/RSs is to achieve very dense storage of unit loads while simultaneously exercising very tight control of the inventory stored in these systems.

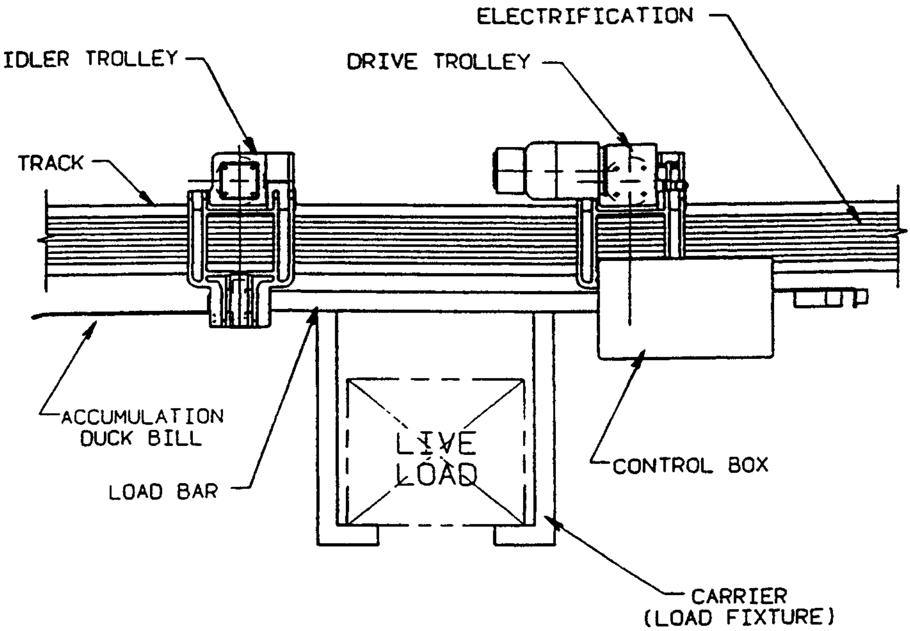


Fig. 38.27 Automated electrified monorail.

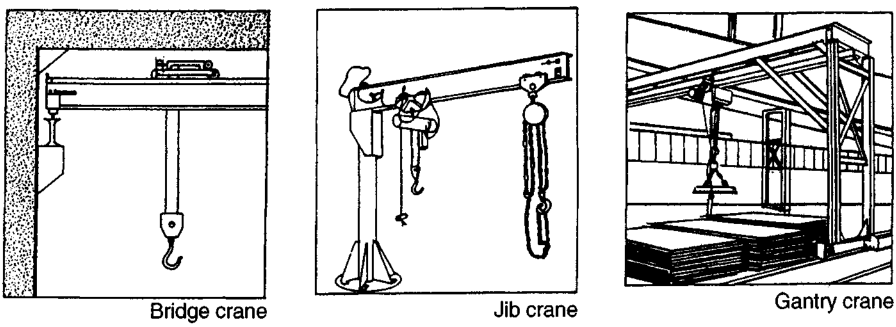


Fig. 38.28 Cranes.

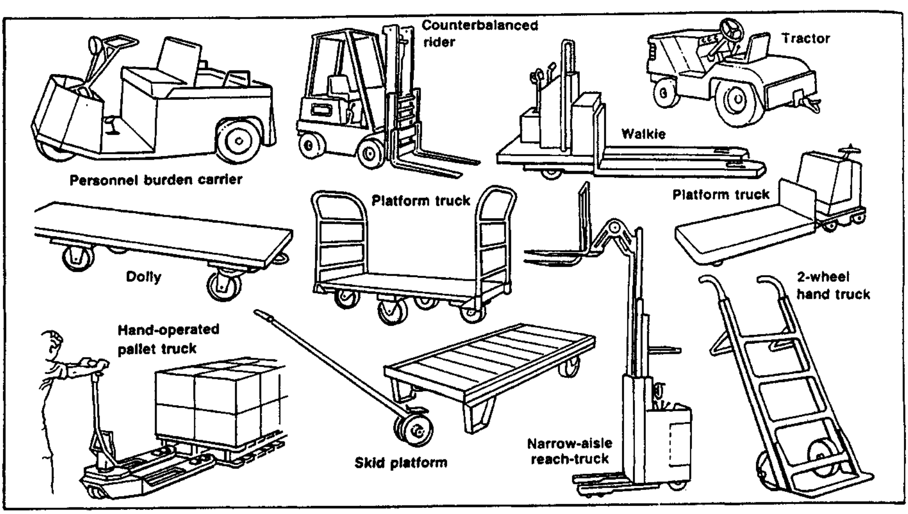


Fig. 38.29 Industrial truck equipment.

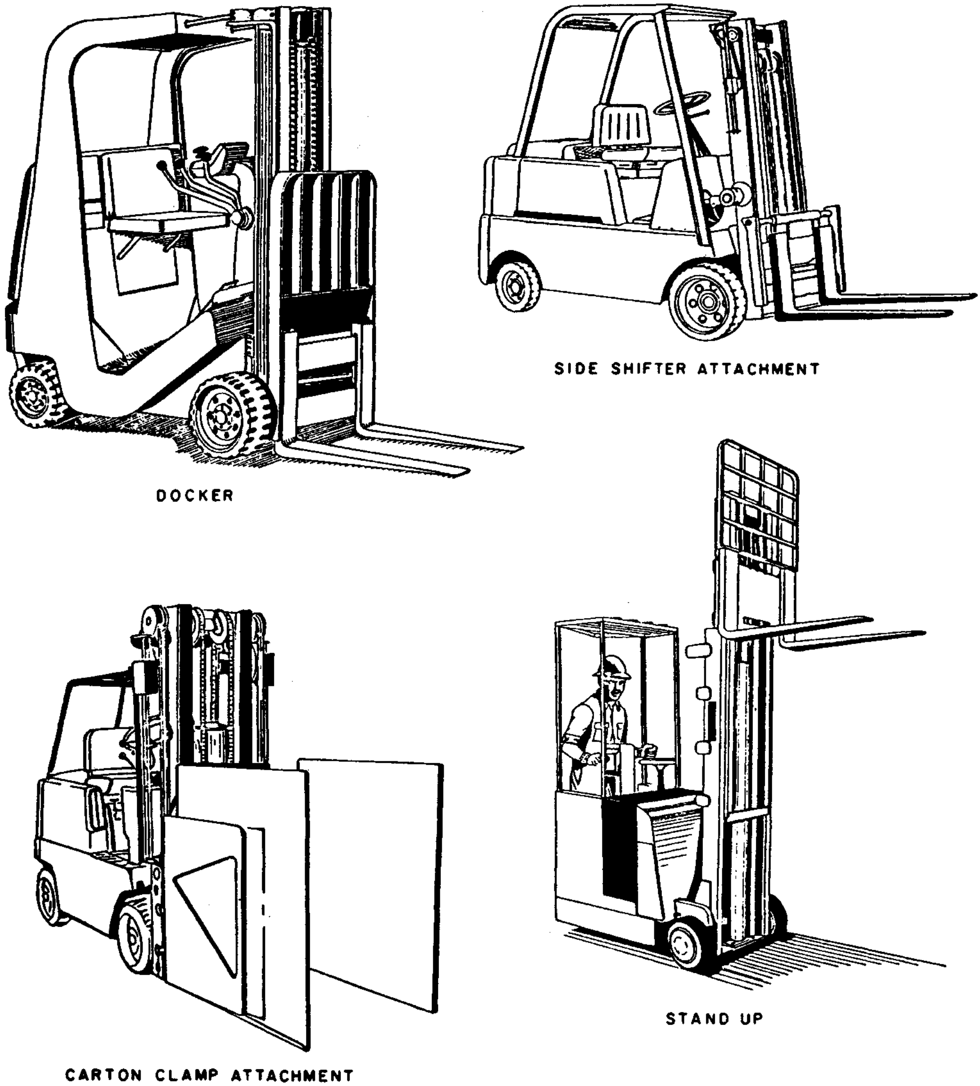


Fig. 38.30 Industrial forklift trucks.

AS/RSs which store palletized unit loads can be 100 feet or more high and hundreds of feet deep. However, these systems can also be of much smaller dimensions and store small parts in standard-sized drawers. Such systems are called *miniload AS/R systems.* An example is shown in Fig. 38.33.

In a typical miniload AS/RS, the machine retrieves the proper coded bins from specified storage locations and brings them to an operator station. Each bin can be divided into a number of sections, and the total weight of parts contained in each bin typically ranges from 200–750 pounds. While the operator is selecting items from one bin at the operator station, the machine is returning a previously accessed bin to storage. The system can be operator-directed through a keyboard entry terminal, or it may be operated under complete computer control.

38.5.7 Carousel Systems

A carousel is a series of linked bin sections mounted on either an oval horizontal track (horizontal carousel) or an oval vertical track (vertical carousel). A horizontal carousel is illustrated in Fig. 38.34. When activated, usually by an operator, the bins revolve in whichever direction will require the

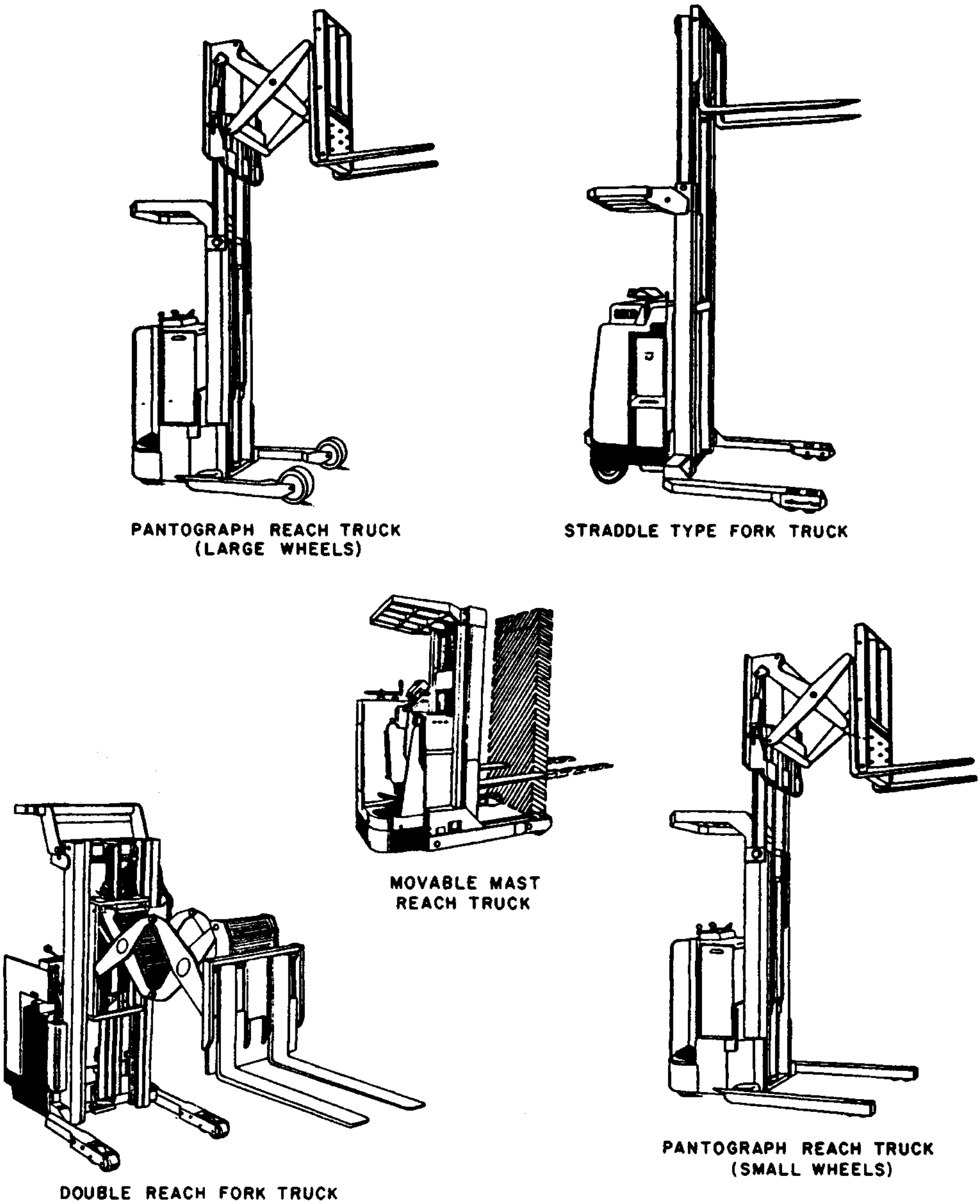


Fig. 38.30 (*Continued*)

minimum travel distance to bring the desired bin to the operator. The operator then either picks or puts away stock into the bin selected.

Some of the standard applications for carousels are

- Picking less than full case lots of small items for customer or dealer orders
- Storing small parts or subassemblies on the shop floor or in stockrooms
- Storing tools, maintenance parts, or other items that require limited access or security
- Storing work-in-process kits for assembly operations
- Storing documents, tapes, films, manuals, blueprints, etc.

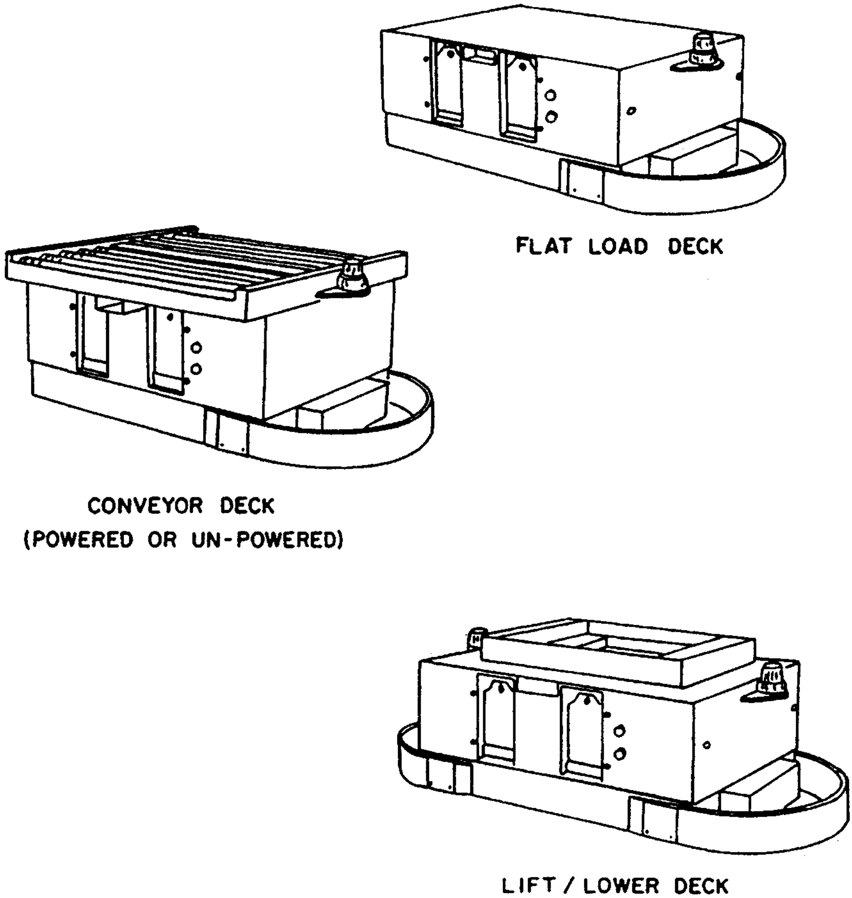


Fig. 38.31 Typical automated guided vehicles.

- Storage and accumulation of parts between processing operations
- Storage during electrical burn-in of products by mounting a continuous oval electrified track on top of the carousel

Since carousels bring the bins to the operator, multiple carousel units can be placed adjacent to each other ($\leq$18 in.), with no aisles. Carousels can also be multitiered, with the various tiers capable of rotating in directions and at speeds independent of the other tiers. These designs result in very dense but easily accessible storage systems.

Carousels can be of almost any length, from a minimum of 10 feet to over 100 feet. However, most are in the 30- to 50-foot range so as to minimize bin access times. Carousels may be arranged so that one operator can pick or put away items in bins located on different systems or tiers while the other systems or tiers are positioning the next bin for access.

38.5.8 Shelving, Bin, Drawer, and Rack Storage

Shelving is used to economically store small, hand-stackable items that are generally not suited to mechanized handling and storage due to their handling characteristics, activity, or quantity. Standard shelving units are limited to about seven feet in height, but mezzanines can be used to achieve multiple storage levels and density.

Bin storage is, in most instances, identical in application to shelf storage, but is generally used for small items that do not require the width of a conventional shelf module. Bin storage usually represents a small part of the total storage system in terms of physical space, but it may represent a

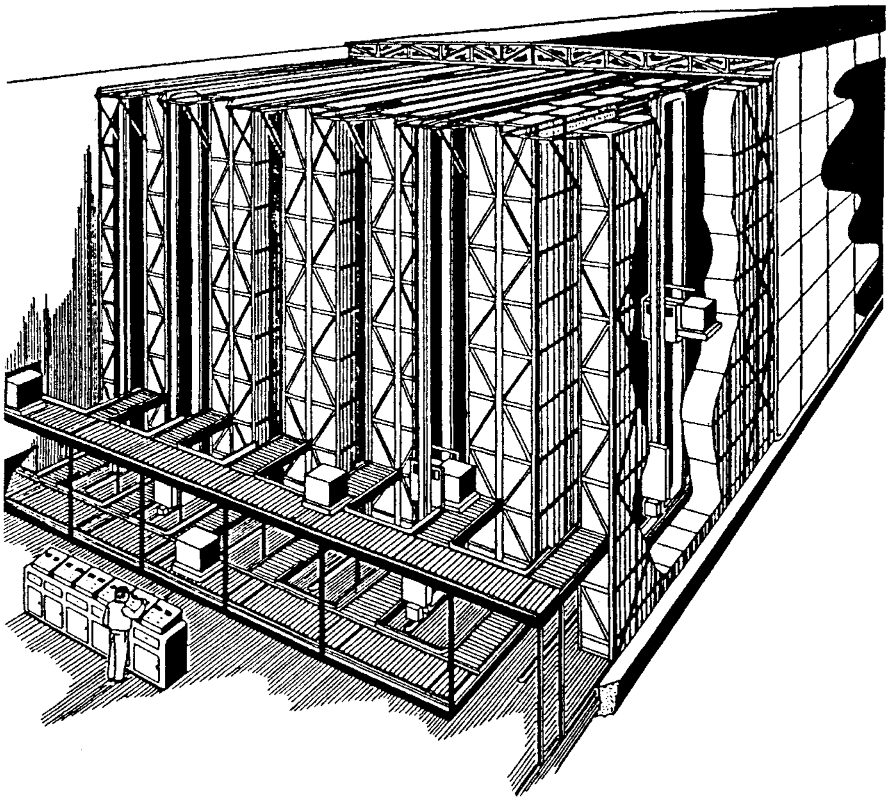


Fig. 38.32 Automated storage and retrieval system.

significant portion of the total storage in terms of the item positions used or stock keeping units (SKUs).

Modular drawer cabinets provide the advantages of increased security and density of storage over shelving and bin storage. As illustrated in Fig. 38.35, drawers provide the operator a clear view of all parts stored in them when pulled out. They can be configured to hold a large number of different SKU parts by partitioning the drawer volume into separate storage cells with dividers. This provides high storage density, good organization, and efficient utilization of storage space for small parts in applications such as tool cribs, maintenance shops, and parts supply rooms.

A pallet rack, as illustrated in Fig. 38.36, is a framework designed primarily to facilitate the storage of unit loads. This framework consists of upright columns and horizontal members for supporting the loads, and diagonal bracing for stability. The structural members may be bolted into place or lock-fitted.

Standard pallet racks can also be equipped with shelf panel inserts to facilitate their use for storage of binnable or shelvable materials. They may be loaded or unloaded by forklift trucks, by AS/R machines, or by hand. They may be fixed into position or made to slide along a track for denser storage. The primary purpose in using rack storage is to provide a highly organized unit material storage system that facilitates highly efficient operations in either manufacturing or distribution.

38.6 IMPLEMENTING THE SOLUTION

After the best system for solving the material handling problem has been designed, it is recommended that computer simulation be used to test the design before implementation. Although somewhat expensive to build and time-consuming to use, a valid simulation model can effectively test the overall operation of the material handling system as designed. It can identify potential bottleneck flows or choke points, isolate other costly design errors, determine efficient labor distribution, and evaluate various operating conditions that can be encountered. In other words, simulation enables the material-handling system designer to look into the future and get a realistic idea of how the system will

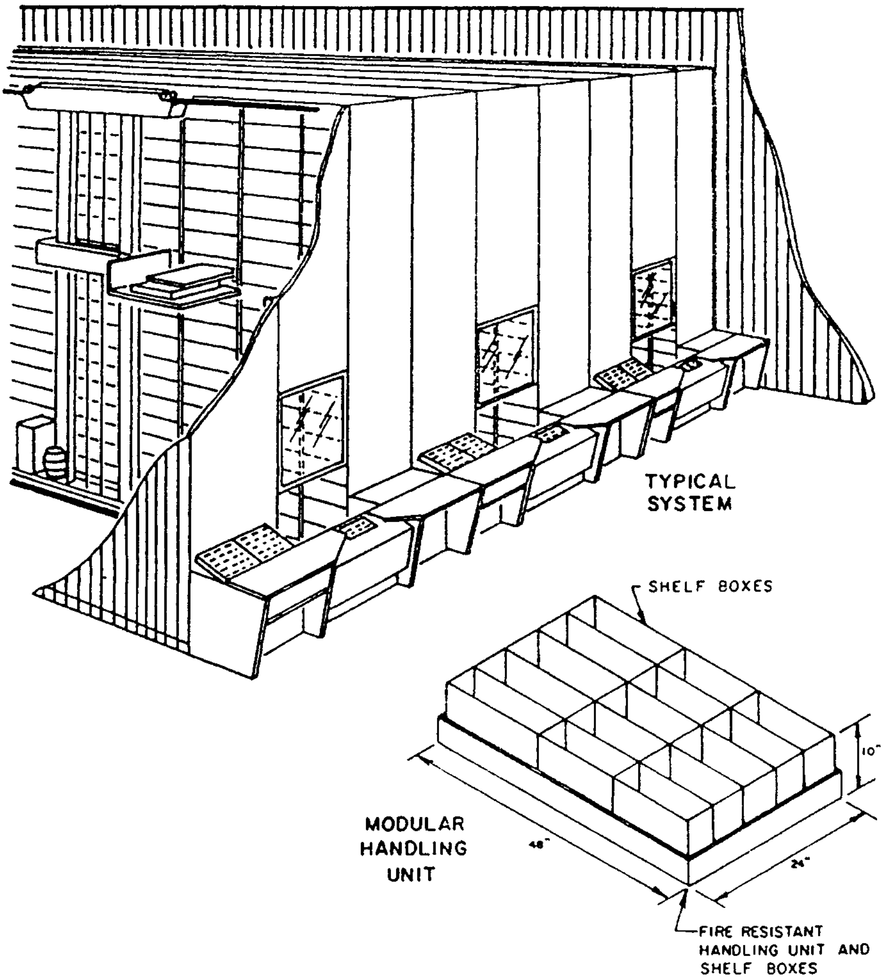


Fig. 38.33 Miniload AS/RS.

operate before proceeding to cost justification—or before the millwrights start bolting the wrong equipment together.

The final step is to implement the solution. Once total system costs—initial costs, recurring costs and salvage costs—have been calculated, an engineering economic analysis should be done to justify the investments required. Then the justification must be presented to, and approved by, appropriate managers. Once approval is obtained, a carefully prepared, written bid specification called a *request for quotation* (RFQ) is typically sent to several qualified vendors or contractors. Competing bids or proposals submitted by the vendors or contractors must then be evaluated carefully to ascertain whether they all are quoting on the same type and grade of equipment and components.

Each step of the equipment-acquisition process must be closely monitored to ensure that any construction is accomplished in a correct and timely manner and that equipment-installation procedures are faithfully followed. Once the completed facility is operational, it should be fully tested before final acceptance from the vendors and contractors. Operating personnel must be fully trained to use systems installed in the new facility.

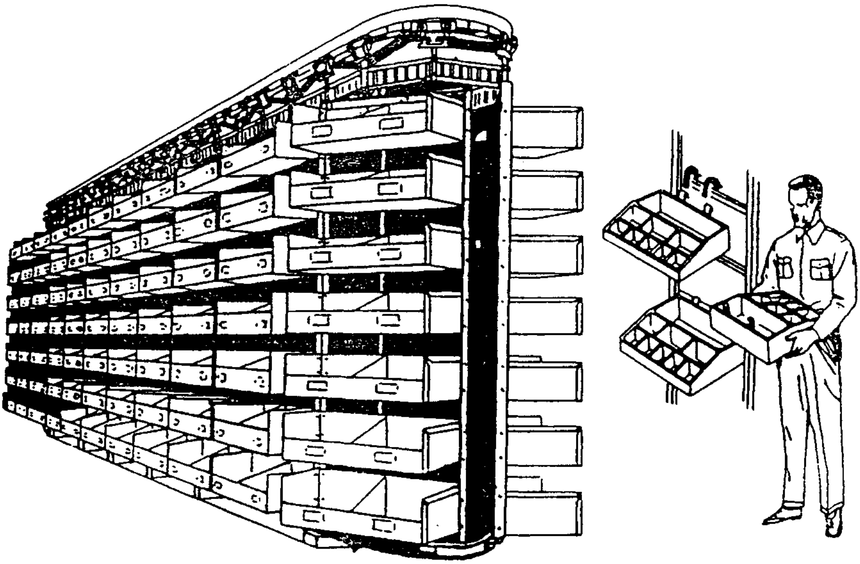


Fig. 38.34 Horizontal carousel.

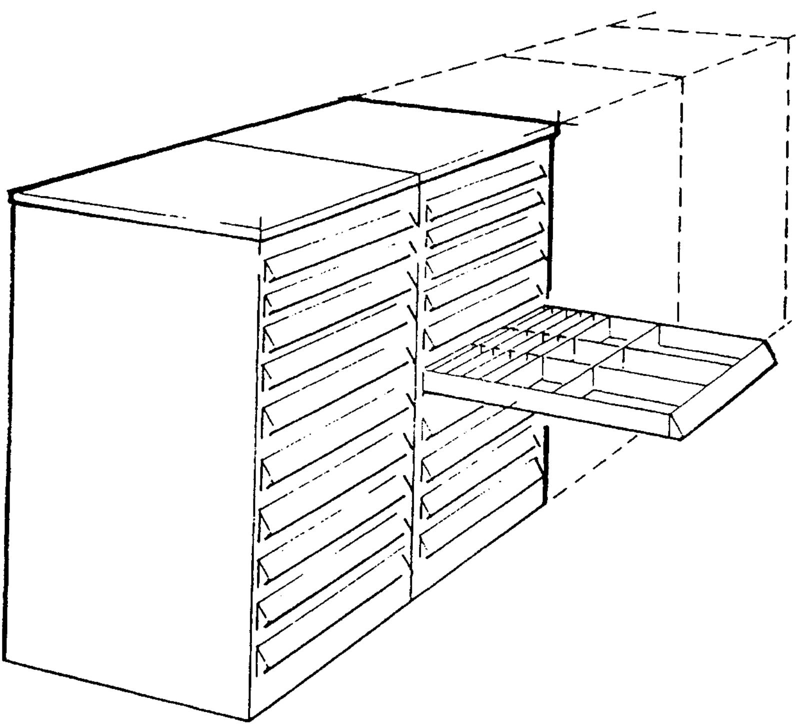


Fig. 38.35 Modular cabinet drawer storage.

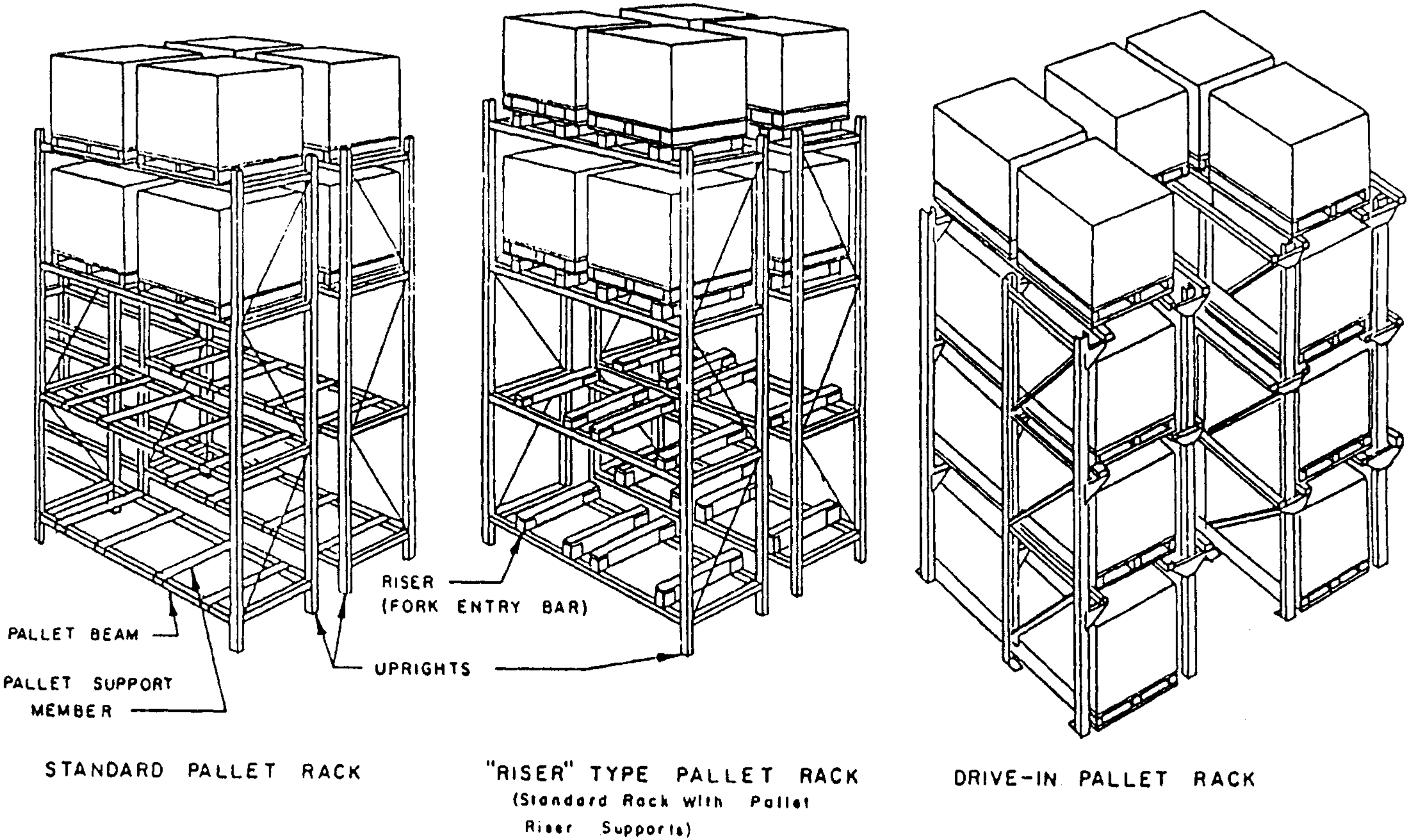


Fig. 38.36 Pallet rack storage.