THE MATERIAL HANDLING INSTITUTE, INC.

Basics of Material Handling

Prepared by
The Material Handling Institute, Inc.

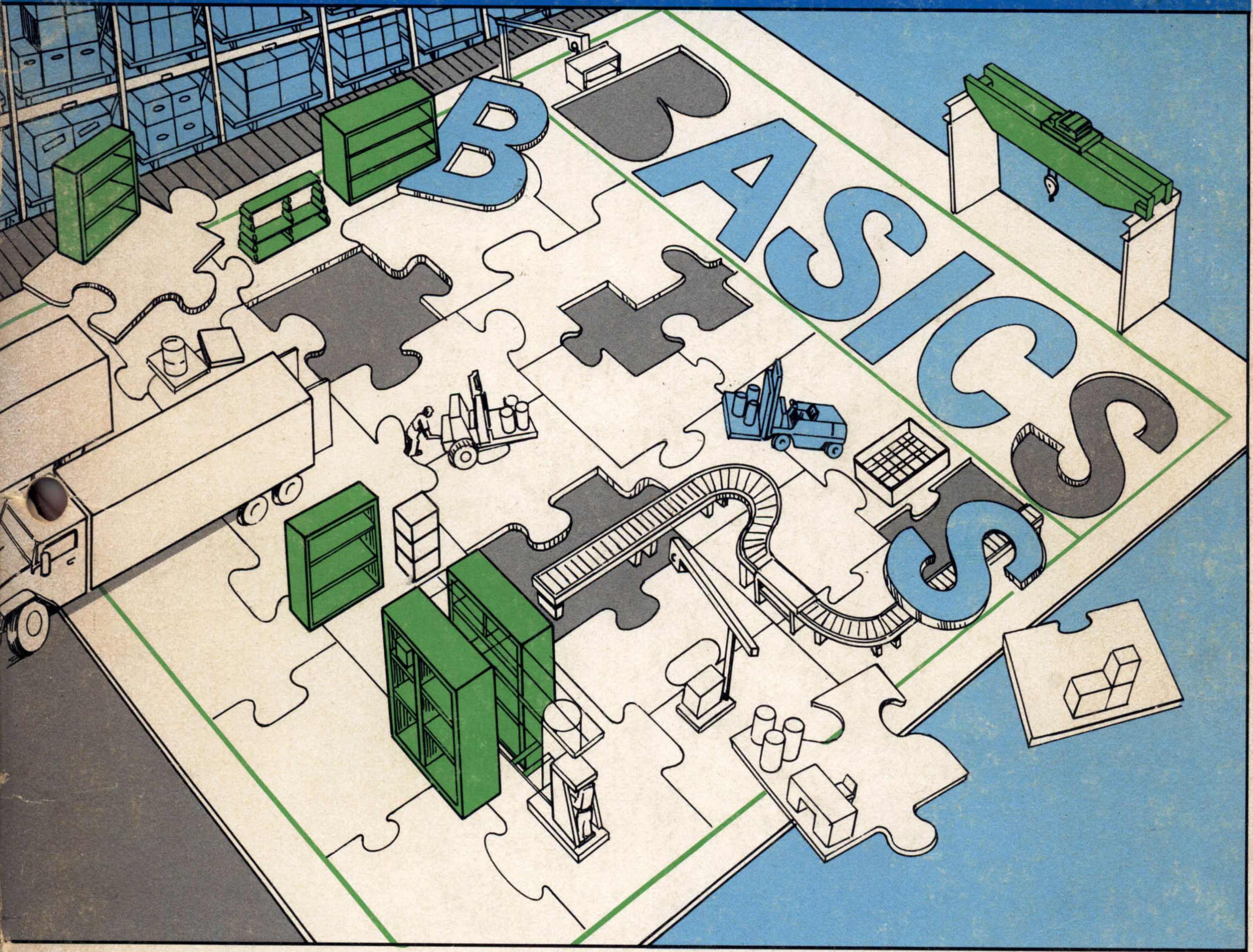

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Table of Contents

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About the Author

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Chapter 1
Material Handling — The Common Denominator

What Is Material Handling? How does it affect me?

Although we are not always aware of it, material handling can be found in almost every facet of our daily lives, as well as in commerce and industry. Actually, very little of our modern lifestyle would be possible without some form of handling — moving, lifting, transferring, and storing of goods and materials, Fig. 1-1. One broad definition of material handling calls it *the art and science of moving, packaging, and storing of substances in any form.*

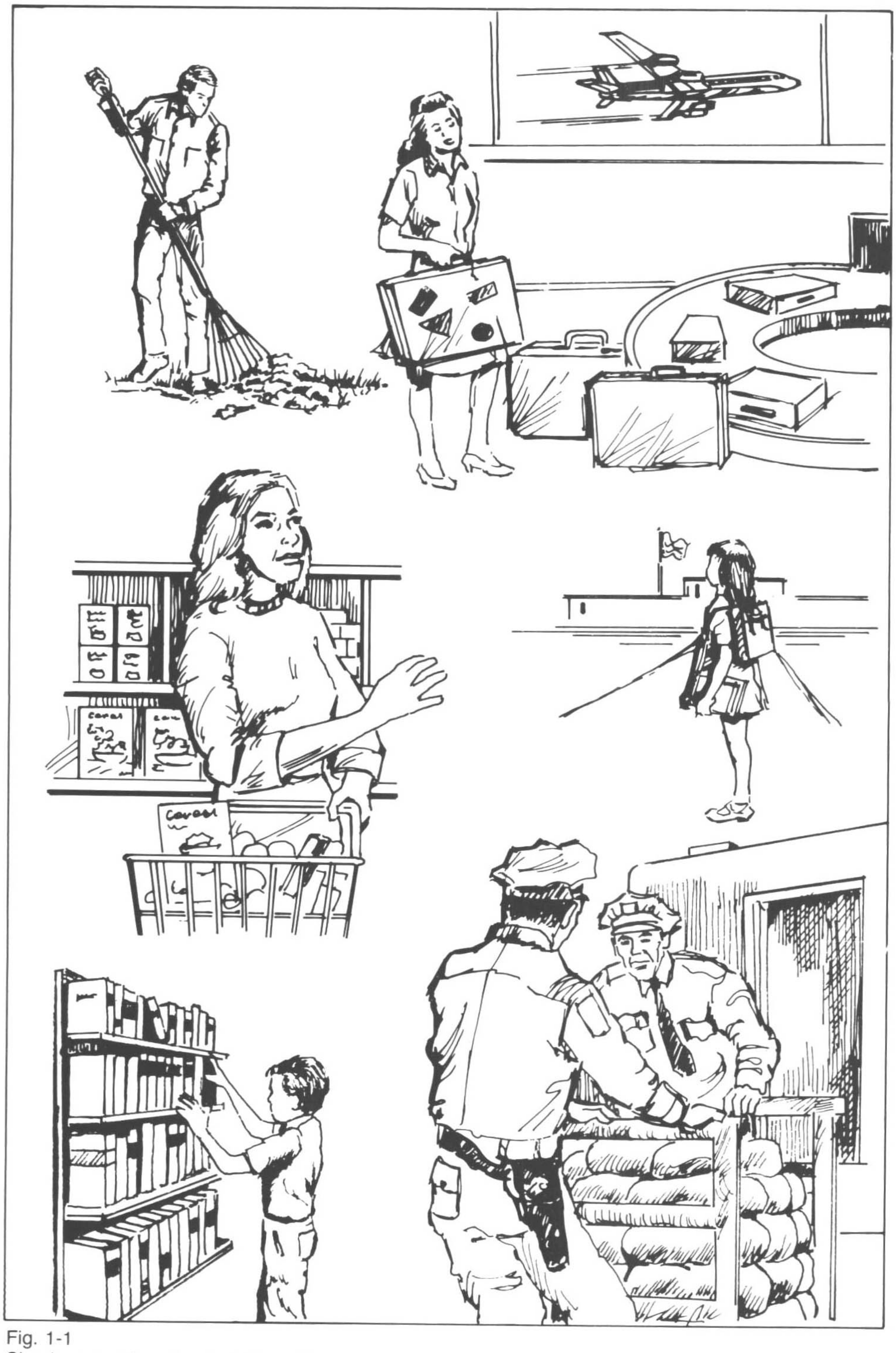


Fig. 1-1
Simple examples of material handling can be readily found in various aspects of our everyday lives.

Your grocery supermarket provides numerous examples. Goods in cartons and cases are transported by hand trucks to shelf locations, where individual items are placed in stock. Order pickers (customers) select desired items and place them in carts for transport to a final inspection station (checkout counters). Here, scanners may be used to identify merchandise and unit price, and scales are used to help determine total costs. After packaging (bagging), the materials are shipped (by family car) to the point of use (the home), where they are received, unloaded, and placed in storage or routed to the kitchen for processing.

Conveyorized handling of your luggage at the airport is another example of material handling at work, as is the pneumatic system that transfers money and receipts between your car and the drive-in bank teller. Mechanized handling of medical supplies, food, and clothing is becoming a familiar scene in hospitals. Retail furniture warehouses provide excellent examples of handling equipment, including high-rise storage racks and narrow-aisle lift trucks.

At work, the mail cart pushed by an office clerk represents a simple manual handling activity. A more sophisticated version is the automated, driverless mail cart (automatic guided vehicle) that follows a programmed signal path in the floor.

Ages ago, primitive man also used material handling techniques, when he learned to move heavy objects on rolling logs. Early records show many uses of simple levers and slings. Handling was already well-advanced in ancient Egypt, and further developed in Greek and Roman civilizations. Uses of treadmills, cranes, pulleys, and other devices are well-documented in medieval literature.

The Industrial Revolution brought further material handling developments, and the fledgling automobile industry made giant handling strides in the early 20th century with conveyors and mechanical assembly lines.

It was not until World War II that material handling began to mature as a discipline, and to grow at a rapid rate. Manpower shortages caused by the war effort forced the development of mechanical methods for handling unit loads, and a major symbol of material handling — the fork-lift truck — came into its own as a versatile labor-saving tool.

Material Handling in Industry Fig. 1-2. Today, material handling equipment and systems have become indispensable in almost all plants and warehouses. Types of handling equipment range in size and complexity from a simple cart or two-wheel hand truck to large, computer-directed, integrated systems for storing, retrieving, and handling.

The purpose of material handling equipment and techniques is to provide needed materials at the right place and right time. This goal should be accomplished by maximizing space utilization and minimizing the number of handling steps, while performing the necessary ones as efficiently as possible. An old saying is, "The best handling is no handling at all." However, that is an ideal that can never be achieved. Goods and products always have to be received, sorted, counted, moved, stored, processed, and shipped. The key is how effectively these activities are carried out. When performed inefficiently, handling can be a costly expense. On the other hand, when well-planned and implemented, it can boost productivity substantially.

Depending on the nature of the industry, material handling may account for 30 to 75 percent or more of the cost of making a product. Yet its effect is often obscured by that of other, more familiar functions or disciplines. Thus, what is in reality a material handling problem may be perceived as a production problem, or a problem associated with inventory or quality control.

There are a number of telltale signs of material handling problems in a plant. Let's take a walk through *your* plant. Do you see cluttered docks? Excess manual effort? Wasted space? Obstructed aisles? Disorganized storage? These are but a few of the symptoms of ineffective material handling, Fig. 1-3. They are also opportunities for cost savings that should not be overlooked!

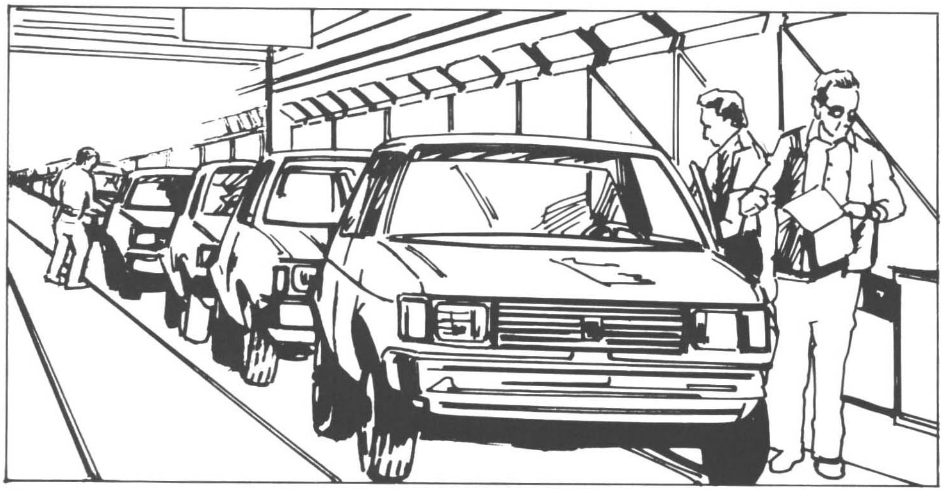


Fig. 1-2

A Tool for Cutting Costs Here are a few brief examples of how material handling has been put to work to cut costs at several facilities.

Receiving Dock Congestion

Problem: Bottlenecks occurred at drop zones in receiving area, where incoming materials were placed temporarily. Goods were difficult to keep track of, and confusion was becoming critical. It appeared the company needed more floor space and additional docks.

Solution: Three parallel lanes of gravity roller conveyor, served by a rail-mounted transfer car, were installed. All incoming materials are placed on one of the three lanes, depending on priority, and are moved away from the immediate dock area. At the end of a lane, the transfer car moves loads onto another conveyor leading to inspection. Cost of the manual system was minimal. Receiving congestion was ended, and the

Symptoms of Inefficient Material Handling

- Backtracking in material-flow path
- Built-in hindrances to flow
- Cluttered aisles
- Confusion at the dock
- Disorganized storage
- Excess scrap
- Excessive handling of individual pieces
- Excessive manual effort
- Excessive walking
- Failure to use gravity
- Fragmented operations
- High indirect labor costs
- Idle machines
- Inefficient use of skilled labor
- Lack of cube storage
- Lack of parts and supplies
- Long hauls
- Material piled up on the floor
- No standardization
- Overcrowding
- Poor housekeeping
- Poor inventory control
- Product damage
- Repetitive handling
- Service areas not conveniently located
- Trucks delayed or tied up
- Two-man lifting jobs

Fig. 1-3

size of the area reduced from 14,000 sq. ft. to 7,800 sq. ft. No added docks were needed, and the number of lift-truck operators was reduced from five to two.

Inefficient Storage

Problem: Machine operators constantly had to wait in long lines to get needed items from a plant tool crib. The crib housed up to 7,000 tools, accessories and equipment, worth about $100,000, in various bin locations. The area had grown in piecemeal fashion as plant operations grew, without any overall systematic planning. Over 450 operators had to face long waits at the crib an average of two or three times a day, for a total of more than 1,000 issues per shift.

Solution: The entire crib area was overhauled by organizing parts storage in a system of modular drawers equipped with adjustable dividers. The company saved 1½ min. of average issue time per item, or 33¾ hr. per shift. The number of crib attendants was reduced from five to three, and required storage space was cut from 700 to 350 sq. ft. The process of taking a complete inventory was slashed from 20 man-days to four. Cost of the new system was almost $17,000, but the investment was recovered in only 14 months.

Fragmented Operations

Problem: Warehousing operations were becoming too scattered and spread out to efficiently service production and distribution needs for a major multi-plant manufacturer. As the company grew, various off-site locations were leased, and effective material control was becoming increasingly difficult to maintain.

Solution: The company centralized all warehousing operations in one computer-controlled, high-rise storage and retrieval facility. The system utilizes nine 54-ft.-high storage/retrieval (S/R) machines and 3,400 ft. of conveyors. An investment of over two million dollars was involved, but by consolidating and automating warehousing in a single location, the company was able to reduce operating costs by 20 percent. In addition, external trucking was cut 48 percent and internal trucking 45 percent. Total space requirements were cut 38 percent, leased facilities were eliminated, and product damage was reduced significantly.

Broad Application Those few examples illustrate the fact that material handling can be a major tool for cost reduction, whether it be in a small application involving a few hundred dollars of investment, or in a large multi-million-dollar complex.

And, the opportunities for putting this cost-cutting tool to work exist in almost every area of a facility, from the receiving dock on through to the shipping area. In each case, appropriate equipment should be used to help reduce manual effort and increase efficiency of the operation. Here are some typical ways material handling equipment may be used in different areas of the plant:

Receiving Fig. 1-4. Incoming goods are received from trucks or railcars and moved over dockboards, then transferred into the plant by lift truck or conveyor.

Inspection Fig. 1-5. Typically, incoming materials are inspected to verify contents and quantities. The inspection may be a simple, visual task, or it may involve the use of scales, conveyors, or code-reading scanners. Whether the process is simple or complex, handling is an integral part.

Storage Fig. 1-6. In many cases, inspected materials are placed in a waiting or storage area prior to use. Racks, shelves, drawers, bins and other storage equipment can be used to store materials in an organized, efficient manner.

Fig. 1-4

Fig. 1-5

Fig. 1-6

Retrieval Fig. 1-7. Good storage procedures require that material be accessible and easily retrieved when needed. Various types of equipment can be used in bringing goods out of storage, such as carts, lift trucks, hoists, cranes, and automated storage/retrieval machines. In some cases, the same item of equipment may also transport the materials to a work station, assembly line, or other point of use.

Processing Fig. 1-8. The number of handling steps each part or item undergoes begins to increase rapidly as it moves to manufacturing and processing departments. Materials may be brought by lift truck or other equipment to individual work stations, or they may move continuously past work stations on a conveyor line.

During processing, the item may be lifted by a hoist, transferred by a conveyor, pushed by a gate, carried or stacked in a container, positioned and processed by a robot, or merely moved by hand. Often, materials must be stored or held up between operations. And, in-process and final inspections are frequently required. In all these activities, there often are opportunities for simplifying, combining, or eliminating handling steps.

Packaging Fig. 1-9. After processing, finished goods must be packaged for shipment. They may be packaged as individual items, or combined into unit loads, on pallets or in large containers. The interaction between packaging and other handling operations should be planned thoroughly in advance.

Shipping Fig. 1-10. The operating cycle is completed as goods move out onto the shipping dock for loading onto trucks, railcars, or other means of transport. In effect, the operations here are the reverse of those at the receiving dock. Although receiving and shipping activities may be combined at one dock in some plants, in others the areas are separated by great distances and are served by different crews.

Fig. 1-9

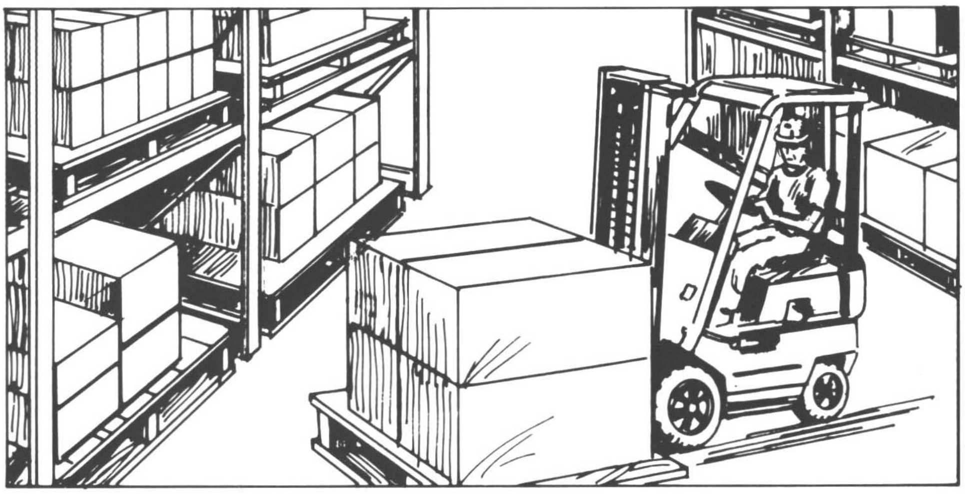


Fig. 1-7

Fig. 1-8

Support Activities In an industrial plant, material handling is not confined to just those activities that are directly related to the making of a product. A great deal of handling also is involved in various support activities, such as maintenance, construction, and equipment installation. Pollution control is another excellent example. Waste materials from the plant and office must be collected, compacted, and shipped out, or processed for recycling, Fig. 1-11. Liquid wastes can be drummed and removed under contract, and within increasingly stringent government regulations.

Distribution Fig. 1-12. Handling of a product does not stop once it leaves a plant. In many cases it is sent to a central warehouse or distribution center. Here it is unloaded, stored, and combined with other items as orders are assembled, packed, and shipped. A broad range of equipment and systems is applied to warehousing and distribution applications depending upon requirements.

Fig. 1-10

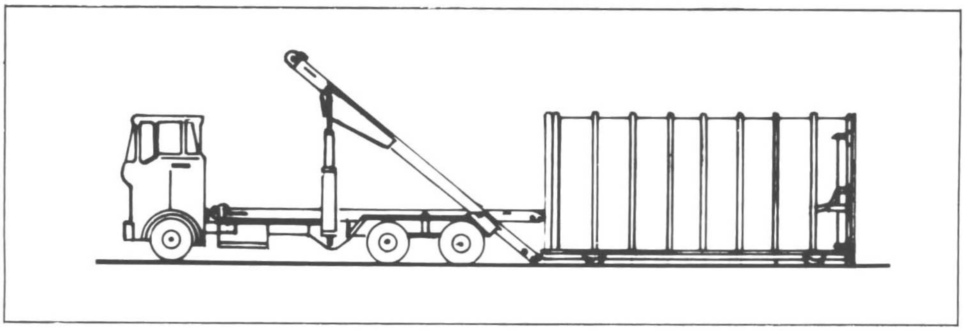


Fig. 1-11

Fig. 1-12

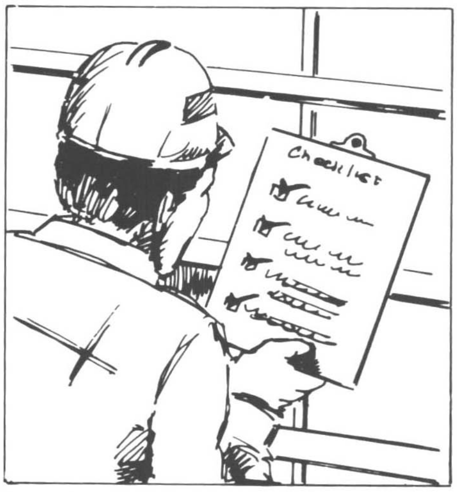


Fig. 1-13

A Safety Aid Good material handling can help improve the safety of an operation, by reducing or eliminating strenuous manual effort, and providing an organized and disciplined way of getting things done. Various classes of handling equipment from reputable suppliers incorporate safety devices designed to protect the operator from injury.

Selection Factors Fig. 1-13. Obviously the type of equipment used for a specific application may range from a simple hand cart or gravity chute to a programmable robot or a high-rise, automated storage and retrieval system under computer control.

In order to use equipment effectively, one must realize that in most cases the solution to a material handling problem does not consist merely of selecting a particular piece of hardware, such as a section of conveyor. Handling should not be looked upon as an isolated activity. Rather, it 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 chosen.

Chapter 2
Scope and Objectives of Material Handling

Properly applied material handling can improve operations in the following ways:

Reduced Costs The cost of an operation can be reduced by eliminating unnecessary or repetitive handling, and by integrating handling steps with material flow through the plant.

Reduced Labor Good material handling practices will avoid strenuous manual effort and will usually reduce labor overhead.

Increased Safety Reducing strenuous labor and unsafe manual tasks increases the safety of an operation. Mechanized systems equipped with safety interlocks can reduce operating hazards significantly. And, safety is enhanced when activities are performed in an organized, planned manner.

Increased Capacity Material handling can increase the capacity of an existing facility by efficiently using available space for work and storage, promoting effective inventory control, and increasing throughput with mechanized equipment.

Reduced Waste Better in-process handling will improve product quality, reduce scrap, and minimize damage. Efficient handling also reduces waste by improving inventory control.

Improved Service Better handling methods will help serve customers more efficiently, ensuring that their supplies arrive when needed, and with a minimum of damage.

Higher Productivity Effective material handling will increase employee productivity, improve machine utilization, and help make a firm more competitive.

Types of Materials Handled

What is the "material" in material handling? It can be any substance from which a product is assembled or packaged for further processing or sale. There are two broad categories — units and bulk materials, Figs. 2-1 and 2-2.

Units or Items These are separate, individual parts, goods, or assemblies, which can include car bodies, engine blocks, bottles, cans, packages, cartons, crates, tennis balls, pallet loads of bricks, shoes, nuts, bolts, dresses, or airplane wings.

Bulk Materials Generally these substances are stored and handled in volume, often in unpackaged form. Examples include dry powders, granules, and lumpy materials, such as coal, fertilizer, plastic resin, sulfur, and salt. Bulk materials also may be liquids, such as oil, solvent, and a variety of petroleum products and liquid chemicals.

Obviously, handling procedures and types of equipment to be used depend on the nature and configuration of the material, as well as its role in the manufacturing or distribution scheme.

All industries are involved in material handling in various ways. Typical industries in which material handling plays a major role include manufacturing, metalworking, chemical processing, petroleum refining, mining, warehousing and distribution, food processing, and power generation and distribution.

Elements of Material Handling

Although the nature of the material, the handling approach, and the type of equipment used will vary widely, there are certain elements that are common to solving any material handling problem, and which must be included in any handling analysis.

Basic handling elements include motion, time, quantity, and space. Materials must be *moved* from point to point during processing and packaging. Further, they must be handled within certain *time* constraints. Parts

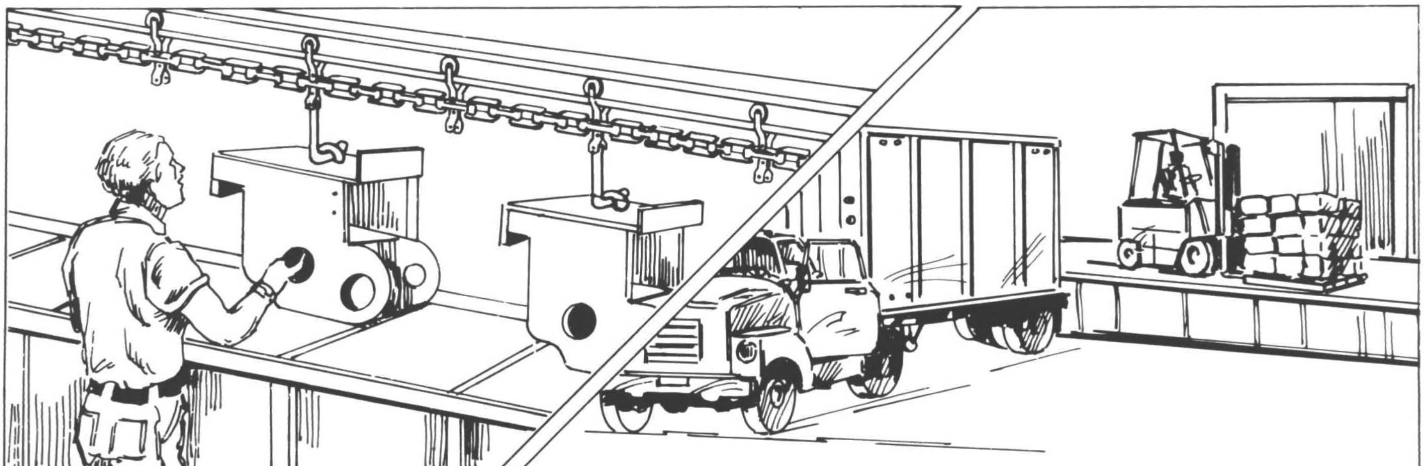


Fig. 2-1
Examples of unit handling.

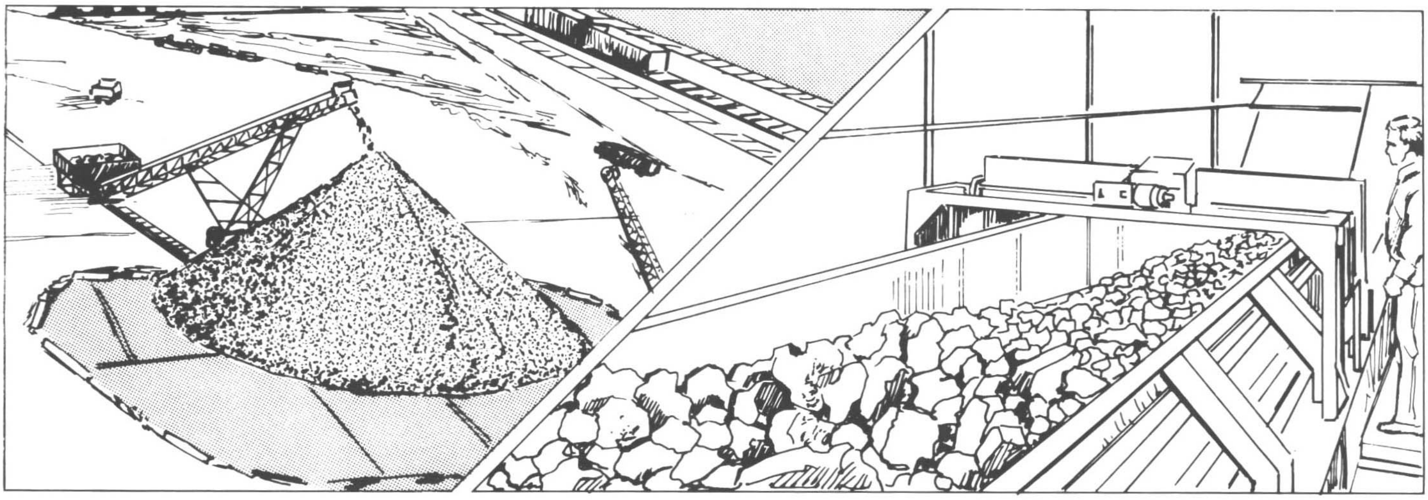


Fig. 2-2
Examples of bulk handling.

must be provided at work points when needed, and in the *quantities* required. Finally, all handling, whether involving movement or storage, must be accomplished within the *space* available in the department or plant building.

A good way to begin evaluating a material handling problem is by considering the classical "Material Handling Equation": Why? = What? + Where? + When? + How? + Who?

The first question to be answered is *"Why?* are we contemplating this activity in the first place? What is the objective?" It may be merely to move one item from point A to B within a corner of the plant, or it may be to provide a major warehouse center that will serve computer-linked distribution points throughout the country.

Example: One firm noted recently that a great deal of time and effort were being expended on receiving inspections for certain types of raw merchandise. The incoming materials had to be placed in a waiting zone, then moved to an inspection area, inspected, and moved to storage prior to processing.

A thorough study of inspection records and vendor reliability history revealed that little was being accomplished with receiving inspection for this particular category of materials. It was something that simply "had always been done that way in the past." Eliminating this step saved a great deal of space and personnel time, and eliminated rehandling — simply by asking the question, "Why are we continuing to perform this particular operation?"

"What?" refers to the type of material to be handled, as classified by group, type, and physical characteristics. Typical classifications are shown in Table I.

Example: A major plastics manufacturer stored bulk quantities of various grades of plastic resin (powders and pellets) in large silos equipped with conical hopper bottoms. The discharge opening at the bottom of each of the identical silos was sized to fit the dimensions of a rotary valve which fed into a pneumatic conveyor. Equipment design was based on tests conducted on samples of material the plastic company provided to the silo manufacturer.

The system worked fine for a few days at a time, but then bridging inevitably occurred, material stopped flowing, and production was halted.

Engineers finally determined that the operation only worked well with one or two grades of material. With the other grades, material flow was erratic at best, and flow stoppages were likely, particularly when atmospheric humidity was high.

The mistake this plant made was to treat different product batches as though they contained identical material. In reality, there were different grades of product, with different degrees of moisture content, and material flow characteristics varied widely among different batches. As a result, the existing handling system worked well for some batches, but not for others. Thus, the question *"What?"* had not been fully answered when the equipment was selected.

"Where?" describes the move. Data include the travel path, distance to be moved, and equipment and building limitations to movement.

Example: Consider the two alternative ways of handling a bulk raw material ingredient in Fig. 2-3. In one case, several men unload a boxcar full of bagged material by placing the bags on pallets and moving the pallet loads with fork trucks. Under certain conditions, this may be an efficient approach. In other cases, however, it may be less costly to receive the same material in enclosed hopper cars and use a pneumatic conveyor for unloading. Factors that can help influence the decision include raw material characteristics, travel path, flow rate, labor needs, delivery rates, and seasonal variations.

The quantity to be handled also must be considered. This is part of the *"When?"* question. It includes the amount of material moving in a given period of time over a specific route, as well as the condition of the load (configuration, makeup of load, batch

Table 2-I
Characteristics of Materials

A. Material Categories			
	Physical State		
Material type	Solid	Liquid	Gas
Individual units	Part, subassembly, bottle, coil	N.A.*	N.A.
Containerized items	Carton, bag, tote box, pallet, bin	Drum	Cylinder
Bulk materials	Plastic resin, sand, cement, coal, granular products	Liquid chemicals, solvents, gasoline, liquid sugar	Oxygen, nitrogen, hydrogen, carbon dioxide

B. Characteristics Affecting Movement and Handling	
Category	Characteristics
Size	Length, width, height
Weight	Weight per item, or per unit volume
Shape	Round, square, long, rectangular, irregular
Other	Slippery, fragile, sticky, explosive, frozen

*Not applicable

sizes). Seasonal or periodic variations also must be considered. (Is one boxcar received per month, or one per day?) *"When?"* also includes the point in time that materials are to be delivered — to the receiving dock, the storage area, the work station, the packaging line, and the shipping area.

"How?" refers to the handling method to be employed. It includes the plan or scheme for the operation — including the layout — and specific techniques and equipment that may be required. For example, had the pneumatic conveying approach been chosen in the last situation, the general layout and flow path dimensions would be specified along with details on air pressure, conveying line size, system horsepower, and other pertinent technical data. Table II provides a general guide to selecting equipment for a number of material handling applications, many of which are found in small to medium-size plants.

Labor requirements also should be specified. This item is part of the *"Who?"* — the final, all-important human factor in the equation, which defines responsibility as well as manpower needs.

Example: One company was find-

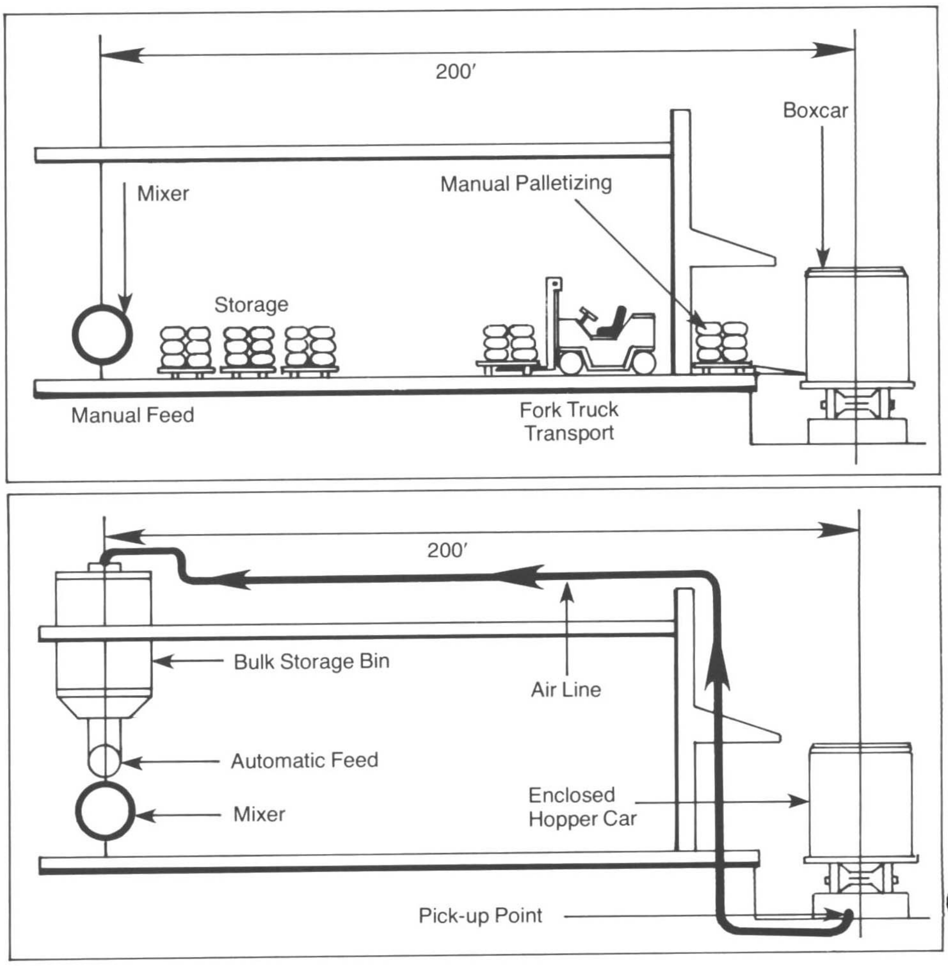


Fig. 2-3
Alternate ways of transporting a dry bulk ingredient from outside receiving area to a mixing operation in the plant.

Table 2-II
Typical Material Handling Applications*

Type of load	Load size	Load weight	General shape	Travel Path		Material Flow Requirements		
				Length	Direction	Throughput	Condition	Other
Pallet, unit load	48″ x 40″	3,000 lb.	cube	150′ (25′ one way)	horizontal vertical (lift truck)	15 moves/hr.	indoors	no conveyors, trucks only
Cartons, boxes	16″ x 14″ x 14″	25 lb.	cube	150′	horizontal	30 pieces/hr.; 300 lb. on conveyor at one time	ambient temperature only	flat carrying surfaces
Drums	22½″ dia. x 36″	500 lb.	cylindrical	12-15′	vertical			
Bags	9″ x 18″ x 36″	50-100 lb.	oblong	20′	inclined			
Dry bulk materials	0-2½″ particle diameter	100 lb./cu. ft.	irregular	500′ 85′ 250′	horizontal vertical (bucket elevator) inclined	350 tons/hr.	product at ambient temperature only	multiple product usage or extremely fine material under 200 mesh

*The intent of this table is to show some common conditions found in many plant or warehouse operations. There are, of course, many material handling applications that fall beyond the arbitrary boundaries of this table.

ing that the performance of a new mechanized handling system was consistently poorer during the second shift of daily operations. Output was below norm, and shutdowns seemed to be longer and more frequent.

Investigations revealed that, by and large, personnel on the second shift had not been brought into the planning phase of the project, and had only limited participation in start-up activities. As a result, they felt little identity with the system, and little or no stake in making it work. In addition, only a skeleton maintenance crew was assigned to the second shift, so that maintenance support was often delayed or not available. The important *"Who?"* question had not been thoroughly evaluated in this case.

Relationships to Other Functions Material handling is never performed in a vacuum, as an entity unto itself. Rather, it is an integral part of other activities and functions, including production, quality control, plant engineering, manufacturing engineering, inventory control, industrial engineering, warehousing, packaging, safety, and environmental control. The knowledgeable engineer and manager must be able to identify the material handling problems that exist within these other functions. Further, he must treat them as handling problems, not permitting them to be obscured as "production problems," "inventory problems," and the like. Otherwise, he may be treating the symptom of the problem, rather than the cause.

Chapter 3
Material Handling Equipment

The Equipment Decision

Choosing the right equipment — or equipment system — for a handling task can be a challenging job. A number of key factors must be kept in mind before the selection process is attempted.

1. Define the problem. It is amazing how often the real problem requiring a handling solution is not understood or fully analyzed. Often the first question that should be asked is, "Does this handling step really have to be performed at all?"

2. Look to the future. Remember — throwing in a section of conveyor, or putting in another row of shelving, may provide a temporary solution today, but will it create more problems than it solves in the future? Equipment selection should be planned with an eye to the future.

3. Remember the systems concept. Rarely if ever is an activity performed in a vacuum, without affecting other operations or being affected by them. Remember that the equipment being selected should play a part in the overall goals of the facility. It's not confined to one small corner of the plant. An individual conveyor or lift truck is part of a total *material handling system!*

4. Keep it simple. Don't go in for unnecessary sophistication when it's not warranted. For example, take advantage of gravity when possible. Make sure your existing equipment is fully utilized before additional investments are made. Make sure qualified personnel are available to take care of the equipment after it is purchased and in the plant.

5. Don't overspecify. It makes little sense to buy the most expensive heaviest-duty equipment available for a light-duty operation, or one with a short anticipated life. Likewise, whenever possible, use a standard design instead of a more costly custom piece of equipment.

6. Check the alternatives. Don't select a particular way of accomplishing the job on the advice of just one equipment supplier. There may be better, less expensive methods and equipment alternatives that you are overlooking.

Basic Types of Equipment

As noted previously, there are two broad categories of materials that require some form of handling: units (individual items, packages, assemblies, pallet loads), and bulk materials (powders, pellets, tank car volumes of liquids). Handling equipment is generally classified into the same two broad categories. This discussion covers both types.

Unit Handling Equipment

Conveyors transport materials along fixed paths. Their function may be pure transportation, or they may move items through various stages of receiving, processing, or assembly. A familiar use of the conveyor system is the progressive assembly line, pioneered in the automotive industry.

Gravity conveyors provide the least costly method of moving objects between points in a plant. Generally, their cost is only a small fraction of that of powered equipment. Chutes, slides, and gravity wheel or roller conveyors are typically found in this category of equipment.

Motor-powered conveyors include a variety of in-floor, floor-mounted, and overhead types. Powered roller — or "live roll" — conveyors move packages and other items horizontally and up 5- to 7-degree slopes without manual aid. Belt conveyors are normally used for inclines of up to 15 to 20 degrees.

Floor-mounted chain conveyors use single or multiple-strand chains to convey heavy products or bulky unit loads. Materials can be conveyed directly on chain links, or they may be carried or pushed by special attachments such as slats, flights, and bars.

Overhead chain conveyors utilize a series of trolleys supported from overhead beams or tracks. Load carriers are suspended from individual trolleys.

The power-and-free conveyor is a special type of trolley conveyor that has load carriers suspended from a second set of trolleys running on an independent or free track. Load carriers can be disengaged from the chain and accumulated, or switched onto spurs. These conveyors are used where loads must be directed onto spur lines, halted for work or inspection, and accumulated for storage.

Another special type of overhead conveyor tows wheeled carts along specific paths on the floor.

In-floor towline conveyors utilize a power-driven chain, traveling in a sub-floor track to propel carts along straight runs or along various combinations of main lines and spurs.

Hoists, monorails, and cranes are used for a variety of overhead handling jobs. A hoist typically consists of a hook, a lifting medium — such as a chain or rope — and a drum or container for storing unused chain or rope. Hoists may be manually operated, or driven by electricity or air.

A monorail is a single-beam overhead track whose lower flange serves as a runway for a hoist trolley. Through the use of switches, turntables, and other path-altering devices, the monorail can be made to follow a predetermined fixed path while serving various stages in processing or assembly.

A crane also typically involves a hoist traveling on a trolley. Frequently, the trolley also may be transported — as in a bridge crane — along runways, to provide wide as well as long overhead handling capability throughout the plant, or within a department or bay.

Cranes may be manual, electric, or pneumatic. Most larger cranes are electric. Some include cabs that permit the operator to ride with the load. Others are operated by push-button controls from the floor, or by remote radio controls. Depending on the type and service classification, cranes can handle loads ranging from several hundred pounds to 500 tons.

Specialized cranes — such as jibs and gantries — are used to provide localized secondary handling for specific operations, freeing the large overhead crane for general-purpose, heavy-duty jobs.

The jib crane has a horizontal beam — on which a hoist trolley rides — cantilevered from a vertical mast and pivoted at one end. It has a broad range of coverage within its rotary path. The gantry has a bridge for trolley travel fixed rigidly to the

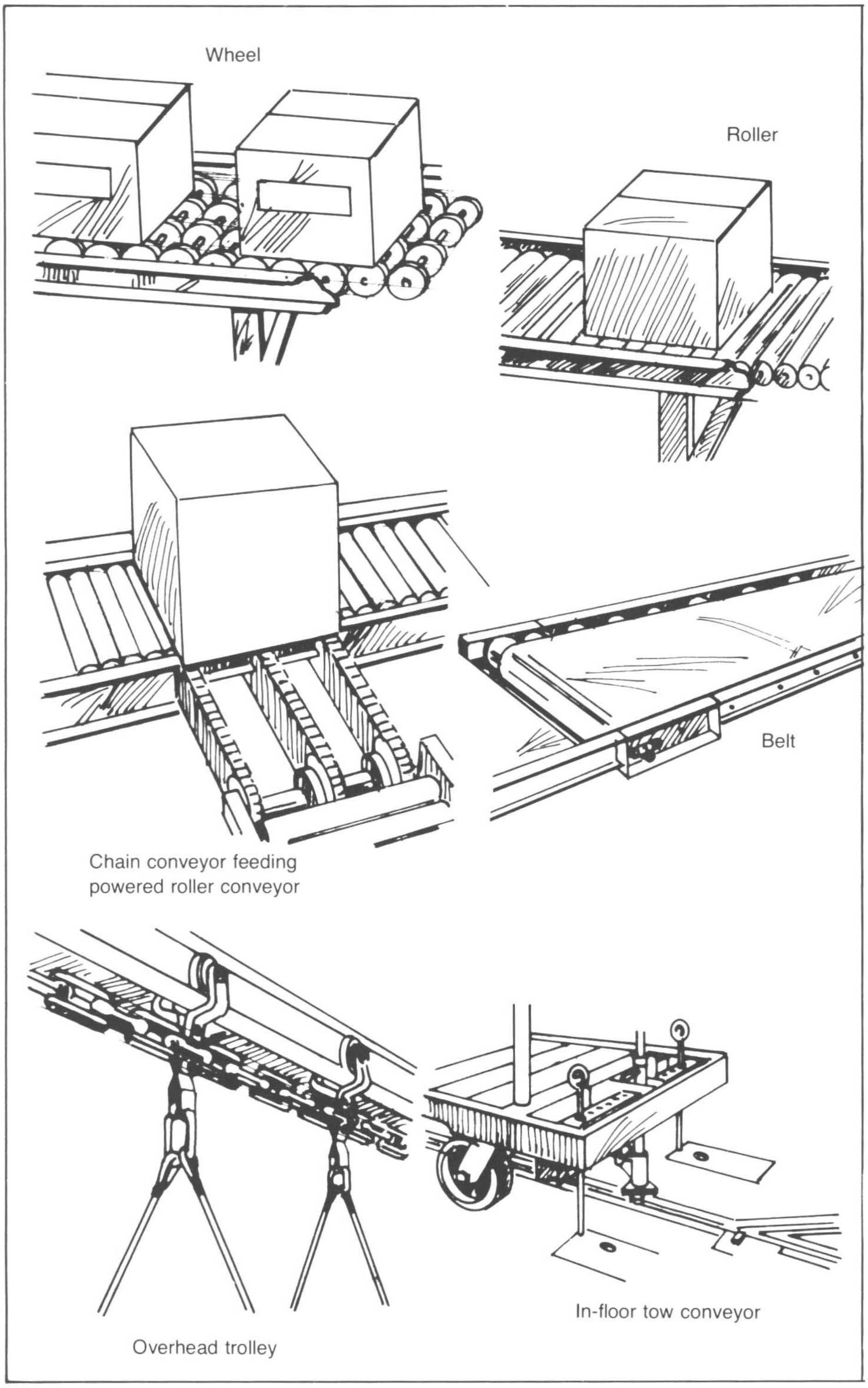


Fig. 3-1
A few common conveyor types.

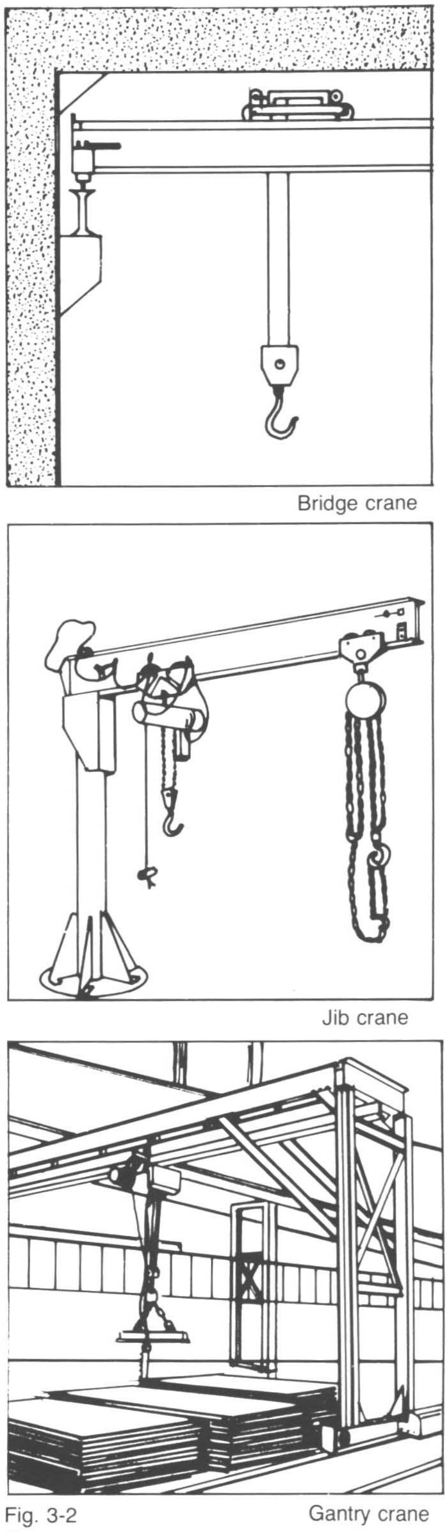


Fig. 3-2
Common crane types.

ends of two supporting columns. The wheeled columns move along a track. A semi-gantry, often used under an overhead crane, has one of its bridge ends fixed to a track-riding column, but the other end rides on a runway mounted to a building wall or to auxiliary columns.

Industrial trucks provide flexible handling of materials along variable flow paths. One of the most familiar types is the fork-lift truck, which uses a pair of forks riding on a vertical mast to engage, lift, lower, and move loads. Lift trucks may be manually propelled or powered by electric motors, gasoline, LPG, or diesel-fueled engines. With some models, the operator walks behind the truck. On others, he rides on the truck, in either a standing or sitting position.

Lift trucks are very effective in lifting, stacking, and unloading materials from storage racks, highway vehicles, and other equipment. They are also used for short-run transporting of goods in the plant or warehouse.

Some lift trucks are designed for general-purpose use, others for performing specific tasks such as stock loading in narrow aisles. And, many trucks can be fitted with attachments for handling special loads such as long items, bales, rolls, drums, and appliances.

Other common industrial trucks include hand trucks, tow tractors, orderpickers, platform trucks, driverless vehicles (that follow an electric guide signal in the floor), personnel and maintenance carriers, and power sweepers. Thorough training of operators and maintenance personnel is a must for successful use of those classes of equipment.

Unitizing equipment is used to combine loose items or individual packages into loads that can be handled as large units. Unit-load handling promotes faster movement of goods, permits personnel to handle larger loads, reduces loading and unloading times, reduces inventory and space requirements, and cuts costs. There are many types of unitizing equipment, some of which are described below.

Pallets are familiar unit-load devices. Made of wood, plastic, or metal, they typically can be handled by lift-truck forks. They provide a platform base for assembling materials into unit loads.

Skids are single stacking platforms with horizontal runners or legs. They can be handled by platform trucks.

Slip sheets are low-cost, space-saving devices for assembling unit loads. The slip sheet is a paper-fiber or plastic sheet on which a unit load can be placed as it is on a pallet.

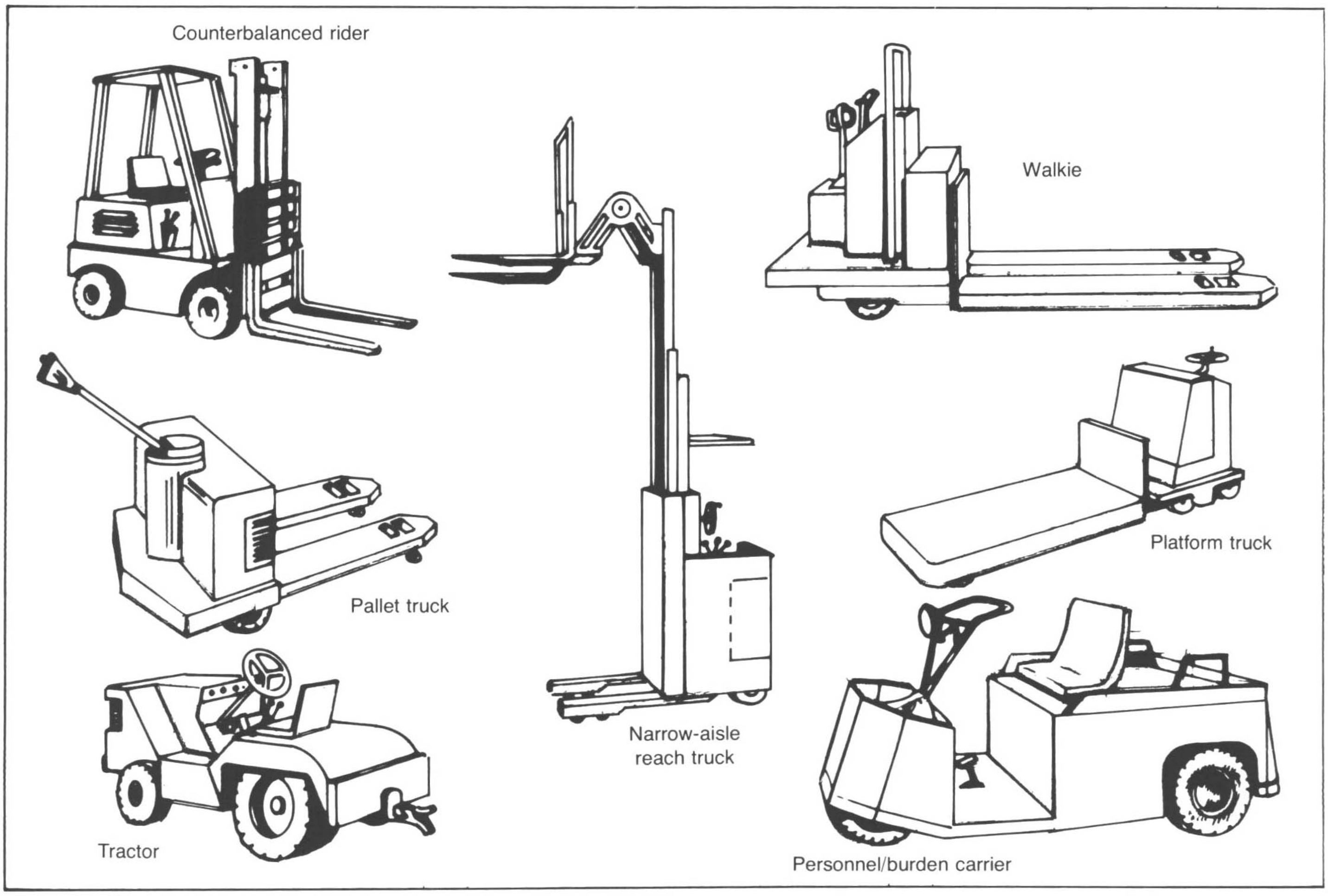


Fig. 3-3
Common powered industrial trucks.

Slip-sheet loads can be handled with a lift truck having special polished and tapered forks, or with a special lift-truck attachment called a push-pull device.

Containers of various types also can be used for unitizing loads. Sometimes called tote boxes, gons, or tubs, containers of this type not only store parts, but are also used for in-process handling and movement of materials.

Containers may be sheet metal, welded rod, or wood. Some are solid; others have perforations, or may be made of wire mesh. Sliding or folding gates may be used to provide access to contents, and locking lids provide product security. Some units are equipped with bases, legs or other attachments to facilitate lift truck or crane handling. Many containers can be nested or stacked for air space and floor space savings.

Strapping provides a means of securing unit loads — such as those on pallets — during transport. Hand tools or powered machines can be used for applying steel or various types of plastic strapping over loads.

Film-wrapping techniques also can be used for unitizing. With shrink-wrapping, a part of subassembly is encased by a plastic film that is shrunk over the item by heat application to form a tight, sturdy package or unit load.

Stretch wrapping is accomplished without application of heat. Plastic film is wrapped about a load — such as a pallet load — under tension to form a strong balanced load for shipment.

Some of the equipment in this category may overlap with a plant's packaging activities. In general, any interaction between material handling and packaging should be kept in mind when selecting equipment and designing systems.

Receiving and shipping docks represent the starting and finishing points for material handling in a plant, and should be designed to provide orderly flow of materials into and out of the facility. Smooth, gradual slopes should be provided in driveway approaches, and proper drainage must be included.

Access for lift trucks into truck trailers or railcars may be provided by dock plates or permanent, adjustable dock levelers. Dock levelers may be of the manual, counterbalanced type, or they may be mechanically or hydraulically operated. They have safety devices to prevent them from dropping when the delivery vehicle moves away, and locks to permit cross travel for lift trucks.

Dock doors often are equipped with weather seals to prevent entry of cold air into the plant, or escape of conditioned air from within. In addition, seals help provide an element of security. Shelters also may be provided to protect trucks and products during inclement weather.

Rubber bumpers and timbers on the dock face absorb the shock of a truck impact. Concrete pipe bumpers are often placed at building corners adjacent to truck maneuvering space.

Storage equipment is used to provide an orderly method — and accessible place — for storing parts, tools, assemblies, and various goods and packaged merchandise. Stacking on the floor invariably wastes space, and makes retrieval of desired items a tedious task. Effective use of cube space should be considered when planning and installing storage equipment.

Large items or assemblies, and palletized or containerized unit loads, typically are stored in pallet racks. Often loads are stacked and retrieved by lift trucks operating in aisles between racks. Special cantilever racks are used for handling long items such as pipe or furniture. Flow racks — with conveyorized storage lanes that bring materials to

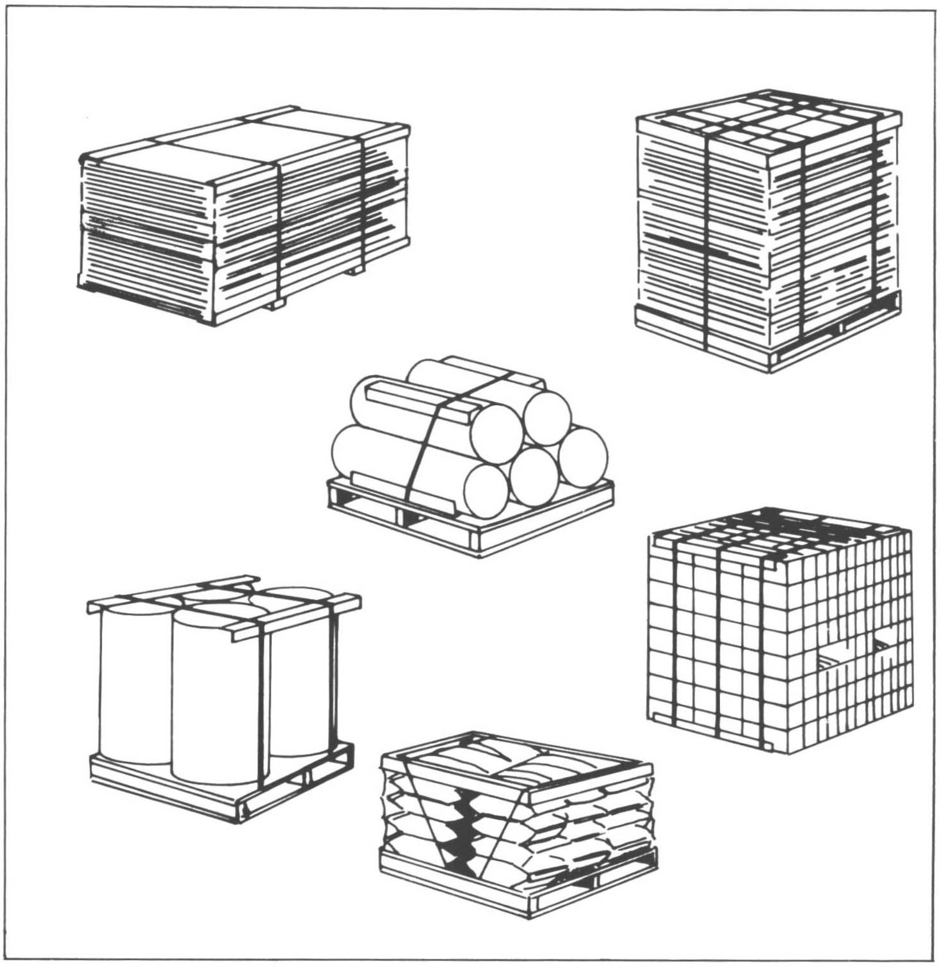


Fig. 3-4
Examples of unit loads.

the operator — find use for handling medium to fast-moving items.

Smaller individual items, fasteners, parts, and tools may be kept in shelves, bins, drawers, or stackable containers. Installations may be served by operators on foot, or on some type of mobile equipment, including rolling ladders, stock-picking trucks, or special order-picking machines. In some cases, parts are brought to the operator instead with carousels and mini-load systems providing this type of operation. The mini-load is discussed further on.

Revolving carousels are activated by pushbutton, foot pedal or other controls. Parts in suspended baskets, tubs, bins, and shelves revolve around defined loops until halted at a fixed operator station.

Automated systems are used for storage and retrieval as well as other handling operations. Both unit-load and parts storage can be partially or fully automated, if warranted by the application.

Unit-load, high-rise storage rack systems may range from 30 ft. to 100 ft. in height. Systems at the shorter end of the scale may be served in aisles by high-rise lift or turret trucks, or by special stacker cranes or storage/retrieval (S/R) machines. Larger systems typically involve automated S/R machines operating under computer control. A machine may operate in only one aisle for very high volume systems, or it may be shuttled between aisles by a transfer car. Generally the operator is positioned at a console located outside the aisle area.

High-density or deep-lane systems involve storage compartments — on each side of an aisle — which may hold up to a dozen or more loads. Loads are moved in and out of a lane by a traveling retrieval device that operates from an S/R machine or a transfer car. The system does not

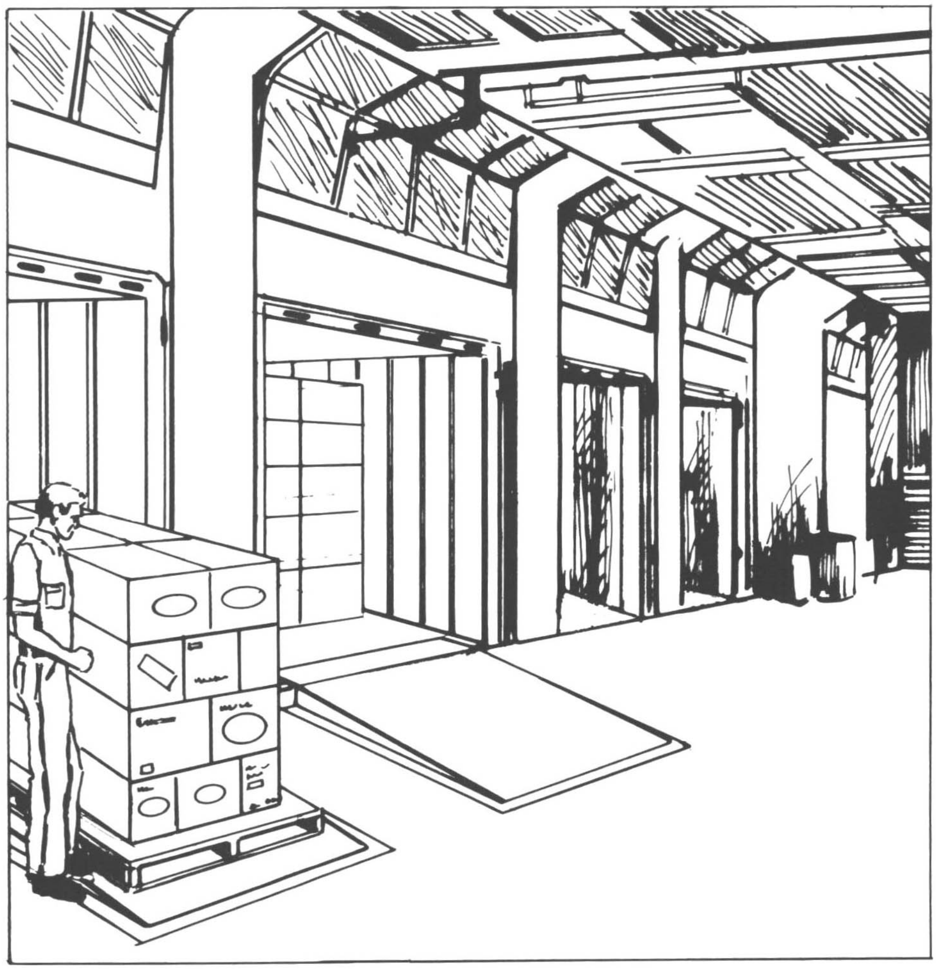


Fig. 3-5
Loading docks equipped with permanent dockboards.

Fig. 3-6a
Common ways of storing parts.

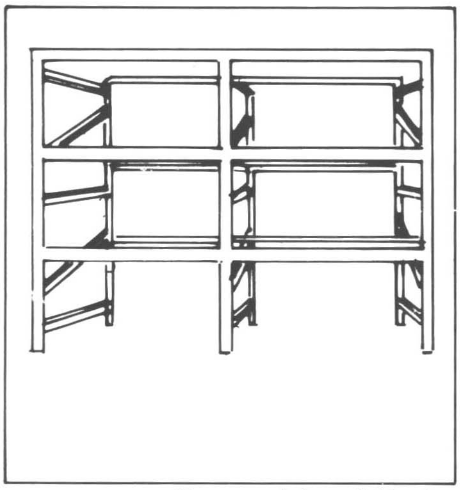
provide ready access to all individual loads, but if like items are stored in a lane, great density and efficiency of storage can be obtained.

For parts storage, high-rise shelving may range to 40-ft. heights, although most current installations are around 20 ft. Modular drawers, wire containers, and various types of bins also can be arranged in high-rise configurations. Smaller installations can be served by operators using manually pushed rolling ladders, ladder trucks, or stock-picking trucks. Man-aboard, mechanical order pickers are used for larger systems, when 500 or more items are in stock and inventory is turned five or more times a year.

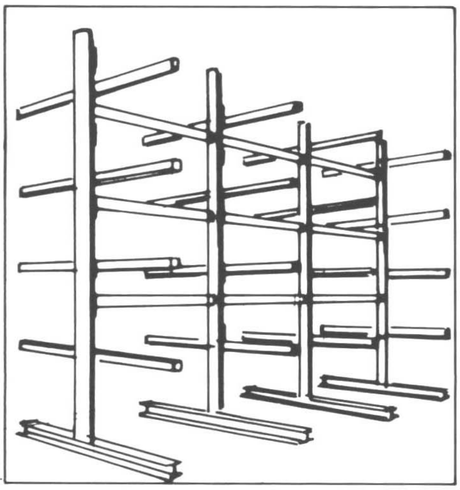
Another approach to automated parts handling is the mini-load system, which brings items to a stationary operator working from a control console. Parts are stored in high-density bin configurations within an enclosed structure. An S/R machine — or ministacker — automatically retracts desired coded bins and brings them to the operator station. While the operator is picking from one bin, the machine can be returning a previously used bin.

Whether for unit load or parts handling, automated storage and retrieval systems (AS/RS) can provide significant benefits, including reduced labor, higher throughput, better organization of materials, reduced building and land costs, improved inventory control, greater product security, reduced product damage, improved productivity, and better customer service.

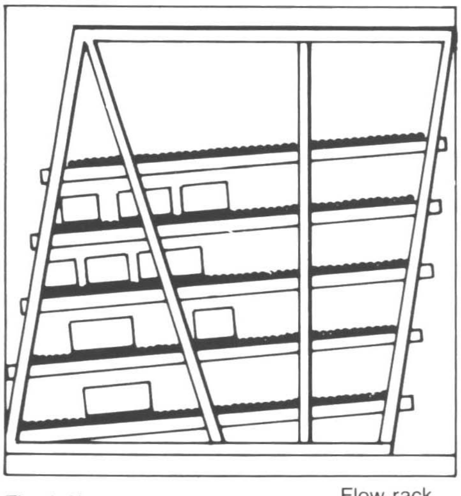
AS/R systems have provided many firms with a more cost-effective warehouse than afforded by low-bay, spread-out warehouse buildings. In addition, AS/R systems are increasingly being tied directly to manufacturing operations, and used for storage of in-process materials as well



Storage rack for pallet loads



Cantilever rack



Flow rack

Fig. 3-6b
Storage rack designs.

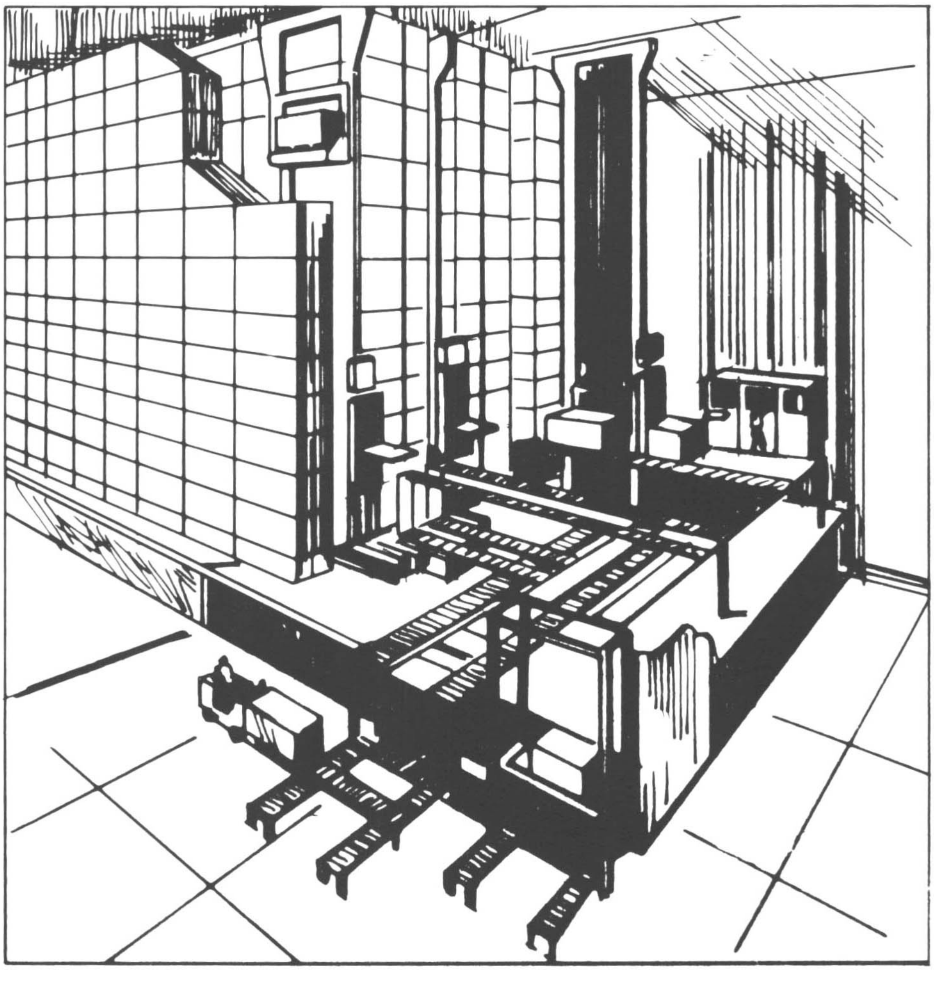


Fig. 3-7
Automated storage and retrieval system.

as finished goods. The tie-in is natural because of increased use of computer control in manufacturing systems. Automatically guided shuttle cars, driverless trains, conveyors, or robot vehicles can be used to transfer materials from the storage area to work stations on the manufacturing floor. Here, automated transfer machines and robot manipulators can be used to perform processing operations. Finished materials can be removed from the floor by transfer vehicles and routed back to storage or the shipping area. Combined into one giant system, these interacting operations provide a glimpse at the automated factory concept.

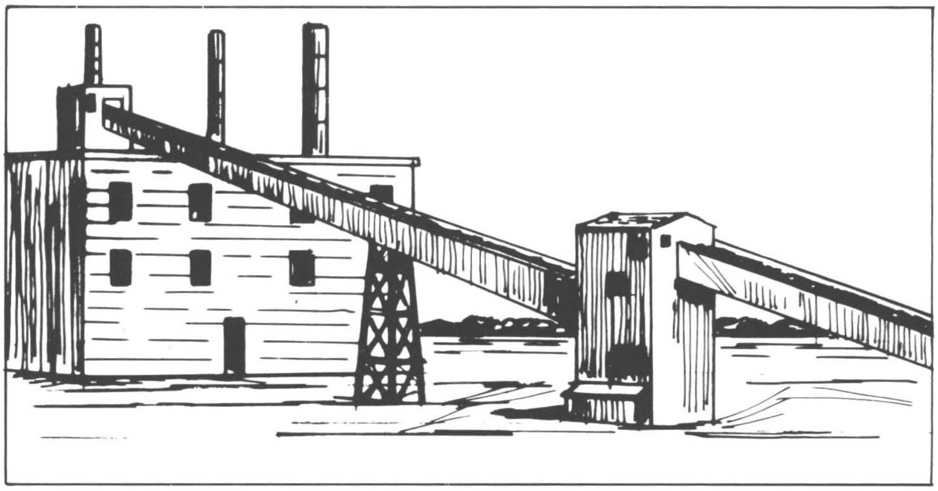


Fig. 3-8
Coal handling at power plant.

Bulk Handling Equipment

Bulk material handling is a complex and extremely broad subject, which cannot be covered adequately in these few pages. Instead, this discussion is limited to common aspects of in-plant handling of bulk materials. Some type of bulk handling is found in almost any type of facility, if only in the manner in which coal or other fuel is distributed and waste materials are removed. Many process industries are heavily involved with bulk handling.

Often the success or failure of a bulk-handling installation hinges on whether the characteristics of the material to be moved have been properly evaluated and incorporated into the system. Various charts and classifications of material properties are readily available.* In many cases, however, tests must be conducted on the specific material before equipment can be properly selected.

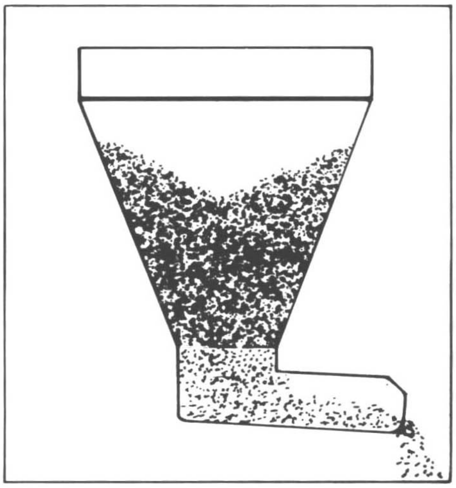


Fig. 3-9
Discharge bin for bulk solid material.

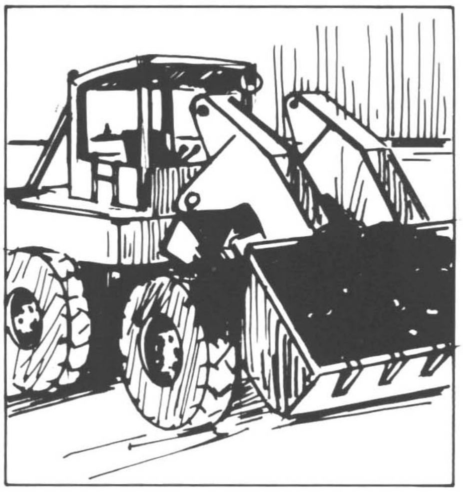


Fig. 3-10
Front-end loader.

Conveyors play a major role in bulk handling. Probably the most common type is the three-roll belt conveyor, which is a familiar sight at many manufacturing facilities, aggregate plants, and power stations. Other common bulk conveyors include chain types (including drag and flight), pneumatic conveyors, screw conveyors, vibrating units, and bucket elevators. Each has specific application advantages. Pneumatic conveying, for example, is not limited to straight-line conveying, and can provide dust-free operation. A very special type of bulk conveyor is the feeder, which is designed to discharge controlled amounts of bulk material in such applications as batching and mixing of food ingredients. Generally, bucket elevators and belt, vibrating, or screw conveyors are not self-feeding, so a bulk feeder serves as a metering device for such equipment.

Bins, hoppers, silos, and other vessels for storing powders and other bulk materials must be designed carefully, to promote proper controlled flow of materials. Most bin-flow problems can be traced to misapplication of handling equipment, and improper matching of bin geometry tests on samples of material to determine such key properties as friction angle, cohesion, compressibility, and air permeability.

Various yard handling tasks can be performed by wheel and track vehicles. Wheel loaders are used primarily for loading and carrying loose, stockpiled materials to central receiving areas served by a truck, conveyor, or hopper. Track machines are the rule for loading hard, compacted materials and for operating on rough terrain with poor ground

* "Classification and Definition of Bulk Materials," #550-1970, Conveyor Equipment Manufacturers Association, 1000 Vermont Ave., N.W., Washington, DC 20005.

support. Wheel machines are faster, but track vehicles have greater flotation, or greater resistance to sinking. Attachments can increase the versatility of these units significantly. The use of quick-coupling attachments can help one vehicle do the work of two or three specialized machines.

In planning a bulk handling system, layout and equipment selection are equally important. Developing the proper layout involves visualizing in three dimensions, and completely understanding the functions of interrelated items such as process equipment and auxiliary bins, chutes, gates, and feeders. Transfer points between units must be planned carefully. Dust control equipment often must be incorporated into bulk-handling schemes.

Controls

Control systems are increasingly important to material handling, particularly with the growth of semi-automated and automated systems.

An important component of any control system is a reliable input device, such as a sensor or other signal device. Photo-electrics have played an important role in the growth of this technology, as have other elements of automatic identification, such as laser scanners.

Basically, key parts of an automatic ID system are: 1) a machine-readable symbolic code that is affixed with a label or plate — or is printed directly on — a part, container, or package, and 2) a light-emitting scanner that can read the coded message and translate it into a usable input signal. Applications for automatic ID systems include control over conveyor and sorter operations, in-plant inventory systems, and shipping ability to provide real-time information for control or business planning.

The explosion in reliable and inexpensive computer hardware has brought about a revolution in computer applications to material handling.

Small computers dedicated to a specific handling task — such as controlling the operation of a conveyor or S/R (storage/retrieval) machine — can now be used as independent control elements. It is now becoming common to use onboard or onsite controllers or microprocessors to oversee a variety of handling operations. A coming trend is to tie in these localized computers with higher-level corporate computers into a hierarchy of business and control information processing. As a result, the systems approach can be applied to material handling in a manner not possible even a few short years ago. And, the technology is within the budget of modest-sized plants, as well as those of corporate giants.

Obtaining the Equipment

There are several approaches to acquiring material handling equipment — renting, buying, or leasing. Tax considerations, cash flow position, projected life of the project, and numerous other factors come into play in the equipment acquisition decision. The possibility of obtaining used equipment also should not be overlooked. In any case, equipment procurement frequently must be justified carefully to top management before approval is obtained. Details on options for obtaining handling equipment are covered more thoroughly in a later chapter.

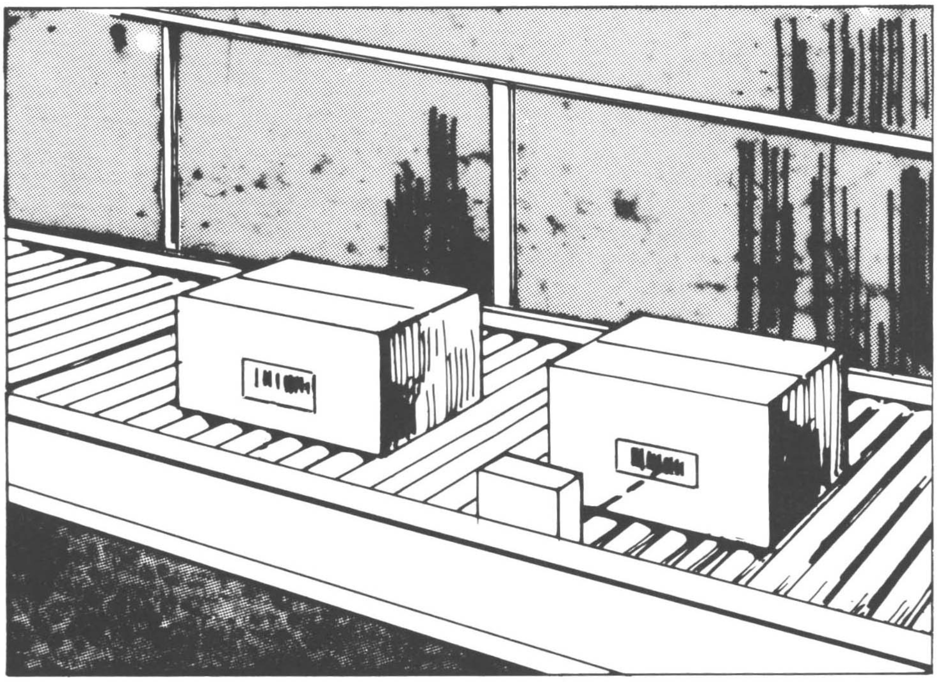


Fig. 3-11
Automatic identification system.

Chapter 4
Analyzing Material Handling Problems

Inefficient material handling can be the cause of many problems and losses in profit. The first step toward overcoming problems involving material handling is properly identifying them as such, then implementing the necessary solutions.

A number of problem-solving techniques is available. Some important ones are discussed in this chapter. Whatever techniques are used, however, it is important to remember that handling operations are not isolated activities, but rather are interrelated parts of a system. Simply stated, a system is a series of integrated actions or situations involving cause-and-effect relations that may be described logically or mathematically. It may be a production system, a warehousing or distribution system, or an entire factory or enterprise.

The following steps can be used in analyzing and solving handling problems — always keeping the systems approach in mind:

- Identify and define the problem
- Collect relevant data
- Develop a plan
- Implement the solution

Identify and Define

In an existing plant, a good starting point for identifying material handling problems is touring the facility, and looking for the material handling aspects of various activities that are observed. It's a good idea to take along a check sheet of the type shown here to make notations of what is seen. Another guide that may be useful is the listing of the common symptoms of material handling problems shown in Fig. 3, Chapter 1.

See if relationships can be detected between the problems that are observed — not just within a department, but also between departments. Remember, the goal is to optimize handling throughout the facility as a whole — somewhat different than optimizing it within each department viewed as a separate entity. If one is not careful, "solving" a handling problem in one area could well create a new one elsewhere. For example, installing a section of conveyor may achieve the goal of transferring products from point A to point B in one area, but it also could introduce a barrier to flow between adjacent departments.

Another useful guide is the listing of "Principles of Material Handling" shown here. These principles are a distillation of accumulated experience and knowledge on the part of many practitioners and students of material handling.

While moving along the tour, see if these principles are being followed in various operations — and spot instances where they are openly violated. If such cases are found, ask the question "Why?" At times, there will be sound reasons for not following a principle. For instance, although the use of gravity is a good general rule, in certain applications powered conveyors are the clear choice over gravity chutes.

Once the problem has been identified, its scope must be defined. For example, suppose considerable clutter and confusion are found at the receiving area. What is the scope of the problem? Is it limited to available space at the dock? Or, is part of the problem due to the fact that too many different load sizes and shapes are received from suppliers? Perhaps there is also a training problem, in terms of dock personnel.

Collect Data

Sometimes a problem cannot be fully defined until all relevant data are collected and analyzed. Data collection also is necessary before a solution can be carried out. This information-gathering step is most important. It should not be viewed as an unpopular, tedious task to be relegated to the most junior engineer available, or the project may never succeed. A solution can be only as good as the reliability of the data upon which it is based.

Some useful data may be derived from interviewing management, foremen, operators, vendors, and competitors, by consulting available technical and sales literature, and by making personal observations.

Generally, however, the task does not stop there. Usually information

Material Handling Checklist

- ☐ Is the material handling equipment more than 10 years old?
- ☐ Do you use a wide variety of makes and models which require a high spare parts inventory?
- ☐ Are equipment breakdowns the result of poor preventive maintenance?
- ☐ Do the lift trucks go too far for servicing?
- ☐ Are there excessive employee accidents due to manual handling of materials?
- ☐ Are materials weighing more than 50 pounds handled manually?
- ☐ Are there many handling tasks that require 2 or more employees?
- ☐ Are skilled employees wasting time handling materials?
- ☐ Does material become congested at any point?
- ☐ Is production work delayed due to poorly scheduled delivery and removal of materials?
- ☐ Is high storage space being wasted?
- ☐ Are high demurrage charges experienced?
- ☐ Is material being damaged during handling?
- ☐ Do shop trucks operate empty more than 20% of the time?
- ☐ Does the plant have an excessive number of rehandling points?
- ☐ Is power equipment used on jobs that could be handled by gravity?
- ☐ Are too many pieces of equipment being used, because their scope of activity is confined?
- ☐ Are many handling operations unnecessary?
- ☐ Are single pieces being handled where unit loads could be used?
- ☐ Are floors and ramps dirty and in need of repair?
- ☐ Is handling equipment being overloaded?
- ☐ Is there unnecessary transfer of material from one container to another?
- ☐ Are inadequate storage areas hampering efficient scheduling of movement?
- ☐ Is it difficult to analyze the system because there is no detailed flow chart?
- ☐ Are indirect labor costs too high?

Fig. 4-1

The 20 Principles of Material Handling

1. Planning Principle. Plan all material handling and storage activities to obtain maximum overall operating efficiency.
2. Systems Principle. Integrate as many handling activities as is practical into a coordinated system of operations, covering vendor, receiving, storage, production, inspection, packaging, warehousing, shipping, transportation, and customer.
3. Material Flow Principle. Provide an operation sequence and equipment layout optimizing material flow.
4. Simplification Principle. Simplify handling by reducing, eliminating, or combining unnecessary movements and/or equipment.
5. Gravity Principle. Utilize gravity to move material wherever practical.
6. Space Utilization Principle. Make optimum utilization of building cube.
7. Unit Size Principle. Increase the quantity, size, or weight of unit loads or flow rate.
8. Mechanization Principle. Mechanize handling operations.
9. Automation Principle. Provide automation to include production, handling, and storage functions.
10. Equipment Selection Principle. In selecting handling equipment consider all aspects of the material handled — the movement and the method to be used.
11. Standardization Principle. Standardize handling methods as well as types and sizes of handling equipment.
12. Adaptability Principle. Use methods and equipment that can best perform a variety of tasks and applications where special purpose equipment is not justified.
13. Dead Weight Principle. Reduce ratio of dead weight of mobile handling equipment to load carried.
14. Utilization Principle. Plan for optimum utilization of handling equipment and manpower.
15. Maintenance Principle. Plan for preventive maintenance and scheduled repairs of all handling equipment.
16. Obsolescence Principle. Replace obsolete handling methods and equipment when more efficient methods or equipment will improve operations.
17. Control Principle. Use material handling activities to improve control of production, inventory and order handling.
18. Capacity Principle. Use handling equipment to help achieve desired production capacity.
19. Performance Principle. Determine effectiveness of handling performance in terms of expense per unit handled.
20. Safety Principle. Provide suitable methods and equipment for safe handling.

Fig. 4-2

must be developed on the flow of materials and the moves that take place within the plant. Various graphical techniques frequently are used to generate this information.

For instance, in a manufacturing situation, a preliminary idea of material flow can be obtained by constructing an *assembly chart.* This graphical tool also shows the component makeup of the product, the relationships between parts, and the sequence in which components are assembled.

The operation process chart provides a more accurate designation of material flow patterns, including sequences of production and assembly operations. It also provides an idea about relative space requirements.

The flow process chart is a tabular record of steps performed in a given process. Symbols are used to differentiate between process operations, transportation, inspection, storage, and delays. This chart is limited to tracking the flow of only one item — or movement of only one person — at a time. However, the operation process chart can be combined with a flow process chart for each component to produce a diagram covering the travel of several items.

The flow diagram provides a graphical record of the steps performed in a process, superimposed on an area layout. It can be used to supplement the flow process chart.

The from-to chart uses a matrix representation of material movement between related activities. Besides establishing material flow patterns, it helps to determine locations of related activities. The chart can also help track the relationships between products, parts, and materials.

Activity relationship diagrams can be used to help lay out the flow of materials between departments. They can be particularly useful for determining locations of service departments such as maintenance shops, tool cribs, stockrooms, and battery-charging rooms.

Develop the Plan

Once the data are collected, they must be compiled into useful formats and evaluated in order to develop a plan of attack on the problem. Some problems will be relatively straightforward, while others require considerable analysis.

Formats for grouping data often take the form of various tables, charts, and graphs, and utilize various evaluation techniques. One common technique, work-volume analysis, is described in detail in the next chapter.

Another ingredient for formulating a solution is a thorough knowledge of types of material handling equipment available, their advantages and disadvantages for specific applications, their purchase, installation, and operating costs, and their adaptability to different operations. (A good way to gain knowledge is to visit other plants, have discussions with vendors, read business publications and books on material handling, and attend short courses, seminars, and trade shows).

When a solution is being planned, don't settle on just one scheme without thoroughly considering other approaches. Remember, once chosen, the system may be around for a long time. Whenever possible, test alternative proposed solutions.

Tests can be conducted on a physical model of the proposed system, using samples of the materials that are to be handled. Alternative approaches also can be tested effectively with simulation models and other quantitative techniques, utilizing a computer. Various quantitative techniques are discussed in the following section of this chapter.

Alternative approaches also should be tested against economic measures in order to arrive at the optimum system depending on the system size. Factors such as cash flow, investment tax credit, and income tax may become critical in the evaluation. A subsequent chapter covers economic justification factors in detail.

Implement the solution. After the strategy for solving the handling problem has been developed, the final step is to make the solution happen. Once the system costs have been established, approval for the

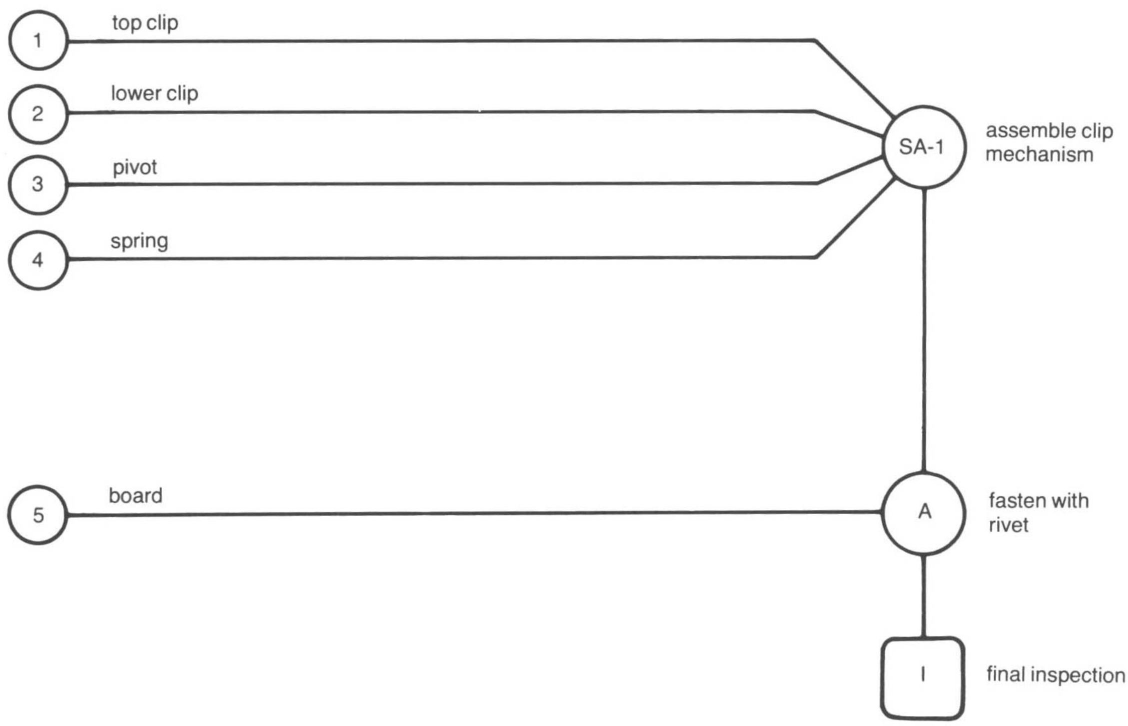


Fig. 4-3
Simple assembly chart for production of a clipboard shows component steps involved in the operation.

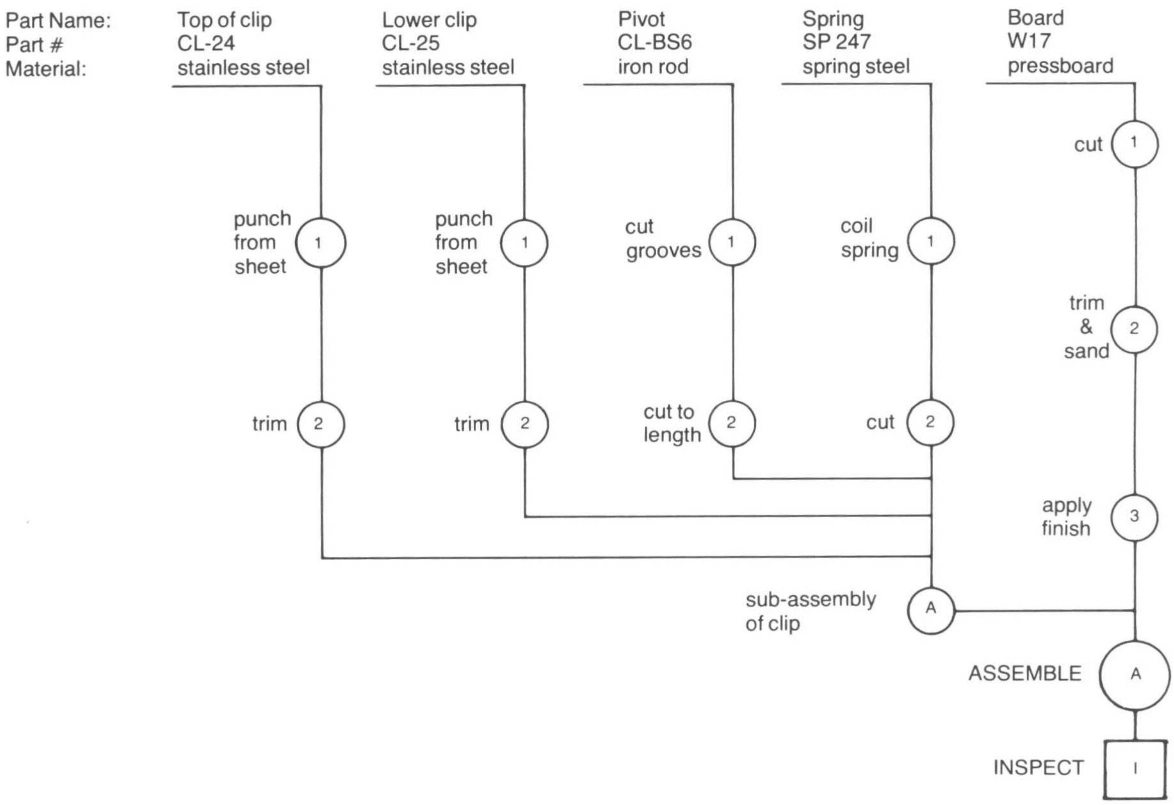


Fig. 4-4
Operation process chart is extension and expansion of assembly chart. It not only shows component steps, but also includes routing information. With this chart, the engineer can begin to develop some flow patterns, and begin to get an idea of relative space requirements.

Symbol	Name	Results
○	Operation	Produces, prepares, and accomplishes
⇨	Transportation	Moves
□	Inspection	Verifies
D	Delay	Interfere, waits
▽	Storage	Keeps, retains

SUMMARY	PRESENT NO.	PRESENT TIME	PROPOSED NO.	PROPOSED TIME	DIFERENCE NO.	DIFERENCE TIME
○ OPERATIONS	5					
⇨ TRANSPORTATIONS	9					
□ INSPECTIONS	1					
D DELAYS	2					
▽ STORAGES	3					
Distance Traveled	1485 FT.		FT.		FT.	

JOB	Manufacture of a tissue box
□ OPERATOR	
☒ MATERIAL	
CHART BEGINS	Receiving (raw materials)
CHART ENDS	Shipping (finished product)
CHARTED BY	T.P.C.

QUESTION EACH DETAIL	ANALYSIS	
	WHAT?	WHEN?
	WHY?	WHO?
	WHERE?	HOW?
DATE		
NUMBER		
PAGE 1	OF 1	

DETAILS OF (PRESENT / PROPOSED) METHOD	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	DISTANCE IN FEET	QUANTITY	TIME	ELIMINATE (POSSIBILITIES)	COMBINE (POSSIBILITIES)	SEQUENCE (CHANGE)	PLACE (CHANGE)	PERSON (CHANGE)	IMPROVE (POSSIBILITIES)	SAFER?	$ SAVED?	NOTES
1. Receive raw materials	○	⇨	□	D	▽	50											
2. Inspect	○	⇨	□	D	▽												
3. Move by fork lift	○	⇨	□	D	▽	40											
4. Store	○	⇨	□	D	▽												
5. Move by fork lift	○	⇨	□	D	▽	45											
6. Set up and print	○	⇨	□	D	▽												
7. Moved by printer	○	⇨	□	D	▽	120											
8. Stack at end of printer	○	⇨	□	D	▽												
9. Move to stripping	○	⇨	□	D	▽	165											
10. Delay	○	⇨	□	D	▽												
11. Being stripped	○	⇨	□	D	▽												
12. Move to temp. storage	○	⇨	□	D	▽	150											
13. Storage	○	⇨	□	D	▽												
14. Move to folders	○	⇨	□	D	▽	200											
15. Delay	○	⇨	□	D	▽												
16. Set up, fold, glue	○	⇨	□	D	▽												
17. Mechanically moved	○	⇨	□	D	▽	90											
18. Stack, count, crate	○	⇨	□	D	▽												
19. Move by fork lift	○	⇨	□	D	▽	525											
20. Storage	○	⇨	□	D	▽												

Fig. 4-5
Flow process chart tabulates steps and moves in a process, in this case for the manufacture of a small box with a printed label. Standard American Society of Mechanical Engineers (ASME) process elements and symbols are used. The first column from the left is the step number, followed by a brief description of the activity. In the next column, the symbol that best describes the activity is used in tracking the step-by-step flow from top to bottom. Improvement opportunities can be noted in the columns headed "possibilities," and additional information can be entered under "Notes." A single chart can be used to track the flow of either an object or a person — but not both simultaneously.

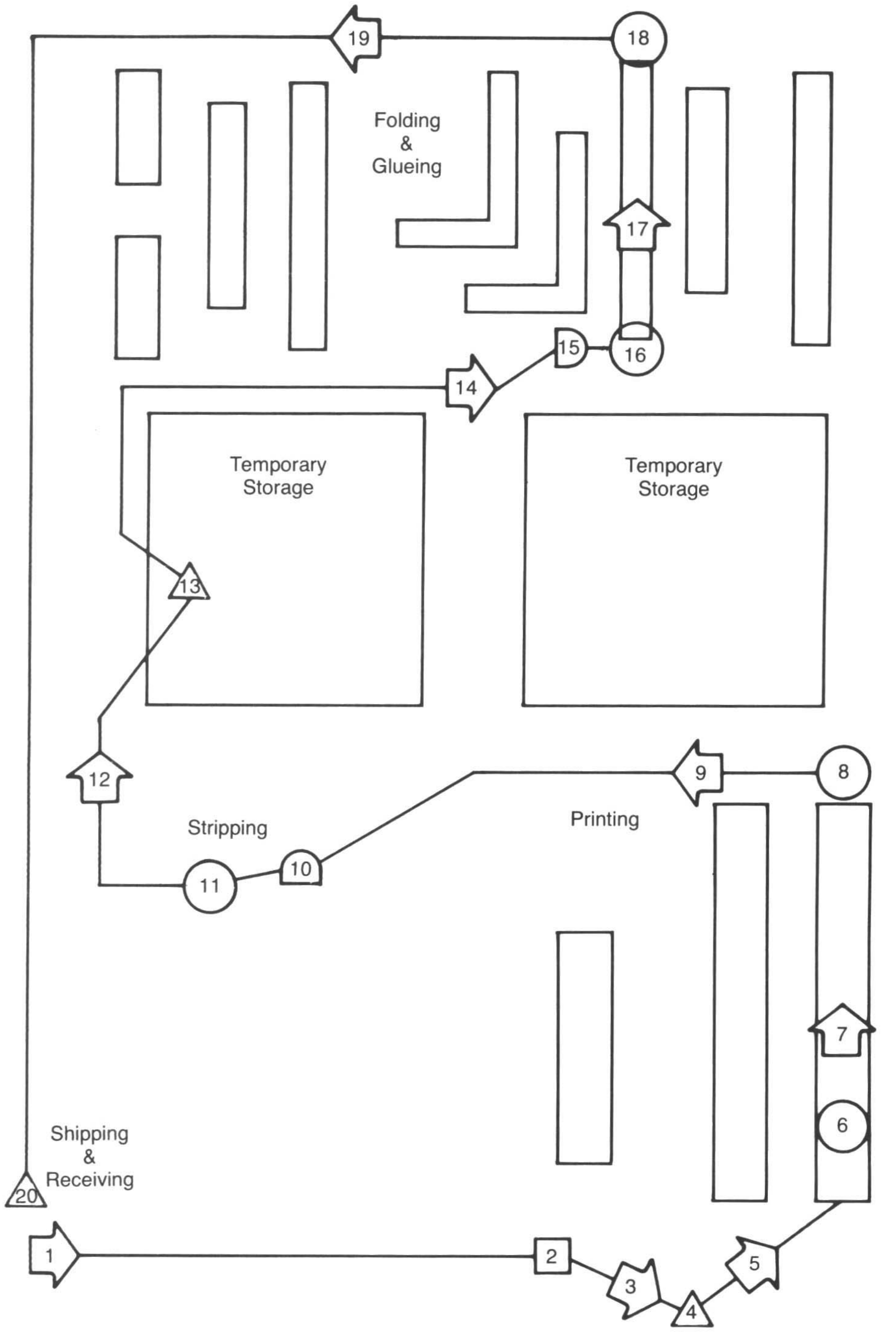


Fig. 4-6
Flow diagram tracks steps as they occur within area layout. Symbols and numbers correspond to those in flow process chart. Symbols are drawn as closely as possible to where the steps will actually occur. This chart helps in flow planning, and also can point out previously unforeseen problems.

project must be obtained from top management. In many cases, thorough, carefully prepared presentations will be required. Techniques of making presentations to management, and justification criteria, are discussed later. However, this is often the most crucial phase of the entire project, because typically it is competing against other projects for limited funds. Carefully prepared, written bid specifications typically are let to several vendors. Competing proposals must be evaluated closely to make sure all are quoting on the same type and grade of equipment and components. Other factors such as vendor reliability history and service capability also must be considered.

In some cases, major systems may best be procured with conceptual bidding and a negotiated contract. Methods of acquiring equipment and systems are discussed further in Chapter 7.

Hiring and training of personnel, developing a preventive maintenance program, and startup and approval of the system are other critical parts of the implementation.

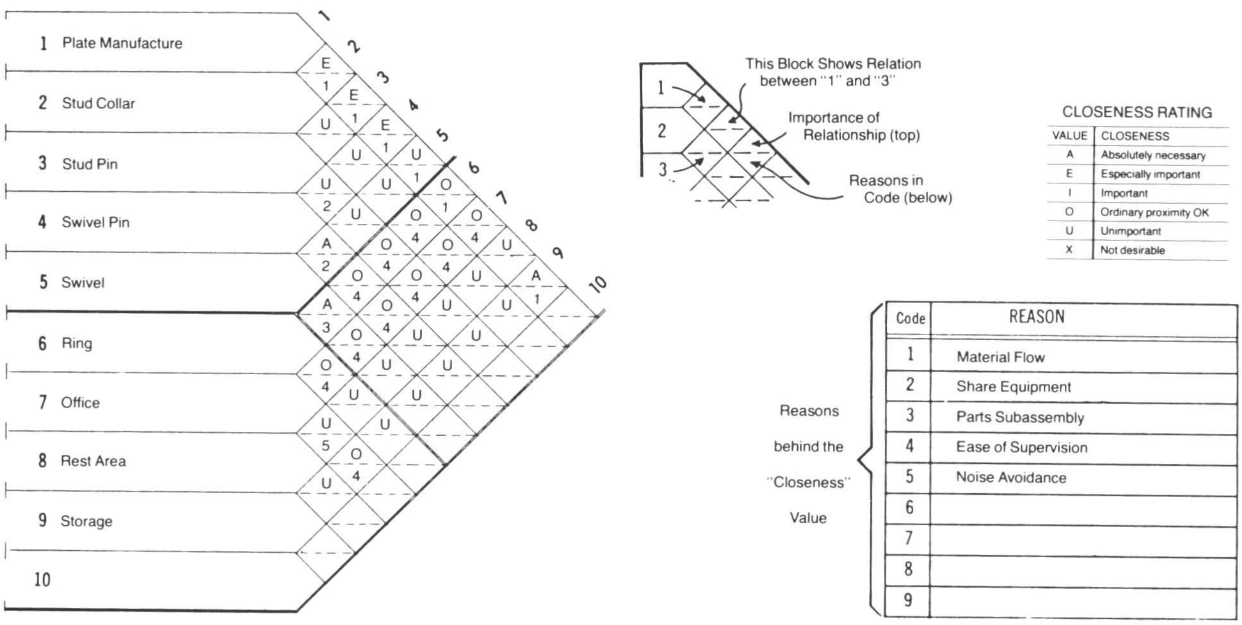
To / From	A	B	C	D	E	F	G
A		13	37	69	85	57	33
B	13		21	53	69	41	17
C	37	21		29	45	17	41
D	69	53	29		13	33	57
E	85	69	45	13		49	73
F	57	41	17	33	49		21
G	33	17	41	57	73	21	

A

To / From	A	B	C	D	E	F	G
A		15	5		4		
B			15				
C	2			20			
D						20	
E						4	
F					1		20
G							

B

Fig. 4-7
From-to chart can show distances between departments (left) and trips per day made between departments (right). In the chart at right, entries below diagonal line represent backtracking. Thus, five trips per day are made between A and C, for example, during the course of process operations. However, two trips are also made back from C to A, representing inefficiencies that should be worked on.



RICHARD MUTHER & ASSOCIATES

Fig. 4-8
Activity relationship chart is used to evaluate relationships between areas, departments, and activities, often to facilitate layout planning. Chart is read like familiar highway mileage table that indicates distance between cities. Thus, it is especially important that plate manufacture and stud collar areas be close to each other, to facilitate material flow. On the other hand, it is unimportant — some might even rate it undesirable — for office and rest areas to be in close proximity, because of the possibility of noise interference.

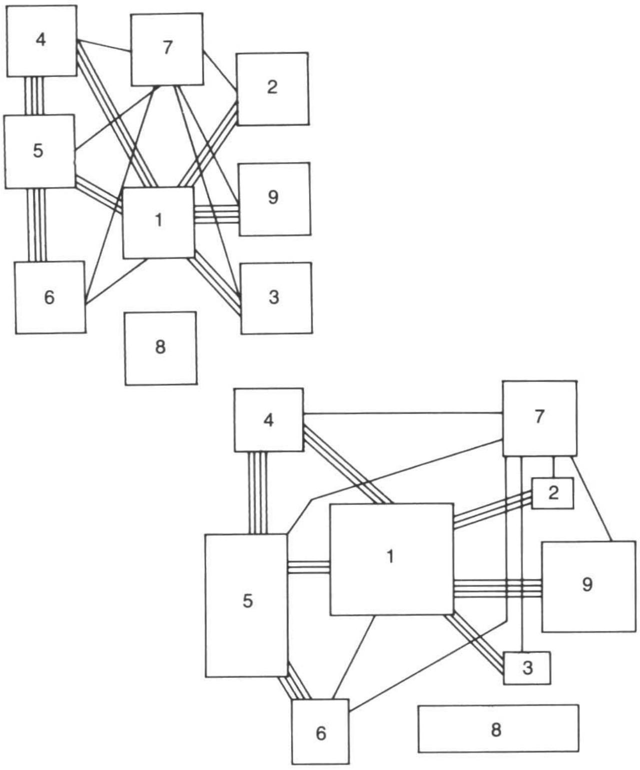


Fig. 4-9
A relationship diagram (top) is developed from information in the activity relationship chart. Essentially the relationship diagram is a block diagram of the various areas to be placed into the layout. The departments are shown linked together by a number of lines. The total number of lines joining departments reflects the strength of the relationship between the departments. For example, four joining lines indicate a need to have two departments located close together, whereas one line indicates a low priority on placing the departments adjacent to each other. The next step is to combine the relationship diagram with departmental space requirements to form a space relationship diagram, bottom. Here, the blocks are scaled to reflect space needs while still maintaining the same relative placement in the layout.

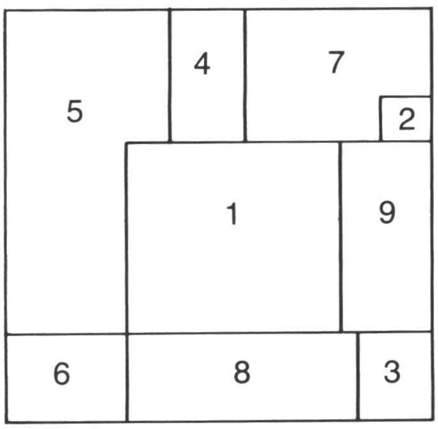


Fig. 4-10
Block plan represents final layout based on activity relationship information. If layout is for an existing facility, the block plan may have to be modified somewhat to fit the building. In the case of a new facility, shape of the building will conform to layout requirements.

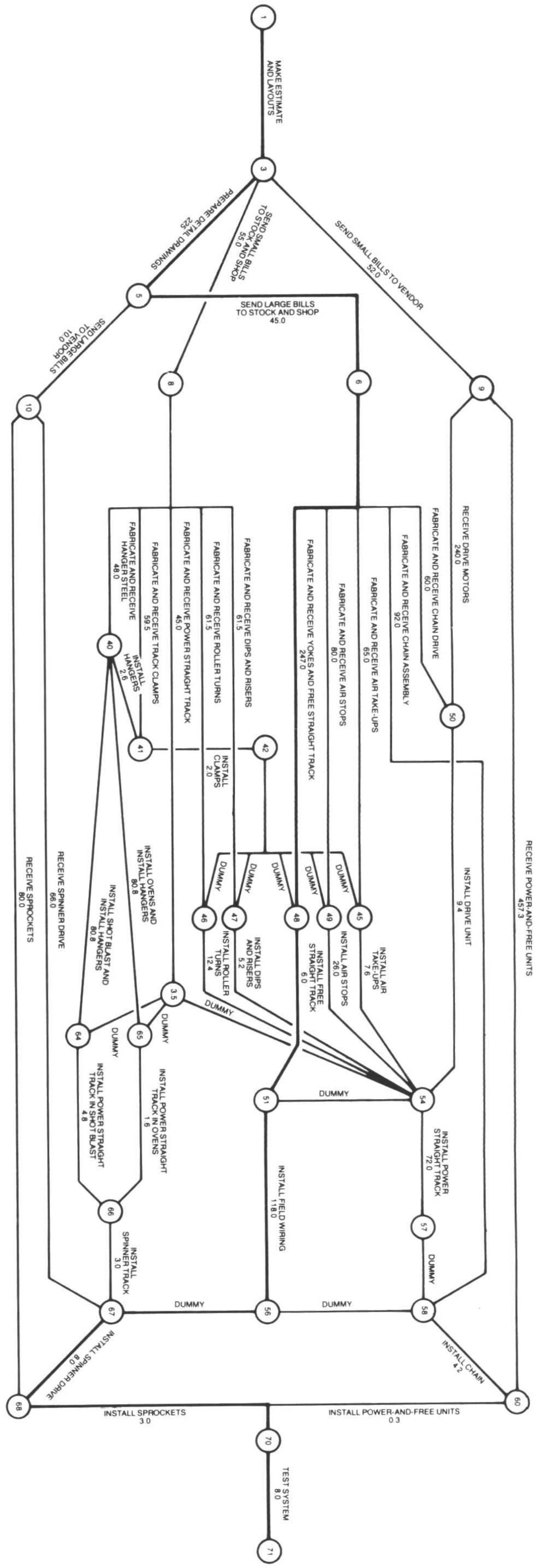


Fig. 4-11
Critical-path diagram for fabrication and installation of a trolley conveyor.

Analytical Techniques

Many of the graphical and schematic techniques just discussed have been used with good results for years to analyze material handling problems and to plan operations and facilities. They generally provide the basis for developing an understanding of material flow, material handling, and plant layout. Typically they are used to introduce students to the concepts of identifying and analyzing handling problems. And, these time-tested methods are still being used in many plants and warehouses today.

Nevertheless, the graphical methods, used by themselves, do have some limitations. Obviously with larger, relatively complex systems, large amounts of time — sometimes measured in many man-months — and effort can be involved in performing analyses. The degree of effort becomes particularly burdensome when various alternative situations must be tested by trial-and-error means. Also, one may not always be sure that the optimum solution has been identified.

In recent years, a new dimension has been added to the problem-solving capability of engineers with the advent of computers and the rapid growth of solid-state technology. These developments, which have made possible the broad use of quantitative mathematical techniques, have come down from the academic ivory tower and have become practical, usable tools for analyzing industrial problems. They can provide significant advantages in terms of speed of analysis and the scope of problems that can be considered. In fact, some problems cannot be analyzed adequately without the aid of these techniques.

Quantitative methods can be used to test the feasibility of alternative solutions, or to evaluate the effects of changes in variables upon an operation. Furthermore, these tasks can be accomplished in minutes or hours, as compared to weeks, months, or even years with conventional methods. Usually, no investment in equipment hardware is required, and the capability can be utilized economically by small plants as well as large. However, these techniques should be applied cautiously, keeping in mind their limitations and the assumptions upon which they are based. Some of the more common quantitative techniques of analysis are discussed here.

Simulation is perhaps the most widely used of the various analytical techniques. It is a technique for performing experiments on a model that represents a system. It can be thought of as a mathematical version of an industrial pilot plant. Simulation can provide valuable assistance in making decisions such as: how high a storage system should be, how many aisles should be used, how many lift trucks are needed, where conveyor lines should be located, how many docks are required, and similar factors. It permits system models to be developed and tested for the current level of business, for double the current level, or for some other value. It aids in forecasting the impact of a change in a product line, or the introduction of new types of raw materials or components.

One of the most widely used simulation languages is the General Purpose System Simulation (GPSS), often used in the design of high-rise storage in warehouses. A simulation study can help determine the lowest cost combination of system length, height, width, number of aisles, and number of storage machines to produce the desired throughput and storage volume.

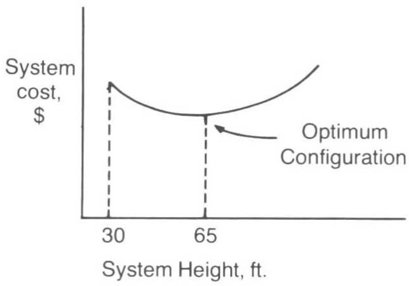


Fig. 4-12
Simulation of automated storage and retrieval system shows that, for this particular application, the optimum storage-rack height is 65 ft. Simulation can also indicate proper number of aisles, storage machines, and system length and width.

In one of the early applications of the method, for designing a new, automated, high-rise storage facility, running a simulation beforehand enabled the company to save $700,000 in investment (land, building, and equipment) costs, save an additional $150,000 by eliminating unnecessary conveyors and lifts, reduce operating costs by 20 percent, external trucking 48 percent, internal trucking 45 percent, reduce total warehouse space by 38 percent and significantly curb product damage and lost parts.

During the past few years several simulation languages have been developed that are most useful for modeling and analyzing material handling systems. There also are various types of special-purpose simulation methods in use, often for large, complex systems, and frequently written in a scientific computer language such as FORTRAN.

Waiting-line analysis — or queuing theory — describes how a system responds to varying demands for service, through the formation of waiting lines or queues. Common examples of waiting lines include: incoming materials awaiting receiving inspection, mechanics or production personnel waiting for parts at a storeroom counter, items moving between processing stations on a conveyor line, and work stations being served by in-process storage bins, which in turn are served by lift trucks.

The time that products or people spend in a waiting line represents a delay in the system operation. Evaluating all the delays in the system can help pinpoint weaknesses and define problems that need attention. Thus, waiting-line analysis can help minimize congestion in critical operations. It also can help determine cost-effective tradeoffs between the predicted size of a queue and the equipment and manpower needed to provide different levels of service — for example, whether delay of material flow and long lines of units waiting to be serviced are more costly than acquiring an additional lift truck or conveyor line to provide an additional level of service.

Fig. 4-13 illustrates a simple queu-

Fig. 4-13a

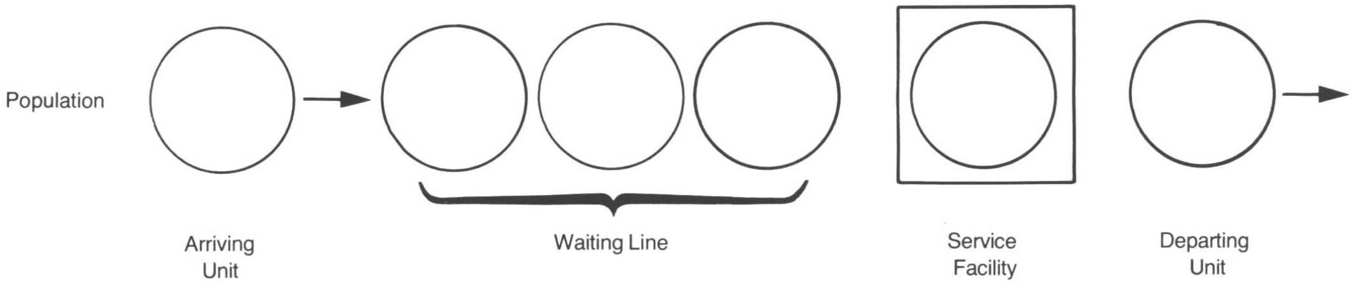
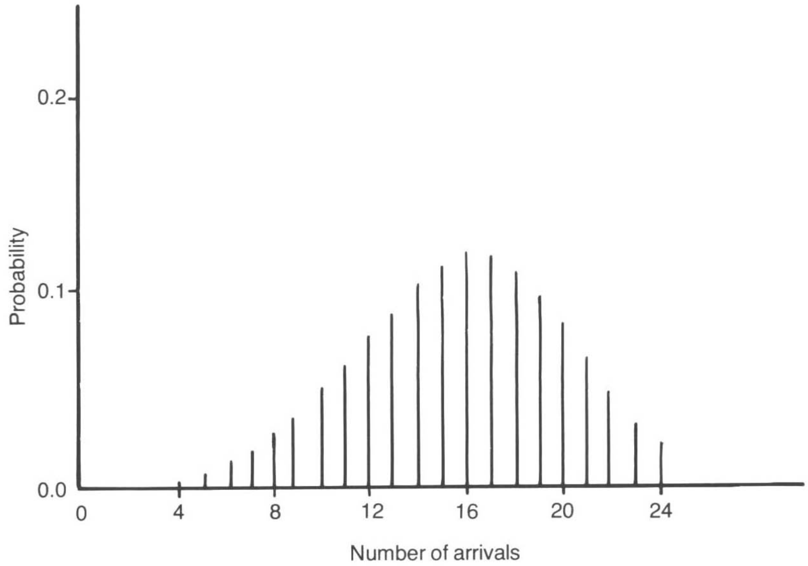
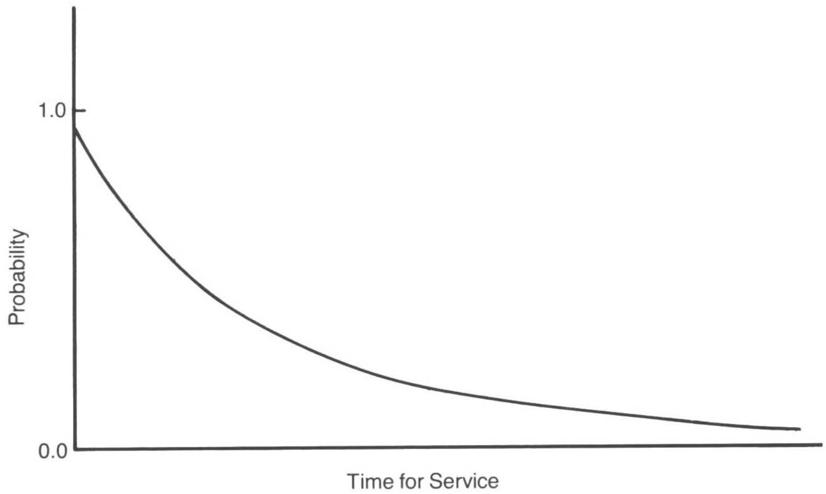


Fig. 4-13b



1. Distribution of arrivals

Fig. 4-13c



2. Service time distribution

Fig. 4-13
Simple queue involves single channel. It has only one waiting line and one service facility. Key variables are number of items in waiting line and amount of time spent waiting. Arrival and service times are assumed to follow distribution curves shown.

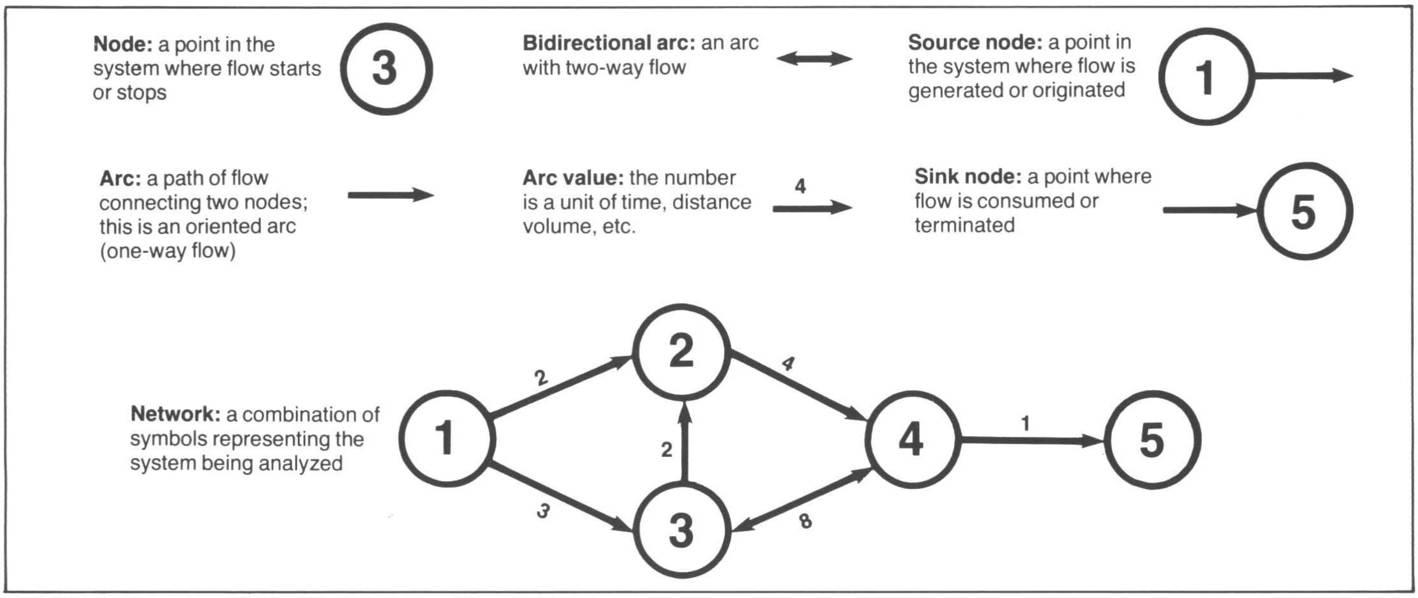


Fig. 4-14a

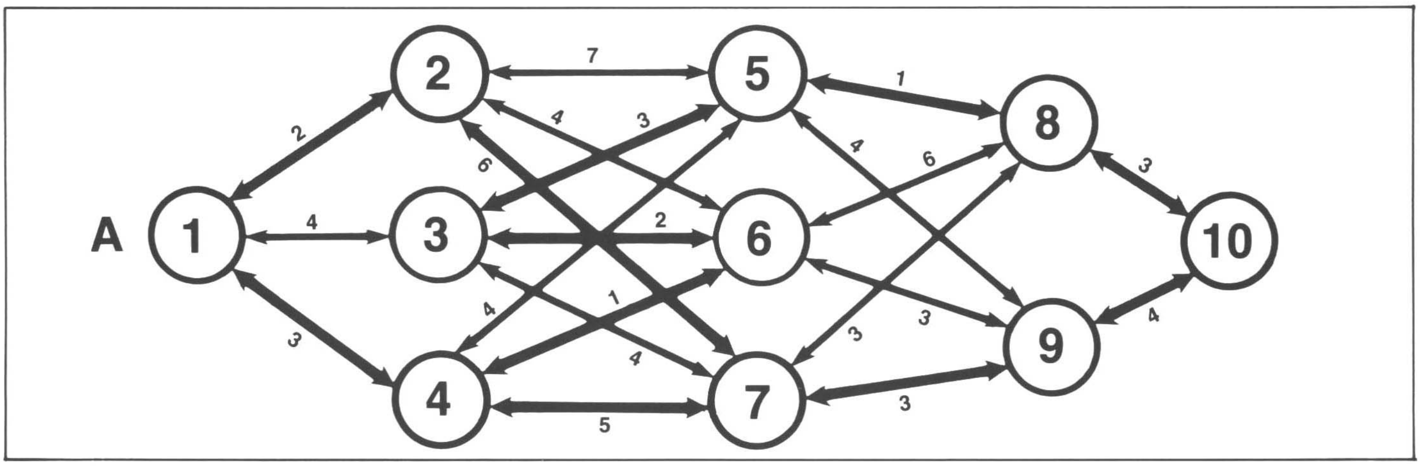


Fig. 4-14b

OPTIMAL SOLUTION:

GO FROM NODE 1	TO NODE 2	AT A DISTANCE OF 2
GO FROM NODE 2	TO NODE 7	AT A DISTANCE OF 6
GO FROM NODE 7	TO NODE 9	AT A DISTANCE OF 3
GO FROM NODE 9	TO NODE 10	AT A DISTANCE OF 4
GO FROM NODE 10	TO NODE 8	AT A DISTANCE OF 3
GO FROM NODE 8	TO NODE 5	AT A DISTANCE OF 1
GO FROM NODE 5	TO NODE 3	AT A DISTANCE OF 3
GO FROM NODE 3	TO NODE 6	AT A DISTANCE OF 2
GO FROM NODE 6	TO NODE 4	AT A DISTANCE OF 1
GO FROM NODE 4	TO NODE 1	AT A DISTANCE OF 3

Fig. 4-14c

Fig. 4-14
Basic symbols of routing analysis and simple network representation are shown at top. Diagram at bottom represents evaluation of shortest picking route for getting parts from nine locations. The problem is as follows: an order picker at location A picks parts at nine locations, visiting each location only once during a cycle. The proper picking sequence using the shortest travel distance, or picking time, is to be determined. The numbers accompanying the arrow lines, representing either time or distance — or costs — are entered in the computer, which is programmed to consider all possible routes and select the shortest. The optimum route is shown at the bottom, in the form of a computer-generated pick list.

ing situation. This is a single-channel queue; it has only one waiting line and one service facility. The important variables associated with the waiting line are the number of items in the waiting line and the amount of time spent waiting. In terms of the analysis of a queuing situation, the most important variables are the arrival rate and the service time. Queuing models are usually oriented to specific situations and the use of a model that does not properly reflect the properties of the system under study will yield incorrect results. Like any tool, when improperly applied, a queuing analysis can be costly.

Most common queuing models assume that the statistical pattern of arrival service times follows the distribution plots shown in Fig. 4-13.

Routing analysis is used to find the best flow path through an operation or facility, in order to minimize the time or cost involved in moving materials. Routing analysis can be used to determine the best routes newspaper trucks should take in delivering papers to newsstands and carriers, or in setting up order-picking routes, sequences, and zones in a warehouse. In fact, warehouse picking is an excellent application for this technique. Because of their complexity, automated storage and retrieval systems also are excellent candidates for the application of routing analysis.

As with most analytical methods, routing analysis is typically performed with the aid of a computer. It frequently involves the evaluation of complex network relationships, and the solution of one or more specialized types of routing problems. In some cases, the mathematics and calculations involved can become quite complex, and are beyond the scope of this discussion. However, the accompanying illustrations indicate the basic elements of routing analysis, and show how the technique can be used in solving material handling problems.

Location analysis can provide insight on where to locate an item of equipment (stretch wrapper, baler, palletizer) in a department, or where to place a department (tool, crib, battery-charging room) within a plant. In fact, it can be an aid in laying out the entire plant or warehouse. It can assist in locating the right rack openings for slow-moving items, or for determining the optimum location of receiving and shipping docks. Optimum placement of persons, materials, and machines is the goal of this technique. It can be used to improve the layout of existing facilities, or as an aid in designing a new plant from scratch.

Various types of computerized layout programs are used with location analysis. Some programs are designed to achieve a quantitative goal, such as minimizing combination of flow volume and travel distance. Others provide a qualitative result, such as maximizing the proximity of related departments.

The accompanying illustration shows a typical example of an application of location analysis.

Linear programming is a well-known technique used for allocating limited resources to achieving goals such as minimizing cost, travel time, or bay space. The variables in such problems must bear a straight line, or linear relationship, to one another.

Typically, solutions involve the use of matrices and specific computation procedures. For larger problems, the computations become long and tedious when done manually, but are readily performed by computer.

Several specialized linear programming procedures are available, such as *transportation* (distribution of a single item from various sources of supply to various demand destinations), *assignment* (allocation of jobs to work centers or facilities), and *transshipment* (use of various sequences and intermediate points in shipping from source to destination).

The accompanying illustration provides a simple example of using linear programming to allocate pallets among departments.

Benefits and Limitations

Various other techniques of analysis can be applied to material handling problems. Specialized models that mathematically describe opera-

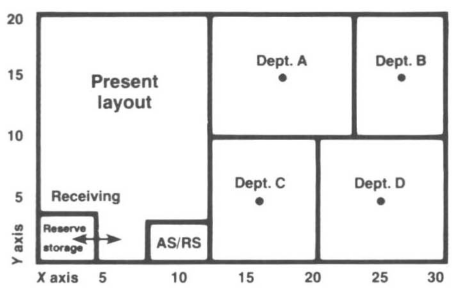


Fig. 4-15a

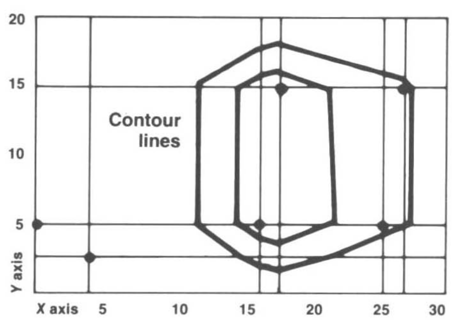


Fig. 4-15b

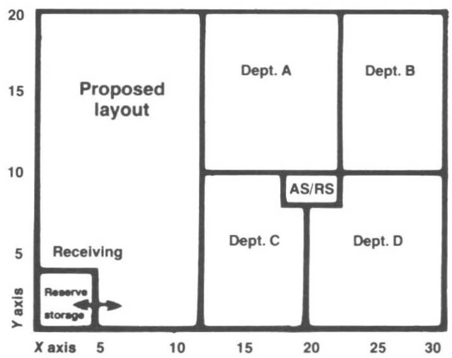


Fig. 4-15c

Fig. 4-15
Evolution of a location analysis. A mini-load automated storage and retrieval system (AS/RS) serves four departments, left. Concerns expressed by various departments indicate that the location of the AS/RS is less than optimal. A weighting procedure is developed whereby the number of trips spent to and from the AS/RS by each department is multiplied by the speed of the trips and by the cost spent in travel. Using the weightings, contour lines are plotted, (middle diagram) to help zero in on the optimal placement of the AS/RS. The mathematical solution places the new AS/RS location in the heart of department C, but a modified, more practical solution is determined to be along a main aisle between departments C and D, right.

tions of certain types of material handling equipment, such as conveyors, have been used successfully. In using any model, keep in mind its limitations as well as its potential benefits. Above all, the assumptions inherent in any model or computer program should be understood thoroughly before use of the technique is attempted. In many cases, real-world factors must be imposed upon the solution received from a computerized technique.

The techniques described here should never be used as a crutch, but rather as valid aids to decision making. Properly applied, quantitative methods can provide a very powerful added dimension in analyzing material handling problems.

From Dept. \ To Dept.	*W*	*X*	*Y*	*Z*	Empties available (loads)
A	10 (7)	22 (1)	10	20	8
B	15	20 (9)	12 (4)	8	13
C	20	12	10 (2)	15 (9)	11
Empties required (loads)	7	10	6	9	32

Fig. 4-16a

From Dept. \ To Dept.	*W*	*X*	*Y*	*Z*	Empties available (loads)
A	10 (7)	22	10 (1)	20	8
B	15	20	12 (4)	8 (9)	13
C	20	12 (10)	10 (1)	15	11
Empties required (loads)	7	10	6	9	32

Fig. 4-16b

Fig. 4-16
A simple type of linear programming problem is shown here. There are three departments, A, B and C, that have an excess of pallets over and above their needs, and four departments, W, X, Y, and Z, that require pallets. Two pallets can be moved by a pallet truck at a time. A material handler is available in each department to deliver or pick up pallets as needed. What method of distributing pallets will result in the least overall travel time? The distribution matrix at the top represents the first pass at the problem. The numbers within small squares in the chart represent round-trip travel times between departments. For example, round-trip time from A to W is 10 min.

In this first pass, loads — or pallets — are assigned in an arbitrary way. Department A has 8 loads available, and W needs 7. Therefore, 7 loads are transferred from A to W. Numbers within circles represent assigned loads. The remaining single load is then assigned to X, and additional loads required by A are assigned from B. The total time required for this approach is:

AW, $7 \times 10 = 70$ min.
AX, $1 \times 22 = 22$
BX, $9 \times 20 = 180$
BY, $4 \times 12 = 48$
CY, $2 \times 10 = 20$
CZ, $9 \times 15 = 135$
475 min.

In a search for the optimum solution, the analyst tries to see if shifting assignments to squares not having any load assignments can result in any time reductions. Such load shifting can be accomplished (with efficient procedures in various operations research texts) until the optimum combination shown in the lower matrix is achieved. No further assignment changes will produce any additional time reductions at this point. The total travel time required for this combination is 330 min., which is 30 percent less than that of the original combination. The calculations involved in this problem are tedious when attempted manually, but can be readily accomplished with the aid of a computer.

Chapter 5
Productivity Concepts

Efficiency and productivity have become topics of major concern in the industrial world. They have a direct bearing on the ability of a company to compete in its industry. Productivity is also becoming an increasingly important factor in the ability of nations to compete in world markets. Properly applied material handling can be a major factor in improving productivity and efficiency of operations throughout any facility.

Measuring Productivity

One overall definition of productivity is the ratio of output to input. Various types of input and output factors and units can be used to tailor the evaluation to a specific case. For example, a measure of productivity in a receiving department might be pounds of materials received per hours of labor expended. A common ratio in warehousing is inventory turnover.

Several typical productivity ratios related to material handling are presented here. Others can be developed to fit specific situations in a plant or industry.

In general, there are no standard, acceptable values for these ratios that can be compared against those obtained in a specific operation. (Some associations and professional organizations are, however, taking steps to establish some productivity standards.) The usefulness of most of these ratios lies in monitoring performance over a time period to determine trends or to establish a need for corrective action. If the numbers are available, absolute figures can be compared against those from other plants in the same industry, or having similar handling operations. The following are some typical ratios:

Material Handling Labor (MHL) ratio.

$$\text{MHL ratio} = \frac{\text{Personnel assigned to MH duties}}{\text{Total operating personnel}}$$

This ratio represents the number of personnel assigned to material handling duties in proportion to the entire work force. It can be determined on the basis of head count or payroll costs. Some support activities (maintenance, tool room, production control) are not devoted full time to material handling. An estimate of the percentage of time spent on handling should be used.

A variation of this ratio, called the direct labor material handling ratio, can be used to measure the percentage of direct labor that is spent on material handling. The required data can be obtained from work sampling or other analysis techniques.

Handling Equipment Utilization (HEU).

$$\text{HEU} = \frac{\text{Items (or load weight) moved per hour}}{\text{Theoretical capacity}}$$

The way this ratio is determined will vary from one facility to the next. Therefore, it is meaningful only if

TABLE 5-I
A Work-Volume Analysis Example

Dock Identity	Commodity	Transport Via	Loads Per Day: Average	Loads Per Day: Peak	Loads Per Day: Selected Mean (M)	Unload To	Load Quantity	Handling Unit
Dock H	Bulk A	R. R.	.25 c/l	1.0	1.0	Open Bin	100,00 lbs.	800 lbs.-Grab Bucket
Dock F	Bulk A	R. R.	.1 c/l	1.0	.5	Container Type 626	100,000 lbs.	400 lbs.-Shovel
	Loose A	R. R.	2.1 c/l	5.0	3.5	Container Type 626	100,000 lbs.	600 lbs.-Shovel
	Package A	R. R.	.2 c/l	1.0	.75	Container Type 540	20 Palletized Unit Loads	1 Unit Load
	Package B	R. R.	2.1 c/l	5.0	3.5	Container Type 610	Loose, Equal to 20 Cntnrs.	1 Container Full
	Total		4.5 c/l	12.0	8.25			
Dock M	Bulk B	Truck	8.0 t/l	5.0	4.0	Underground Tank	3,000 gals.	
Dock C	Loose B	Truck	1.25 t/l	3.0	3.0	Container Type 610	30,000 lbs.	1,500 lbs. per Container
	Package A	Truck	.5 t/l	2.0	1.25	Container Type 540	10 Palletized Unit Loads	1 Unit Load
	Package B	Truck	6.5 t/l	10.0	8.0	Container Type 610	21,000 lbs.	1,500 lbs. per Container
	Total		8.25 t/l	15.0	12.25			

*Equivalent of 4.4 spots allowed because spur can be switched only once per day.

**Equivalent of 1.3 spots allowed for refuse and scrap trucks.

used to make relative comparisons, over a period of time, within a given operation. To use this ratio properly, one must first decide what is meant by theoretical capacity — or full utilization — and then stick by the definition. For example, some engineers may consider a piece of equipment fully utilized only when it is carrying a full load. On the other hand, others may feel it is properly utilized when empty but heading toward a loading station.

Storage Space Utilization (SSU).

$$\text{SSU} = \frac{\text{Storage space occupied}}{\text{Total available storage space}}$$

Obviously this measure will be applied most frequently in warehousing and other storage operations. Cubic space should be measured rather than floor area. In collecting the data, keep track of the percentage of bin and rack openings that are empty. Of the ones that are occupied, note whether they are fully or partially utilized, and if practical, try to estimate percentage of utilization.

Aisle Space Percentage (ASP).

$$\text{ASP} = \frac{\text{Space occupied by aisles}}{\text{Total space}}$$

Space is becoming extremely costly, in both manufacturing and warehousing. Aisles and traffic patterns should be laid out carefully in order to use available space most productively. The calculation should generally be based on cubic feet of total space.

Also, keep in mind that too low an ASP figure may be as bad as one that is too high. A reasonable number of both traffic and access aisles must be provided to maintain desirable levels of throughput and productivity.

Movement/Operation (MO) ratio.

$$\text{M/O ratio} = \frac{\text{Number of moves}}{\text{Number of productive operations}}$$

This relationship reflects the overall efficiency of material handling operations in the plant. It can indicate the number of handling — and rehandling — steps that are involved in receiving, storage, manufacturing, and other departments. Typically, a high ratio will indicate an improvement opportunity, in the form of fewer handling steps, simplified operations, or use of mechanized equipment.

Manufacturing Cycle Efficiency (MCE).

$$\text{MCE} = \frac{\text{Time spent in actual production operations (machine time)}}{\text{Time spent in production department}}$$

This ratio measures how effectively materials flow through the manufacturing process. Delays encountered can be caused by various factors, including poor scheduling and routing, inefficient machine operation, or insufficient local storage. Obviously different figures can be expected from job shop operations and continuous processing systems. As with most of these ratios, the key is to apply and observe them consistently over time.

Damaged Loads (DL) ratio.

$$\text{DL ratio} = \frac{\text{Number of damaged loads}}{\text{Total number of loads}}$$

This ratio gives a handle on how effectively and properly crews are handling incoming and outgoing goods and in-process materials. Some program of sampling should be established to generate damage data. The ratio can be applied to a number of different departments and stages of material flow in the plant.

Energy ratios. More than ever before, every one of us is concerned with the energy efficiency of our equipment and operations, and ratios covering this important factor can be utilized.

It may be possible to determine separate energy efficiency ratios — relating throughput to energy consumption — for individual items of

								Fork Truck Unloading		
Handling Units per Load	Estimated Handling Minutes per Handling Unit	Handling Hours per Load	Dock Hours Per Load, including Allowances (D)	Operating Hours per Day (O)	Dock-Spot Capacity per Day (C) (O + D)	Calculated Number of Dock Spots Required (M + C)	Actual Number Required	Handling Units per Day	Handling Hours per Day (H)	Number Trucks Required (H + O)
125	3	6.3	7.0	16	2.2	.5	1			
250	3	12.5	13.0	16	1 2	.5		125	6.25	
167	3	8.4	9.0	16	1.7	2.1		585	29.25	
20	3	1.0	2.0	16	8.0	.1		15	.75	
20	10	3.3	4.0	16	4.0	.9		70	3.50	
						3.6	8*	795	39.75	2.5
	1,000 gph	3.0	3.5	16	4.5	.9	1			
20	10	3.3	4.0	8	2.0	1.5		60	3.0	
10	3	.5	1.0	8	8.0	.2		13	.7	
14	7	1.6	2.0	8	4.0	2.0		112	5.6	
						8.7	5**	185	9.8	1.2

equipment such as conveyors or lift trucks. However, a more meaningful evaluation may be energy utilization for the entire facility — for example, btu's consumed per cubic feet of warehouse space. These ratios can be kept low with such measures as providing minimum heating and cooling in unmanned areas or automated storage facilities, and using task lighting or lights mounted on mobile equipment in place of permanent overhead lighting.

Work-Volume Analysis

A first step toward increasing productivity in a facility might be the evaluation of effectiveness and appropriate application of existing handling systems. One technique for accomplishing this task is work-volume analysis. It also can be used for determining new system requirements. Work-volume analysis is a procedure in which the characteristics, volume, and handling requirements of the material that is to be transported within an area of the plant are systematically arranged on a chart. By itself, the procedure does not solve any material handling problems. However, by displaying important handling system data on a work-volume chart, hidden system requirements can be discovered and many benefits realized.

A work-volume analysis normally leads to the establishment of important system parameters. Very often this technique will help to support decisions such as:

- Determining the general class of equipment to perform a task within a department.
- Determining the amount of work to be done in units appropriate to the type of equipment.
- Determining the specifications and the quantity of handling equipment required.
- Determining the placement of equipment and personnel requirements.

To develop a work-volume chart for a selected class of operations or for an area, detailed data must be collected on each of the types of material that is handled. It is important that all pertinent data are gathered. The actual selection of data to be included on a work-volume chart will depend on the situation under study.

Work-volume charts follow the same sequence that governs the physical flow of materials: receiving, processing, and shipping. Each operation must be examined and identified separately on the work-volume charts, because certain operations will require variations in equipment and labor grades. The following steps can be utilized when constructing a work-volume chart:

1. Determine the major class of operations to be studied (i.e. receiving, shipping, processing) and identify the individual operations to be analyzed (material moves, inspections, storage, machining, etc.)
2. Gather data on the material handled at each operation. For each unit handled, the size, shape, fragility, material and handling method shall be noted. Also the volume, quality inspection procedures, storage method and characteristics of a unit load are important data. The data should reflect the nature and volume of the work as well as the conditions under which the operations are performed.
3. Examine the data collected and determine if any important information can be calculated from the collected data. For example, load quantity data could be divided by handling unit data to obtain handling units per load.
4. Lay out a matrix (rows and columns) type of chart with columns that are of a width that will facilitate recording the data gathered in step 2 or calculated in step 3. Place the headings along the top of the columns.
5. On the left hand side of the chart identify the areas or operations for which data has been gathered or calculated.
6. Record the data.

The example given in Table 5-I is a work-volume analysis for a receiving area. The processing and shipping operations can be outlined in a similar fashion because this form of analysis is very flexible. The work-volume chart illustrated was developed to examine the handling work required and the facilities needed to perform the receiving operation.

In creating the work-volume chart illustrated in the example, the analyst has used collected data to calculate important parameters of the system. For example, the load quantity has been divided by the handling unit to obtain the handling units per load and the handling units per load have been multiplied by the estimated handling minutes per handling unit to obtain the handling time per load.

A work-volume analysis is especially useful for identifying equipment or personnel that are under-utilized. A procedure sometimes referred to as work-density analysis involves balancing the work loads on the operations that have been charted. There are no known formulas for calculating work density. Each individual operation must be studied and compared with other operations. Some of the general rules to be observed when performing a work-density analysis are:

- Material handling personnel are generally most efficient when under constant supervision. Try to concentrate activity to provide effective supervision.
- Locate storage areas as close to each center of work density as practical.
- In using conveyor loading and unloading, consider the possibility of automatic handling.
- Make use of quick-change attachments for trucks and cranes to make them adaptable to different handling operations within an area.
- Consider compromising the specifications for handling equipment to broaden the usefulness of each unit. This rule applies to all types of equipment — conveyors, containers, trucks, trailers, and cranes.
- Analyze the work requirements of the material handling activity as a whole, as well as by segments, to improve the work-density factor.

Chapter 6
Material Handling Costs

Material handling adds to the cost of an operation, whether it be manufacturing, warehousing, transportation, or distribution. As mentioned earlier, the portion of total costs that can be attributed to handling may range from 30 to 75 percent, and even higher in some instances. Thus, it follows that material handling costs must be included in any cost reduction or improvement program.

Some authorities say that while material handling adds cost to manufacturing, it adds no value to the product. The ultimate conclusion is, "the best handling is no handling at all." A somewhat different view, however, holds that handling does indeed add value to a product — in the form of time and space utility. It can be argued that a product does not have much value if it is not at a particular place, at the time that it is needed. Thus, value has been added to a grocery item, for example, through the efforts taken to get it onto the shelf at the time that the shopper is looking for it.

In the final analysis, the question of whether or not material handling actually increases the value of a product may be academic. The fact is, every time a piece, product, or package is picked up, moved, or set down, a cost has been incurred. The firm that minimizes such handling costs, or generates the greatest benefits from the handling it does, will have the competitive edge in its industry and in the market place it serves. In some cases, it may be necessary to increase handling costs (as, for example, by purchasing mechanical handling equipment) in order to reduce overall costs.

The initial necessary step in controlling material handling costs is identifying them within the total scope of an operation. Some will be obvious — such as the cost of a full-time lift-truck operator. Others may be more difficult to extract out of the cost of production or other activities. Accounting practices also can mask the role of material handling. In some companies, handling is simply buried as part of "indirect production costs." Material handling costs can be identified by segregating them into the following categories:

Direct material handling activities. These tasks are directly identifiable as material handling activities, as for example, driving a lift truck, unloading a truck at the dock, operating a crane, or stacking pallet loads into a rack. Often these tasks have full-time personnel and equipment assigned to them, and their costs can be isolated.

Combined activities. Examples of handling tasks combined with other activities include feeding material into and out of a press, transferring it between work stations in an

Job Descriptions and Job Numbers

Job No.	Description
11 —	**RECEIVING** — checking, inspecting and signing for inbound merchandise
12 —	**UNLOADING CARS** — including all work connected with piling merchandise on warehouse pallets
13 —	**UNLOADING TRUCKS** — including all work connected with piling merchandise on warehouse pallets
14 —	**PILING INBOUND** — merchandise by forklift truck
15 —	**PILING INBOUND** — merchandise by hand
16 —	**UNLOADING AND PILING PALLETIZED LOADS INBOUND** — includes removing unit loads to platform, transporting to storage and stacking
21 —	**FILLING SLOTS** — filling slots in selection line
22 —	**REWAREHOUSING** — performing work in connection with making room and consolidating lots
23 —	**RECOUPING DAMAGED MERCHANDISE** — warehouse damage
31 —	**SELECTING** — selecting outbound orders with forklift truck including checking done by selector
32 —	**SELECTING** — selecting outbound orders into containers including checking done by selectors
33 —	**CHECKING** — on loading platform only
34 —	**LOADING CARS, Handstacking** — including all work connected with loading cars and handstacking containers into cars
35 —	**LOADING TRUCKS, Handstacking** — including all work connected with loading trucks and handstacking into trucks
36 —	**LOADING OUT PALLETIZED LOADS** — including transporting and positioning unit loads in cars or trucks
41 —	**FREEZING** — including all work done in connection with blast freezer
42 —	**GLAZING** — including all work done in connection with glazing
43 —	**RECOUPING DAMAGED MERCHANDISE** — carrier damage
44 —	**MISCELLANEOUS SERVICES** — performing services, not otherwise described, at hourly rates
51 —	**HOUSEKEEPING** — sweeping, trash disposal, painting, etc.
52 —	**MAINTENANCE** — repairing, equipment service, repairing pallets, erecting storage racks, etc.
53 —	**MISCELLANEOUS** — include description on time sheet
61 —	**SUPERVISION**

Fig. 6-1
Job descriptions can be printed on the back of a time card to help operators fill card out properly.

Range (cases)	Average (cases)	Labor (man-minutes) Per Case	Per Order
Under 5	2.5	1.50	3.75
5 to 9	7.0	1.15	8.05
10 to 14	12.0	.98	11.76
15 to 19	17.0	.86	14.64
20 to 24	22.0	.74	16.28
25 to 29	27.0	.70	18.90
30 to 34	32.0	.67	21.44
35 to 39	37.0	.65	24.05
40 to 44	42.0	.64	26.88
45 to 49	47.0	.60	28.20
50 to 54	52.0	.60	31.20

Fig 6-2
Time standards for order assembly in a warehouse, based on number of cases in an order.

Cost of Performing Typical Warehouse Jobs

	Manual (Cents)	Machine (Cents)
1. Hook/unhook warehouse tractor to/from trailer train	12.22	
2. Mount/dismount start/stop electric fork lift truck		6.19
gas lift truck		10.93
3. Open sealed cartons (medium size, easy to open)	6.00	
(medium size, difficult to open)	7.42	
4. Pick up pallets with fork lift truck:		
a) On floor, no turn required to pick up or travel		4.98
b) On floor, turn and stop prior to or after pick-up		6.70
c) In storage, first level only		8.62
d) In storage, second level only		10.72
e) In storage, first or second level (average)		9.67
f) In storage, third level		17.77
g) In storage, up to three levels (average)		12.36
h) In storage, up to four levels		13.73
5. Stack pallets with fork lift truck		
a) On floor, no turn required to stack or travel		4.51
5. b) On floor, turn and stop prior to stacking or travel		6.44
c) In storage, first level only		8.21
d) In storage, second level only		12.51
e) In storage, first or second level (average)		10.36
f) In storage, third level		21.07
g) In storage, up to three levels (average)		13.92
h) In storage, up to four levels		15.71
6. Close and seal box car doors	20.39	27.24
7. Manhandle 4 x 8 plywood sheets — 10 sheets	71.09	96.71
50 sheets	355.46	483.56
100 sheets	710.92	967.14
8. Open and close trailer doors	23.85	32.45
9. Pull copies of shipping document set	3.21	4.37
10. Travel time manual pallet jack round trip 10 ft. one way	21.40	
100 ft. one way	43.56	
11. Travel time fork lift truck round trip 10 ft. one way		4.02
100 ft. one way		21.51
1000 ft. one way		145.65
12. Obtain an empty pallet from storage		17.98
13. Pick up pallet and load on conveyance		34.53
14. Move pallet load to storage 200 ft. one way (travel only)		70.24
15. Place empty pallet and move loaded pallet to storage 200 ft.		81.78

Hourly costs based on $12.07 per productive labor hour, worker only; $16.42 per productive labor hour including fork lift truck.

Fig. 6-3
Cost analysis covers both labor and equipment factors.

assembly line, moving items past a quality control inspection station, or shifting materials during an inventory check. The costs involved in these moves may be accounted for as production, quality control, or inventory control costs. In some cases (primarily production), they may be classified as direct costs, whereas in other instances they will be indirect expenses.

Distribution-related activities. Costs of activities in this category are commonly considered to be distribution costs. They can include the cost of transporting materials to the plant, or from it, along with a variety of handling tasks performed in yards, docks, and other locations outside the plant. In-plant packing and packaging are also often included in this category.

Sources of Cost Information

Data on handling costs can be obtained from various sources, including labor time records, shop requisitions, equipment vendors, other equipment users, and material handling consultants. In many cases, the data are not readily available, but must be extracted with considerable effort. Often, historical data alone are not adequate, and additional information must be developed.

Time Cards provide an easy-to-use, direct measure of handling labor costs, providing an operator's full time is spent on material handling. His time multiplied by his total hourly cost (wages, benefits, share of overhead) equals the handling labor cost.

In any such simple calculation, remember to account for idle or waiting time. Also, be sure to design time cards in terms workers understand and use. Otherwise, the cards will not be filled out properly, and resulting records will have little value. Printing standard job descriptions on the back of time cards is a good way to help avoid such problems. An example of some job descriptions that might be appended to a warehouse time card is shown. (Fig. 6-1)

Time studies provide a more detailed breakdown of individual handling steps, and can be used to help identify that part of an operation that involves material handling, as in the following example. Items followed by an asterisk indicate handling activities.

Activity	**Time, Minutes**
Pick up tray of parts	0.20*
Turn to machine	0.10*
Place tray on table	0.40*
Pick up piece	0.07*
Load in jig	0.10*
Drill 3 holes	0.47
Unload jig	0.07*
Inspect part	0.15
Set part aside	0.05*
Pick up piece	0.07*
	1.68

Such studies can help determine the proportion of activity costs that should be allocated to material handling. In this particular case, 1.06 minutes out of a total of 1.68 — or 63 percent — were devoted to material handling. Time studies should be performed only by persons knowledgeable in work measurement. This type of study is accurate but expensive.

Work sampling is another useful type of work measurement. It uses statistical techniques involving random observations to determine whether operators are working or idle. One common application is determining the percentage of time that workers are spending for personal reasons, as opposed to time spent on delays that are actually part of the job. The technique can also be used to determine work standards. A worker's material handling activities can be identified through a work sampling study.

Pre-determined time standards can be used to help evaluate costs of handling operations, particularly manual activities. These standards use time values that have been associated with basic body motions. Information on such standards can be obtained from basic industrial engineering texts. Specialized training is required for applying this technique.

Accumulated data from time studies and pre-determined time standards can be used to establish basic time standards for different handling activities in a plant. The accompanying table provides an example of average time standards developed for order assembly in a warehouse, based on the number of cases in an order. (Fig. 6-2)

Equipment cost data can be obtained from an internal engineering department, equipment vendors, consultants, and other users of the same or similar equipment. Initial cost is only one side of the story. The plant engineering department should be able to provide a good handle on operating and maintenance costs of the equipment.

Acquiring equipment that is cost effective for an operation is by no means an easy task, particularly if material handling equipment is acquired infrequently. Proper bid specification is a must, and is covered in detail in a following chapter. Don't overlook the so-called "hidden" costs in equipment — installation, site preparation, erection labor, controls, guarding, supports, and auxiliary equipment, such as feeders, chutes, or dust-control units. Also, remember that safety devices do not necessarily come free. Be prepared to pay extra for some of the additional safeguards that are specified. Plan for these costs ahead of time.

An analysis that covers both labor and equipment costs in an activity is shown in the accompanying table. (Fig. 6-3)

When all individual costs have been identified, the total cost of an operation — or of an entire plant system — can be determined with the aid of process flow charts, flow diagrams, and cost sheets, shown in the illustrations. (Fig. 6-4a, b, & c)

Part Name Item No. 10 — Wax

Process Description Move wax from R. R. car to Melt

Department Production

Plant Apple Aerosol Products Co.

Recorded by A.M.J. **Date** 9/20

SUMMARY	NO.
○ OPERATIONS	1
⇨ TRANSPORTATIONS	6
□ INSPECTIONS	0
D DELAYS	0
▽ STORAGES	6
TOTAL STEPS	13
DISTANCE TRAVELED	96′

STEP	Operations / Transport / Inspect / Delay / Storage	Description of Present Method	Dist.	How Moved	Est. Hrs./ Load	Hrs. per Bag
1	○ ⇨ □ D ▽	in R. R. car — (10,000 100# bags)				
2	○ ⇨ □ D ▽	stack onto pallet (25/pallet)	20 ft.	hand	.01	.0100
3	○ ⇨ □ D ▽	on pallet at dock				
4	○ ⇨ □ D ▽	pallet from Dock to Receiving Stores(25b./p.)	30′	F.T.	.08	.0032
5	○ ⇨ □ D ▽	in Receiving Stores on floor				
6	○ ⇨ □ D ▽	Pallet to Mixing Area (25 bags/pallet)	30′	F.T.	.10	.0040
7	○ ⇨ □ D ▽	On floor in Mixing Area				
8	○ ⇨ □ D ▽	Pallet to Mixing Level (25 bags/pallet)	10′	F.T.	.12	.0048
9	○ ⇨ □ D ▽	Pallets on floor at Mixing Level				
10	○ ⇨ □ D ▽	Lift bag from pallet to dumper (1 bag)	5′	hand	.08	.0800
11	○ ⇨ □ D ▽	Rest bag on dumper				
12	○ ⇨ □ D ▽	Dump bag into kettle (1 bag)	1′	hand	.05	.0500
13	○ ⇨ □ D ▽	Melt wax in kettle				
	○ ⇨ □ D ▽		96′			.1520
	○ ⇨ □ D ▽					hour/ bag

Fig. 6-4a
Graphical techniques can be used to help identify and isolate material handling costs. In this example, a process flow chart is used to track moves involving one component (wax) in an aerosol packaging plant. Same charting procedure is carried out for all other ingredients.

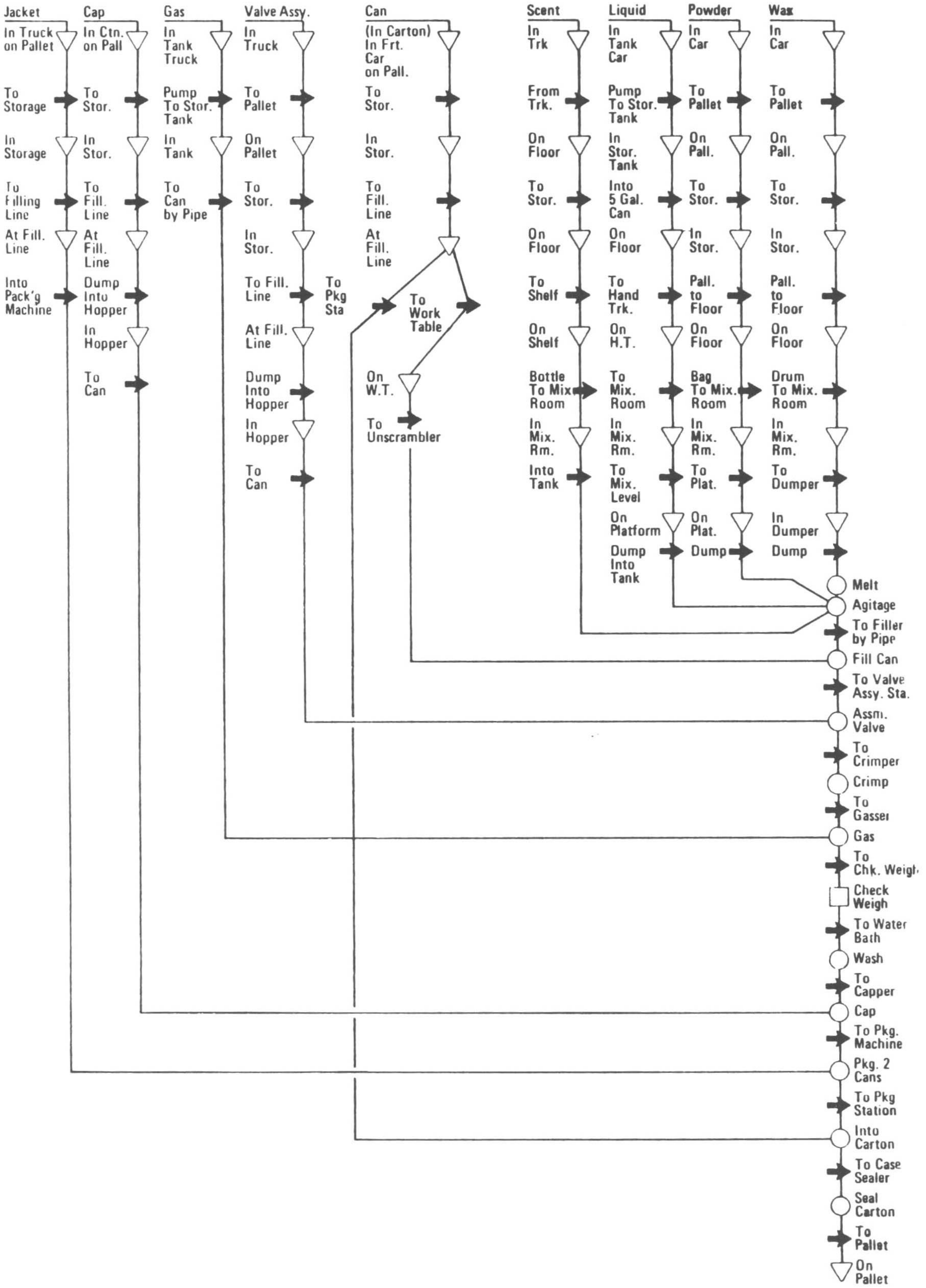


Fig. 6-4b
Flow diagram indicates moves within plant layout.

COMPANY APPCO PLANT Filling DEPARTMENT PRODUCTION PROJECT NO 1 ANALYZED BY AML DATE 9/25

MOVE IDENTIFICATION					MANPOWER COST				HANDLING EQUIPMENT COST					AUXILIARY EQUIPMENT COST (containers, pallets, racks, etc.) DO NOT enter more than once if equipment stays with material						TOTAL COST			
Move No.	Move Description	Yearly Quan. A	Item per Load B	Loads per Year (A÷B) C	Time per Load Hrs. D	Hrs. per Year (CxD) E	Wage per Hour F	Cost per Year (ExF) G	Equipment Identification	Time/Load in Hrs. H	Hrs. per Year (CxH) J	Cost per Hr. K	Cost per Yr. (JxK) L	Equip. Ident.	No. Reqd. M	Cost per Item N	Amort. Rate P	% Used This Move Q	Cost per Yr. (MNPQ) R	Man-pow. Cost/Yr. G	Equip. Cost per Yr. L	Aux. Cost per Yr. R	Total Cost per Yr. S
1	car to pallet	10,000 BAGS	1	10,000	.010	100	$1.50	$150												$150	-	-	$150
2	Pallet to rec. store	10,000	25	400	.080	32	2.50	80	fork truck	.08	32	$1.50	$48	pallet	40	$5	25%	100%	$50	80	$48	$50	178
3	rec. store to mixing area	400	1	400	.100	40	2.50	100	fork truck	.10	40	1.50	60							100	60	-	160
4	mix area to mix level	400	1	400	.120	48	2.50	120	fork truck	.12	48	1.50	72							120	72	-	192
5	mix room to dumper	10,000	1	10,000	.080	800	2.00	1600												1600			1600
6	dump	10,000	1	10,000	.050	500	2.50	1250						dumper	1	$2000	20%	100%	400	1250		400	1650
																					TOTAL		$3930

Fig 6-4c
Cost sheet tabulates costs related to move data. Sheet here covers one ingredient. Similar tabulations can be made for other ingredients and activities, to yield a total cost for the plant.

Justifying Material Handling Investments

A thorough understanding of material handling cost factors is essential when the acquisition of new equipment and systems is contemplated. This discussion covers economic tools that can be used for evaluating the cost effectiveness of proposed projects, and in meeting a company's measures of economic performance.

Economic criteria for justifying a project vary from firm to firm. Three widely used methods — payback period, rate of return on investment, discounted cash flow — and MAPI methods are covered here.

Payback period is generally the simplest and most widely used. Basically it involves the time period — usually in months or years — that it takes for earnings or savings realized from a project to equal the original investment. In other words, it tells how long it takes to get invested money back.

One drawback of the payback calculation is that it provides limited information about the project. For instance, suppose that a particular project — or piece of equipment — is estimated to pay for itself in three years. That number, in itself, does not say anything about the expected life of the project or system. Nor does it say anything about earnings that may be realized after the first three years.

However, because of its simplicity, payback period can be useful in making a rough first pass at evaluating a proposed project. It is also a good tool for screening out obviously unattractive projects, or for quickly identifying especially promising ones.

Return on investment (ROI) provides a somewhat broader view, because it considers the entire stream of anticipated earnings from a project. Usually, it relates net profit — after taxes and depreciation — to the total investment.

Discounted cash flow (DCF) is the most sophisticated approach, because in considering the time value of money, it accounts for both the amount and the timing of cash flow during the life of a project. DCF is based on the present-value concept, briefly defined as follows:

Consider first the value of a present sum of money after interest payments have been added to it over a period of time. This value is determined from:

$$S = P(1+i)^n$$

Where S = The future amount, dollars
P = The present amount, dollars
i = Interest rate, percent
n = Time period, years.

The value of a $10,000 investment four years from now, at an annual interest rate of 10%, is:

$$S = \$10{,}000\,(1 + .10)^4$$
$$= 10{,}000\,(1.46) = \$14{,}600$$

The reverse computation represents the determination of present worth. It is determined from the reciprocal of the previous equation, or:

$$P = S\left(\frac{1}{(1+i)^n}\right)$$

In this case, the interest rate is in effect a discount rate. The present value of a sum of $14,600 to be paid four years from now, using a 10% discount factor is:

$$P = \$14{,}600\left(\frac{1}{(1.10)^4}\right)$$
$$= \$14{,}600\left(\frac{1}{1.46}\right) = \$10{,}000$$

The object of DCF is to determine that discount rate which will make the present worths of all cash flows during the life of the project equal to zero.

This rate can then be compared against the firm's criterion of an acceptable present-value return on cash investment. One objection to DCF is that the computations can become quite complex. However, these usually can be readily performed with graphical methods or programmable calculators.

Obviously these techniques are not limited to evaluating the feasibility of one given project. They are also valuable tools for selecting the most attractive project from several under consideration. Applications of payback, return on investment, and discounted cash flow methods are illustrated in the example.

The MAPI (Machinery and Allied Products Institute) investment analysis approach also has been widely used in recent years. It is based on an adjusted after-tax rate-of-return criterion.

Instead of estimating an average rate of return over the life of a project, the method estimates the initial rate of return. A set of forms and charts is available to help simplify the mechanics of the calculation. In arriving at the income-tax adjustment to be made, the charts account for the type of tax depreciation to be used.

The basis of the method is the MAPI formula, which attempts to estimate the rate of return based on a number of factors related to the subsequent year, relative to conditions that would prevail if the company went on without the proposed investment. A typical relationship is:

$$R = \frac{B + C_a - C_i - T}{I_n}\,(100)$$

Where: R = Average rate of return, percent. This figure is also known as an urgency rating. A large number of proposed projects may be assigned different urgency ratings. If funds are limited, the most urgent projects can be undertaken first.

B = Next-year operating advantage (the sum of the increase in revenue and the decrease in operating costs achieved by the project), dollars.

C_a = Next year capital consumption avoided (the loss of disposal value from holding present systems for another year plus the next-year allocation of any capital additions required in the absence of the proposed system), dollars.

C_i = Next year capital consumption incurred (the amount by which the use value becomes depleted during the year), dollars.

T = Next-year income-tax adjustment (the net income tax resulting from installation of the new system), dollars.

I_n = Net investment (the installed cost of the proposed system, minus any investment released or avoided by it), dollars.

A drawback to this method is that it encourages a "cookbook" approach to justification. Be sure the underlying assumptions are understood before attempting to use this approach.

Comparing Payback, ROI and Discounted-Cash-Flow Methods

Consider the following situation: A proposed system for updating an existing operation requires the purchase of equipment at a total cost of $100,000. The equipment is estimated to have a useful life of 10 years, with no salvage value. An annual cost savings of $25,000 is anticipated from the new system. A 10% investment tax credit can be used. In other words, up to 10% of the cost of the new equipment can be deducted from applicable income taxes. A tax rate of 48% is assumed. Three different economic measures of feasibility will be used to evaluate the proposed project.

Payback. Data for the payback calculation are shown in Table 6-I. Years are shown from the year of purchase, 0, to the last year of operation, 10, across the top. All figures in parentheses are negative values. For example, the $100,000 purchase in year 0 represents a negative cash flow or outflow. The 10% investment credit reduces the outflow to a net of $90,000.

The first operating year's savings of $25,000 is a cash inflow. Federal tax on the savings is 48% of $25,000, or $12,000.

Another tax factor that must be considered is depreciation. For the payback analysis, an 8-year double-declining balance method is used. (In this method, a declining periodic charge for depreciation is made throughout the life of the project, with greater amounts being taken during the early years.) In year 1, the depreciation is 25% of $100,000, or $25,000. Taxes are reduced by 48% of this figure, or $12,000. This tax reduction is considered a cash inflow. Thus, the net result for the first year is a cash inflow of $25,000. The cumulative cash inflow is shown as ($90,000) + $25,000, or ($65,000).

The same elements are operative in year 2, except that the depreciation inflow has decreased. At the end of year 5, the cumulative cash flow is a positive inflow of $12,000. At this point the net savings have exceeded the equipment investment by $12,000. The payback period is therefore somewhere between years 4 and 5, and is interpolated at about 4⅓ years.

Return on investment. Data for this method are shown in Table 6-II. Depreciation for the ROI calculation is straight line, meaning that equal depreciation charges are taken during each year of the project life. Also, the investment tax credit does not appear in the calculations. (When ROI is used, investment tax credit generally appears in a tax expense account.)

The year's depreciation charge of $10,000 is deducted from the savings of $25,000 to yield an operating income of $15,000. The 48% tax of $7,200 is subtracted from this figure, leaving a net of $7,800.

Average capital investment for the year is shown in the final column. It is the average of the net investment in equipment at the beginning and end of the year. For example, the net investment is $100,000 at the beginning of the first year, and $90,000 at the end after the $10,000 depreciation charge is deducted, so the average investment is $95,000.

Total return for the 10-year period is $78,000, and the total average investment is $500,000. The return on investment is $78,000 divided by $500,000, or 15.6%. In order for the project to be acceptable, this figure must meet the firm's minimum ROI criterion.

Discounted cash flow approach uses the same basic data as payback. The double-declining-balance method of depreciation also is used, as is the 10% investment tax credit. Cash outflow in year 0 is $90,000. In year 1, there is a net cash inflow of $25,000. In year 2 it is $22,000, and in the 10th year it is $13,000. With the depreciation method used, the total tax depreciation charges have been deducted in the first eight years, so no tax savings are realized from that source in the final two years.

The total net cash inflow for the 10 operating years is $178,000. A discount factor (percentage equivalent to an interest rate) must now be found that will produce present values for the cash inflows that will approximately equal the initial outflow of $90,000. Determined basically by trial-and-error procedures, this figure will represent the rate of return on the cash flows over the life of the equipment.

An annual discount factor of 17% produces the numbers shown in the line labeled "Present value-cash flow." Note that the total of the present value numbers for the 10 operating years equals $90,000. The cumulative total, as shown on the bottom line, is 0.

When different projects are being compared with the DCF method, the one having the highest discount factor will be most favorable. For instance, if the cost savings were $31,000 annually instead of $25,000, the net cash flow would be about $3,000 higher each year. A higher discount factor would then be needed to reduce the cash flows to a cumulative present value of $90,000.

Table 6-I

Payback

Year	0	1	2	3	4	5	6	7	8	9	10
Purchase	(100)										
Investment credit	10										
Cost savings		25	25	25	25	25	25	25	25	25	25
Tax effect —											
Cost savings		(12)	(12)	(12)	(12)	(12)	(12)	(12)	(12)	(12)	(12)
Depreciation		12	9	7	5	4	4	4	3		
Net cash flow	(90)	25	22	20	18	17	17	17	16	13	13
Cumulative	(90)	(65)	(43)	(23)	(5)	12	29	46	62	75	88
Payback	Approximately 4⅓ years										

Table 6-II

Return on Investment

Year	Income	Straight-line depreciation	Income tax at 48%	Net return	Average investment
1	25	10	7.2	7.8	95
2	25	10	7.2	7.8	85
3	25	10	7.2	7.8	75
4	25	10	7.2	7.8	65
5	25	10	7.2	7.8	55
6	25	10	7.2	7.8	45
7	25	10	7.2	7.8	35
8	25	10	7.2	7.8	25
9	25	10	7.2	7.8	15
10	25	10	7.2	7.8	5
Total	250	100	72	78	500

Return on investment is 78 ÷ 500 = 15.6%

Table 6-III

Discounted Cash Flow

Year	0	1	2	3	4	5	6	7	8	9	10
Purchase	(100)										
Investment credit	10										
Cost savings		25	25	25	25	25	25	25	25	25	25
Tax effect —											
Cost savings		(12)	(12)	(12)	(12)	(12)	(12)	(12)	(12)	(12)	(12)
Depreciation		12	9	7	5	4	4	4	3		
Net cash flow	(90)	25	22	20	18	17	17	17	16	13	13
Discount factor	1.00	.85	.73	.62	.53	.46	.39	.33	.28	.24	.21
Present value — cash flow	(90)	21	16	12	10	8	7	6	4	3	3
Cumulative	(90)	(69)	(53)	(41)	(31)	(23)	(16)	(10)	(6)	(3)	-0-

The discount factor above is 17% annually.

Chapter 7
Acquiring Equipment and Systems

In the final analysis, the key to achieving a solution to a material handling problem often lies in obtaining appropriate equipment and systems. This step is the culmination of much hard work expended in analyzing material handling problems, collecting and evaluating data, comparing alternative approaches, developing a solution, identifying equipment needs, and establishing cost justifications. Typically, sources of equipment and services can be categorized as follows:

The manufacturer is a prime source of equipment, although many products are marketed through material handling equipment distributors. The manufacturer or distributor can furnish advice on equipment selection in an effort to improve performance or reduce cost, and may suggest how a piece of standard equipment can be modified to take the place of a special design.

In general, equipment warranties come from the manufacturer. The manufacturer also provides operating and maintenance manuals, training aids, and other literature.

The distributor is often the immediate source of equipment. He can analyze equipment specifications and make suggestions regarding system layout and equipment choice. He can also determine whether or not standard equipment can be supplied. Typically the distributor is responsible for installation and field wiring of equipment. He plays a leading role in feeding back performance data to the manufacturer and any consultants used on the project.

The distributor often can provide specialized training classes for operators and mechanics. Service and parts stocking capabilities are important considerations in selecting vendor and distributor.

The consultant can bring a high degree of objectivity into the analysis of material handling problems. Typically he will perform an engineering study of the problem, and provide specific recommended solutions. He may define volume projections for the system and the required throughput capacity.

Using the project schedule, the consultant develops an overall implementation schedule that guides all parties in the execution of their assigned work. He may also prepare information flow procedures, and help develop the bid specifications. In some cases, the consultant also may be asked to help in startup.

The engineering company can perform engineering studies, design systems and facilities, develop project schedules, erect facilities, install equipment, and start up operations. In some cases an engineering company may be asked to provide a "turnkey" job, meaning that it assumes total, single-source responsibility for the project.

A turnkey approach can have definite advantages in some situations. However, as in any project, the customer's personnel must be involved in every phase of planning and startup in order for the system to ultimately succeed.

The system supplier is a specialist firm dedicated to the design, engineering, installation, and startup of automated material handling systems for storage and retrieval and other operations. Typically such a supplier will manufacture some portion of the equipment or controls to be used in the system, subcontracting other portions and frequently serving as prime contractor. In a few cases the customer may serve as prime contractor, using several system — or subsystem — suppliers.

For a system to be successful, the supplier should be brought in early in the project planning. He should be provided with all pertinent data about the operation. Finally, his responsibilities — along with those of all others involved in the project — should be well-defined at the outset. It is important that a master plan for project implementation be established and followed.

Proper Bid Specification

The importance of preparing well-planned, written specifications — accompanied by scaled drawings if possible — cannot be overemphasized, even for small jobs involving only one or two pieces of equipment. If equipment specifications are not spelled out precisely, with little chance for misinterpretation, competitive bids can vary widely in price.

For example, consider a simple application requiring an inclined belt conveyor to serve a temporary storage mezzanine. Cartons are to be loaded onto the mezzanine, and removed from it, several times a month. The 50-lb. cartons are 24 in. long, 18 in. high, and 24 in. wide.

Operators at top and ground-floor levels will handle the cartons manually. The conveyor is to be reversible, and inclined 25 degrees. Two vendors are called in individually and provided an oral description of the application requirements. No written specifications or drawings are provided. The instructions end with the statement, "Quote a good piece of equipment."

Resulting bids are shown in Table 7-I. Both units quoted will work, although maintenance needs and service lives may differ greatly.

Now assume that the verbal instructions ended with the statement: "This is only a standby operation. Quote the most economical conveyor available that will do the job."

Under these circumstances, Vendor 1 can offer a unit from a lower-priced line he also carries. This alternative will still do the job, and is priced $909 less than the conveyor quoted by Vendor 2.

Buying, Leasing and Renting

There are three basic ways to acquire the use of material handling equipment. The equipment can be purchased with cash or borrowed money, leased, or rented. The cost of money should always be kept in mind when making the decision. (However, some types of equipment may not be available on a lease or rent basis.)

Outright purchase may be the simplest method. However, alternative uses for the cash, including earning interest, or other investment, should be considered. Or, the funds might be applied to a project offering a higher rate of return. Outright purchase, of course, has the advantage of conserving lines of credit. Because it involves no debt, financial or operating ratios are not affected adversely.

Financing may be more attractive for companies that have most or all of their capital funds tied up in acquisitions,plant expansions or modernizations. Payments can be prorated in equal amounts over the useful life of the equipment. The interest portion of annual debt repayments is tax deductible, and principal payments can be offset by depreciation.

Leasing makes full use of the equipment available without the need for paying the full purchase price. The customer pays for the economic value of the equipment. The lessor retains title to the equipment, and realizes its residual or salvage value.

In a true lease, the length of the lease is usually based on an agreed-upon estimate of the economic life of the equipment in its intended application. The residual value of the equipment is then deducted from the acquisition cost, and the customer pays for the percentage of the equipment's value that applies to his operation. The title does not pass from lessor to lessee.

Assume, for example, that a company leases a lift truck for its economic life, which is five years in a specific application. At the end of the five-year period, the truck will have a residual value of 20 percent of its acquisition cost. The terms of the lease would then be based on 80 percent of the truck's acquisition cost. A true lease must be distinguished from a lease with option, which is considered to be a conditional sales contract.

In a purchase-option approach, the user can contract for the same monthly payments as in a standard lease, but also may have the option to purchase the equipment for its fair market salvage value. Numerous variations of these two basic types of lease agreement can be drawn up.

Leasing may be attractive for several reasons. The level of a firm's taxes or income may be such that it cannot use an investment credit or an accelerated depreciation schedule. However, because the lessor can use these benefits, he can pass some of the savings on, in the form of a lower lease payment. Thus, in this manner one can regain some of the benefits that were not available with outright purchase.

Leasing also provides a hedge against equipment obsolescence. The agreement may be written in such a way that the user can replace equipment that has become obsolete for technical or environmental reasons or because of application changes with more up-to-date equipment.

Renting typically is the most expensive method of acquiring the use of equipment, when compared to other methods on a per-hour basis. However, for many short-term situations, it may well be the most economical over the life of the application.

For example, renting is beneficial if additional equipment is required for only a few weeks a year, perhaps during an inventory period, or to meet peak-season demand. Renting can also avoid or minimize the high cost of equipment downtime. It may be feasible to bring in a rental unit to keep production going while a key item of equipment is down for repairs.

Consider a lift truck example. Typically the rental fee is based on the hourly cost of use of the machine. The customer still pays for fuel, maintenance, and the operator(s).

Assume that the agreement with a distributor calls for renting a truck for four months, at a rate of \$625 a month. The total rental cost is $4 \times \$625 = \$2500$. Assuming the truck

Table 7-I
Example of Competing Bids for Inclined Belt Conveyor

	Belt Data			Drive				
Bidder	Width, in.	Length, ft. (center to center)	Type	Size, HP	Type	Frame Width, in.	Controls	Price, dollars
Vendor 1	24	24	Rough top	2	Center	28	Starter wired to motor. Two pushbuttons: forward, stop, reverse.	2214
Vendor 2	18	24	Rough top	1½	Center	24	Manual starter. Control rod for top and bottom operation.	1992
Vendor 1 (alternate bid)	12	24	Semi-rough top	1	End	22	110 volt plug, control rod, reverse switch.	1083

will be operated on a one-shift basis, for 170 hours a month, the number of total operating hours then is 4 × 170 or 680 hours. The hourly rental rate then is $2500 divided by 680, or $3.68 per hour.

A rental-purchase agreement may be entered into, as an alternative to straight renting. With this approach, rental payments can be applied toward the purchase of the equipment at the end of the rental period.

The rental-purchase option thus avoids the need for an immediate capital outlay. It may be useful when there is uncertainty about the future level of business. Also, it can provide an answer when sufficient cash is not immediately available for a down payment on the new equipment. However, such an agreement is considered a conditional sales agreement and must be accounted for as such.

The Used Equipment Option

For some applications, used equipment can provide several advantages beyond the obvious one of low initial cost. For example, where the equipment may be used only occasionally, a used unit in good condition may be the economical choice. Or, if capital funds are limited, used items may provide the answer to a need for additional equipment or a specialized unit.

Often used equipment is available immediately, and can mean the difference between being in production right away or delaying operations for months while awaiting delivery of new equipment.

In many cases, the used equipment may still be in good condition. The owner merely found it more economical to replace it with new items, particularly if his operations changed. In some cases, the equipment may not have been applied correctly initially.

Another reason for getting rid of equipment is obsolescence. Some types of equipment may be obsolete for one company's needs, but may still be highly applicable for another's. Still another reason is bankruptcy. The owner may simply be going out of business.

However, if the equipment has received hard usage, particularly in harsh environments as, for example, in a foundry, it may not be as desirable a buy. So, obviously, it is important that the history of the equipment be reviewed. In any case, when considering used equipment, determine whether a warranty is offered, and if so, for how long and by whom. Also be sure to establish who is responsible for dismantling the equipment at the old site, and for paying the shipping charges.

Chapter 8
Making Presentations to Management

One of the most crucial steps in the life of any material handling project is selling the concept to top management. In general the project is competing against other demands on available corporate funds, so the chances of gaining acceptance will depend on how carefully and effectively the project's case is prepared and presented.

Even today, the role of material handling in cutting costs and improving productivity is not fully understood or appreciated in many companies. As stated earlier, many people do not normally think of material handling as a separate discipline, or of problems in the plant being related specifically to material handling. Even traditional business language and accounting principles tend to obscure the impact of material handling.

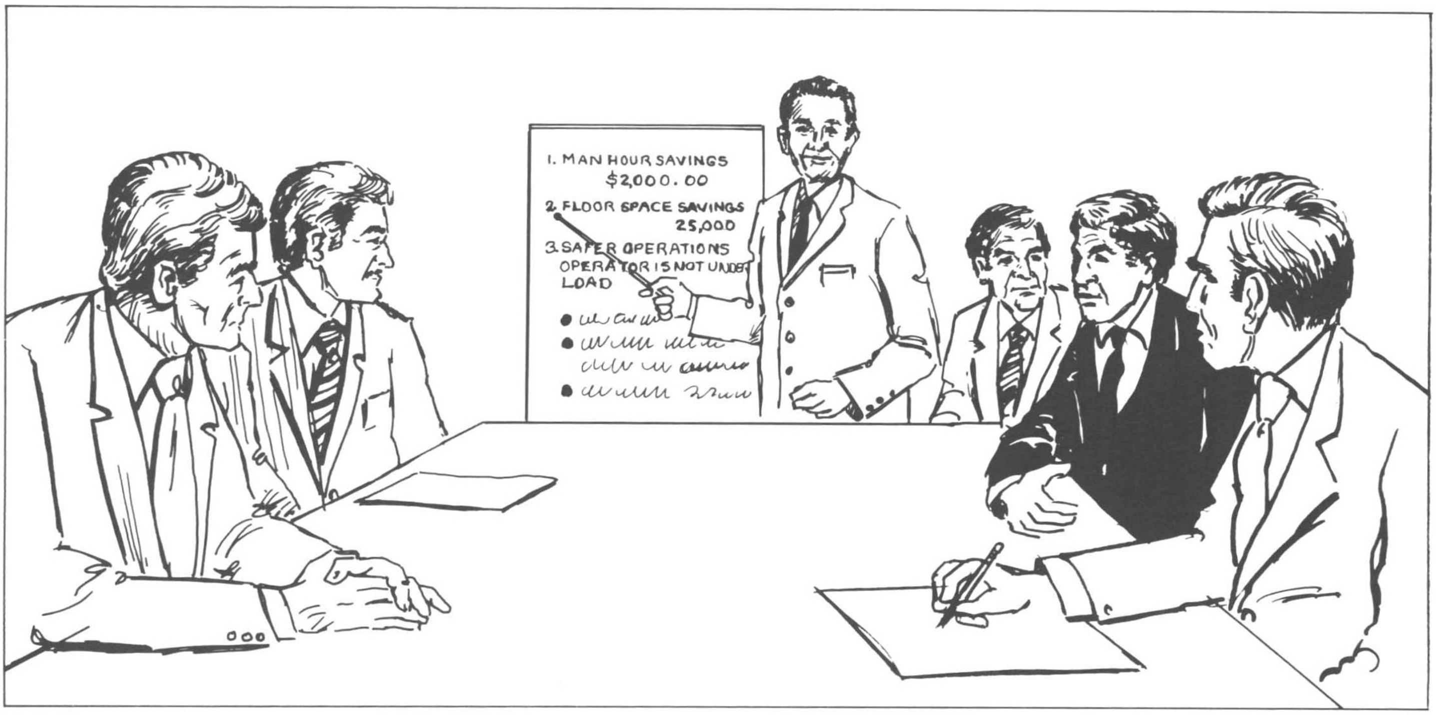
Whenever possible, try to build an awareness and appreciation for the benefits available from proper material handling on the part of your management and others in your organization. By itself, material handling is not typically in the curriculum of most executives, so one of the tasks may be to help educate management in this area. Articles in business publications and news about material handling success stories at other companies can be pointed out whenever possible. In some instances, findings or prepared reports related to handling should be distributed. A management confronted with inflation, foreign competition, raw material shortages, and shortages of skilled workers should be more attentive to the message than ever before. This presents the opportunity of serving as the "material handling ambassador" in one's company or plant. However, the time to start is right away — not just prior to making a specific request for project funds.

Justifying the Project

The primary purpose of the presentation will be to describe the proposed project, explain its merits, and tell why it should be undertaken by the company. In general, there will be more stress on economic information than on technical data. Management usually will be inclined to accept the technical soundness of the project, and it is entirely possible that technical questions may not come up at all. Obviously, assumptions cannot be made about what questions will be asked. Be prepared to field any technical points that may come up.

In some situations, presentations will be made to more than one level of management, in which case a technical screening may come first. Naturally, the support of one's immediate manager or supervisor should be gained before proceeding further.

Economic justification criteria were discussed in detail in Chapter 6. The presenter must, of course, follow the criteria and decision rules used by his firm, whether they involve payback period, return on investment, discounted cash flow or other approaches. A cardinal rule in such



presentations is to speak the language of the audience, and use its rules, words, and conventions. Also keep in mind that management is interested in how the proposed project will relate to long-term company goals, and how it may affect various functions within the organization. Support the project with facts.

To present the best possible case, be sure that all the potential benefits of the project, including intangible or non-quantifiable factors, are accounted for. For example, if the project promises safety or environmental advantages that will help meet stringent government regulations, one can be sure of having management's attention, even if these items cannot be assigned specific dollar values.

The following factors typically have been used in justifying AS/R systems. Most are equally valid for other kinds of material handling projects. Check to see how many of these benefits the proposed system promises to provide and be sure that they are covered in the presentation.

• **Reduced labor.** By providing labor savings, material handling systems may cut payroll costs, for direct as well as non-direct personnel.

• **Greater production efficiency.** Effective material control will avoid delays in production or warehousing operations, and minimize lost worker time caused by material shortages. Scheduling can be made with greater confidence.

• **Space savings.** Properly applied material handling and plant layout procedures can result in substantial savings in floor and cube space. In many cases, construction of building additions or even new buildings can be avoided. If space savings are a factor in the project, be sure to quantify them in percentage terms, or in terms of increased production capacity.

• **Fewer errors.** Errors in production and order picking can be reduced significantly with a properly designed handling and storage system. Try to provide a quantitative figure for error reduction if possible.

• **Reduced pilferage.** Better control over parts and materials reduces the opportunities for pilferage. (An average figure for inventory losses due to pilferage amounted to $7,000 to $10,000 per year, for each $1 million of inventory in stock.)

• **Lower turnover expenses.** The cost of recruiting, equipping, and training a new employee such as a stock picker was in the neighborhood of $3000. Automated S/R systems have been estimated to reduce turnover by about 50 percent.

• **Reduced product damage.** Eliminating some handling steps and minimizing manual handling of inventories will inevitably result in less damage to products.

• **Improved customer service.** The costs of lost orders caused by slow or inaccurate deliveries may be difficult to quantify, but they are very real. An effective material handling system that can speed deliveries and serve customers better in other ways is bound to result in new or increased business.

• **Reduced inventory costs.** Better control over materials can permit reduced investments in inventory, along with greater confidence in inventory records. Studies have shown that the average cost of carrying inventory is about 30 percent of the value of the inventory. A 10 percent reduction in a $1 million inventory could cut carrying costs by at least $24,000 a year.

• **Potential tax benefits.** Often the investment tax credit can be applied for storage structure portions of AS/R systems, and for rack-supported buildings. In many cases higher interest and depreciation expenses can be written off against income taxes.

• **Improved job satisfaction.** The elimination of drudgery and difficult manual handling will improve job satisfaction and morale, thus leading to a more stable work force and higher levels of productivity. In some cases, employees in low-level job categories may be upgraded as a result of the changeover.

Providing Options

In making the proposal, be prepared to provide modifications or alternate schemes for management's consideration. Such alternate proposals may be needed if restricted funds or other limitations hinder full approval of the project as initially proposed. Of course, each feasible alternative should be accompanied with pertinent economic data to aid management in making the final decision.

If possible, each alternate approach also should be accompanied by some type of risk estimate. Management is naturally concerned with the degree of uncertainty involved with a proposed project, such as the accuracy of cost and payback estimates. Management also is concerned with future uncertainties. For example, if there is a high probability that certain items of equipment will not be fully utilized over the life of the project, the decision may swing to leasing instead of outright purchase. However, if leasing were not suggested as an option, the entire project could well be cancelled.

Presentation Techniques

Even if the project is technically sound and promises attractive economic benefits, its success or failure may depend on the nature of the presentation. A great deal of thought should be given to ways of presenting information clearly and concisely, and to the use of effective visual aids. Remember, the audience is composed of people whose interests can be aroused or easily turned off. Always speak the language of the listener.

Strive to capture the attention of the audience quickly, at the outset of the presentation. Some experts say that the first 50 words — and 30 seconds — are the most important, because they are crucial in commanding initial favorable attention. There is no second chance to create a good first impression. At this stage, the speaker should establish the relationship between himself, the subject of the presentation, and the audience. In short, he is justifying his appearance before this group at this time, because of the importance of the subject matter to the organization.

He must then generate genuine interest in the project, followed by a desire to see it implemented. The final step is motivation — getting the group to *act* in support of the proposed project.

As in any good report, key information should be presented in clear, concise, summarized form. Do not belabor any points, or dwell on unnecessary, extraneous material the group does not need for decision making. Make sure the project benefits being sold stand out clearly and can be absorbed quickly.

The use of pie charts or bar graphs can help immensely in getting key points across. Sometimes scale models can do wonders in aiding understanding. Simple plan drawings, with areas of interest emphasized by special colors or overlays, also can be very effective. Try to think of ways to express facts quickly with clear, good-quality visual aids. Use them as necessary to get the message across, but avoid being tricky or overly theatrical.

Respect the time demands on the audience, and at the same time maintain control of the meeting. One way that control is sometimes lost is by ending the formal presentation with a question-and-answer session. In this manner, control is relinquished to the audience. Some difficult questions may come up, and there is a danger of the meeting ending on an ambiguous or negative note.

An alternate approach is to hold a question-and-answer session prior to the end — perhaps two-thirds or three-quarters through the presentation. After questions have been fielded, there is an opportunity for clearing the air, regaining control over the presentation, and ending on a positive, upbeat note. A good ending can have a tremendous impact on the success of the presentation, and can be as important as the initial, attention-getting phase.

It may be important to identify the one or two key opinion leaders in the group, and especially aim the presentation toward their interests. In fact, it would be desirable to pre-sell these key individuals in advance of the meeting. They could be strong allies later.

After the project has been sold, responsibility must be taken to make sure that it is implemented properly and delivers the results that were promised. Remember, a track record is being established that will influence future project proposals. There is no better way to generate initial favorable attention than by being able to refer to past successes. On the other hand, it will be difficult to generate enthusiasm in the wake of mediocre past performance.

Engineers and other technical professionals, accustomed to dealing with facts, data, and analytical procedures, may feel uncomfortable with having to "sell" a concept. However, they should strive to develop the necessary skills for this aspect of their jobs, to ensure that their work bears fruit, and that their contributions to the success of the firm do not become lost through lack of clear communications.

Chapter 9
Material Handling in the Total Organization

Although the words "material handling" may not necessarily appear in a company's organization chart, the material handling function may nevertheless be represented strongly at various levels of the organization. A number of factors influence how material handling is organized in a company or plant. They include the size of the company, its use of modern business methods, its objectives, and the nature of the product or service.

In a manufacturing facility material handling provides a service and support function to production. Therefore in some plants, it may occupy a staff position. However, in other cases it may be at a line level. It is especially likely to be at a senior line level where it is the primary activity. An example might be a distribution center, where operations center around storing, retrieving, transporting, and selling of goods produced elsewhere.

The nature of the product also may affect the role that handling plays. For instance, material handling may be a major element of the entire cost of producing a low unit value bulk product such as ore or coal. On the other hand, it may have a more subordinate role in the manufacture of high unit value products such as automobiles, jewelry, or machine tools, where handling provides a smaller contribution to the final price of the product. At the same time, manufacture of high unit value but fragile items may involve higher handling costs.

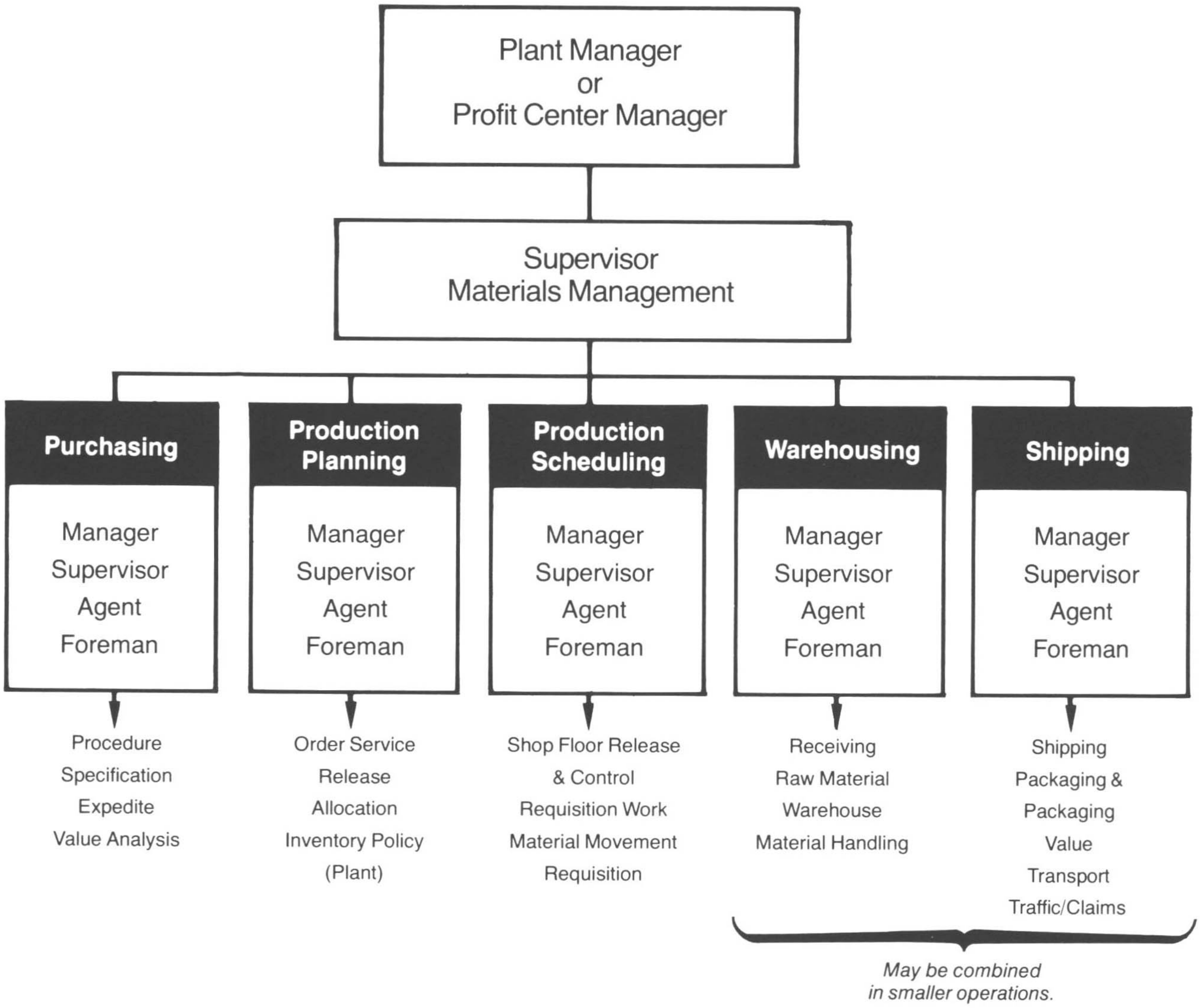


Fig. 9-1
An example of a material management organizational structure at one company indicates broad responsibility over many functions including material handling.

Organization Approaches

Material handling can — and often does — have both staff and line roles in an organization. For example, it can be part of the plant's staff engineering responsibility, with reporting lines to the top company engineering executive, the plant manager, the plant engineering department, or head of industrial engineering. Some companies have a corporate material handling manager or specialist at a senior staff position, reporting to operating management or the senior manufacturing executive. This individual — and his support staff — may set company-wide material handling practices, drawing upon internal engineering or outside suppliers or consultants for specialized assistance.

In some cases, individual plants may each have a separate material handling department, with operating responsibility for all or portions of the facility's material handling activities. The material handling department works closely with production or various support functions to coordinate scheduling of materials, labor, equipment, and storage facilities to meet ongoing requirements.

Some material handling activities may be under the control of individual production departments, as for example when fixed handling equipment such as cranes and conveyors is assigned to a department. Maintenance service typically is provided by plant engineering. Such an approach is often taken by organizations having decentralized and autonomous departments.

Depending on the nature of operations and the size of the company or plant, greater efficiencies often can be realized by having equipment controlled by a plant-wide pool, with individual items being shared by departments as required. Maximum equipment utilization often is achieved in this manner. In cases where equipment is assigned outright to a department, its daily operation is the responsibility of the department head. Training, maintenance, and other support activities are provided by the pool. Units also might be dispatched to departments on a job basis with the pool retaining control over the equipment.

The pooling approach is often taken with mobile equipment such as lift trucks, tractor trains, personnel and burden carriers, and mobile cranes. The practice is frequently followed in organizations having strong centralized operations, or in large companies.

For example, at one major automotive manufacturing complex, lift trucks, and other industrial vehicles, and commercial transport carriers are under the control of a general foreman for truck repair and transportation. The department head is responsible for specifying and purchasing all new vehicles for the facility, as well as for performing all vehicle maintenance and repair. Its responsibilities include engine rebuilding, motor rewinding, designing battery-charging rooms, developing truck replacement criteria, and training of mechanics and drivers. Specific production departments are assigned lift trucks as they need them.

Relationship to Other Functions

From the discussion so far, it should be clear that material handling responsibilities may appear in several places in the organization structure. This fact is true also because of the relationship of handling to other functions. The following are some of the major areas in which material handling has a role:

Manufacturing. In industrial manufacturing plants, the primary role of material handling is to support the production function, by providing materials to the production floor when needed, moving them into the configurations required at the workplace, and removing and storing processed goods.

Production and inventory control. Receiving, shipping, and production schedules imply a close correlation with the handling and storage resources of the facility. Changes in inventory levels may require modification of storage practices. Storage also plays a vital balancing role when production runs with different rates are involved.

Plant engineering. Design, erection, and maintenance of the facility are among the responsibilities of this group, along with installation and maintenance of material handling equipment. The plant engineer must be intimately involved in the planning of any major project, including AS/R systems, to help ensure long-run success. Maintenance may be performed on a work-order basis from a central department, or plant engineering personnel may be assigned full or part time to departments.

Industrial engineering. Much of the industrial engineer's work involves utilization of efficient material handling. Plant layout must of necessity include consideration of material flow and handling requirements. Process and Methods engineering involves the positioning and flow of work, and work standards can be applied to evaluation of material handling activities.

Quality control and inspection. Appropriate handling practices are necessary to minimize damage to products during storage, in-plant handling, and shipment. Inspection procedures can be greatly enhanced by the methods used in moving and identifying materials.

Purchasing. Purchasing policies can affect inventory quantities, which in turn have an impact on handling methods and costs. And, the purchasing function can be used to influence delivery methods and schedules, and the load configurations that are acceptable for plant handling systems.

Packaging. In-plant handling methods often are affected by packaging and shipping requirements. The package also serves as a handling aid in protecting the product during its transportation, and in further functioning as a storage aid at the destination point, as in the case of a package designed to permit stacking.

Warehousing. Material handling is usually the primary activity in a warehouse, whether it is part of a production plant or an independent distribution center. Typical handling activities include receiving, sorting, storing, retrieving, conveying, combining, packing, and shipping. For some firms, automated high-rise storage and retrieval systems represent the technological state-of-the-art in applying material handling efficiencies to warehousing.

Physical distribution. Another area having a high material handling component is the broad range of activities involving the movement of products from the manufacturing operation to the ultimate consumer. Warehousing and traffic management are among the disciplines that can be covered under this "umbrella" function, which is also concerned with inter-plant movement of materials by multiple-plant companies.

Marketing and sales. A company's marketing efforts can have a significant effect on handling practices in its plant. Order volumes can determine manufacturing methods, means of bringing materials to and from the production floor, and methods of raw, in-process, and finished-goods storage. Packages may be designed to be sales and merchandising tools. Agreements with customers can dictate shipping load configurations, and the use of pallets, slipsheets, or other unitizing equipment. Types of carriers and delivery schedule commitments will also impinge on plant and dock handling methods, and the degree of mechanization required. In an age where fast, decisive response to market requirements is necessary, it is difficult to think of another function that has as much an overall effect on a plant's handling operations.

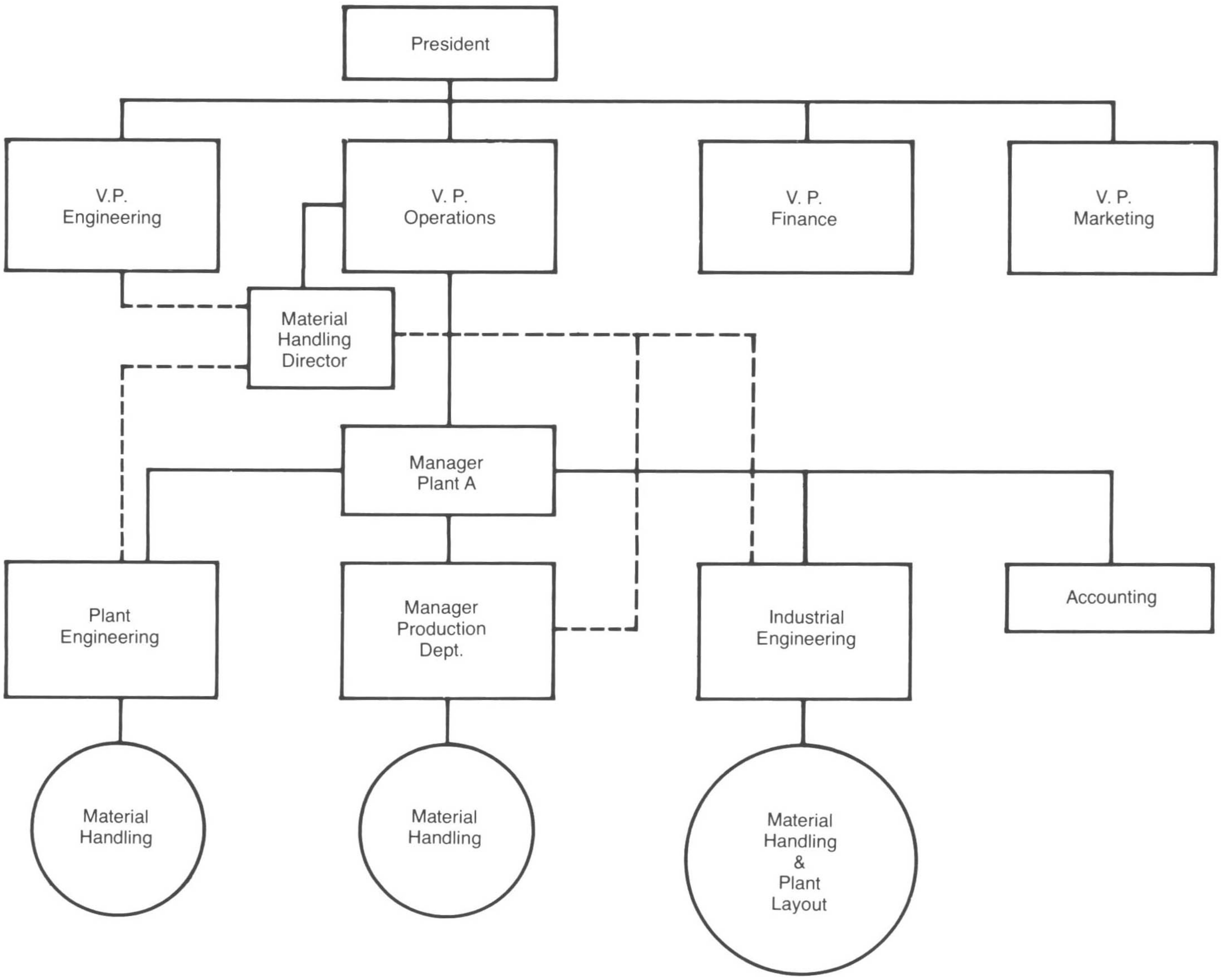


Fig. 9-2
In this organization, a Director of Material Handling reports to the Vice President of Operations in a staff capacity. He has a dotted line relationship with the corporate Vice President of Engineering, because at times he may call upon internal engineering for assistance. He also has dotted line relationships with Plant Engineering, Production, and Industrial Engineering, because he sets corporate guidelines for material handling procedures. The circles at the bottom represent functions, rather than departments or management levels. They indicate that Plant Engineering, Production, and Industrial Engineering each perform a material handling function within the organization.

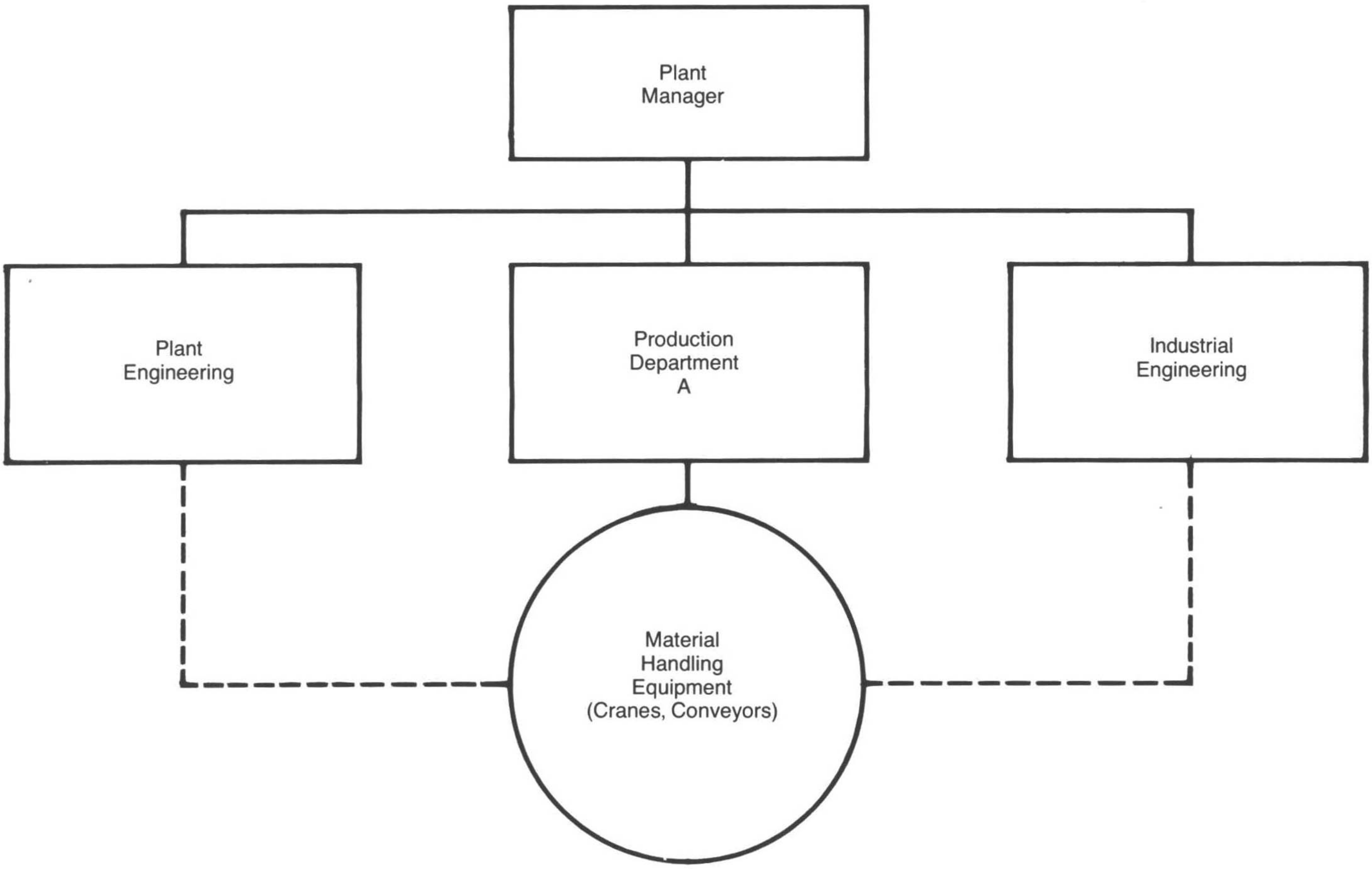


Fig. 9-3
In a decentralized approach, Production Department A has complete control over material handling equipment in its area. It may call upon Plant Engineering for installation and maintenance assistance, or upon Industrial Engineering for help with equipment layout. However, final authority for equipment disposition rests with the production department.

The Team Approach

The interrelationship of handling with other functions often promotes the formation of interdisciplinary project committees or teams to plan and implement major material handling systems. Such teams constitute special material handling organizations set up for the life of the project or facility.

An example of this approach was a team program developed several years ago by a major engine manufacturer planning a new plant that would incorporate automatic high-rise storage and towline conveying. The internal material handling team included representatives from maintenance, production control, plant layout, industrial engineering, purchasing, systems development, and financial control. Plant engineering, manufacturing, and manufacturing engineering also provided inputs. Team members were slated to become members of the plant management staff when the new facility was completed.

These representatives provided inputs regarding their department needs, and communicated material handling plans back to their associates. They also shared in the selection of the hardware and system suppliers. In addition, team responsibilities included scheduling, personnel training, startup, and monitoring of system performance. Almost invariably, the ultimate success or failure of a material handling system depends on the effectiveness of such a project team, as it strives to incorporate the perspectives of various disciplines in the system plan.

Material Management

The interrelationships among various functions concerned with the flow of materials have led to a material management organization in a number of companies. Under this approach, the director of material management is responsible for coordinating the activities of purchasing, material handling, packaging, production planning, receiving distribution, order processing, inventory control, warehousing, shipping, and transportation. Usually one of his basic tools is Material Requirements Planning (MRP), a time-phased system of procuring and scheduling materials tied to specific operating plans or manufacturing schedules.

One type of material management structure is shown here. Many variations are possible, including having a senior-level director of material management responsible for coordinating corporate-wide material flow control.

Organization Alternatives

By now it is obvious that material handling cannot be neatly pigeonholed in the corporate organization chart. The needs of the firm, traditional practices of its industry, nature of the product, and various other factors influence how it is organized in a plant or warehouse. Various alternative approaches are shown here. Perhaps more important than the form of any specific chart is having the material handling function visible and effectively organized and controlled, and seeing its contribution to overall operating efficiency and profits properly recognized.

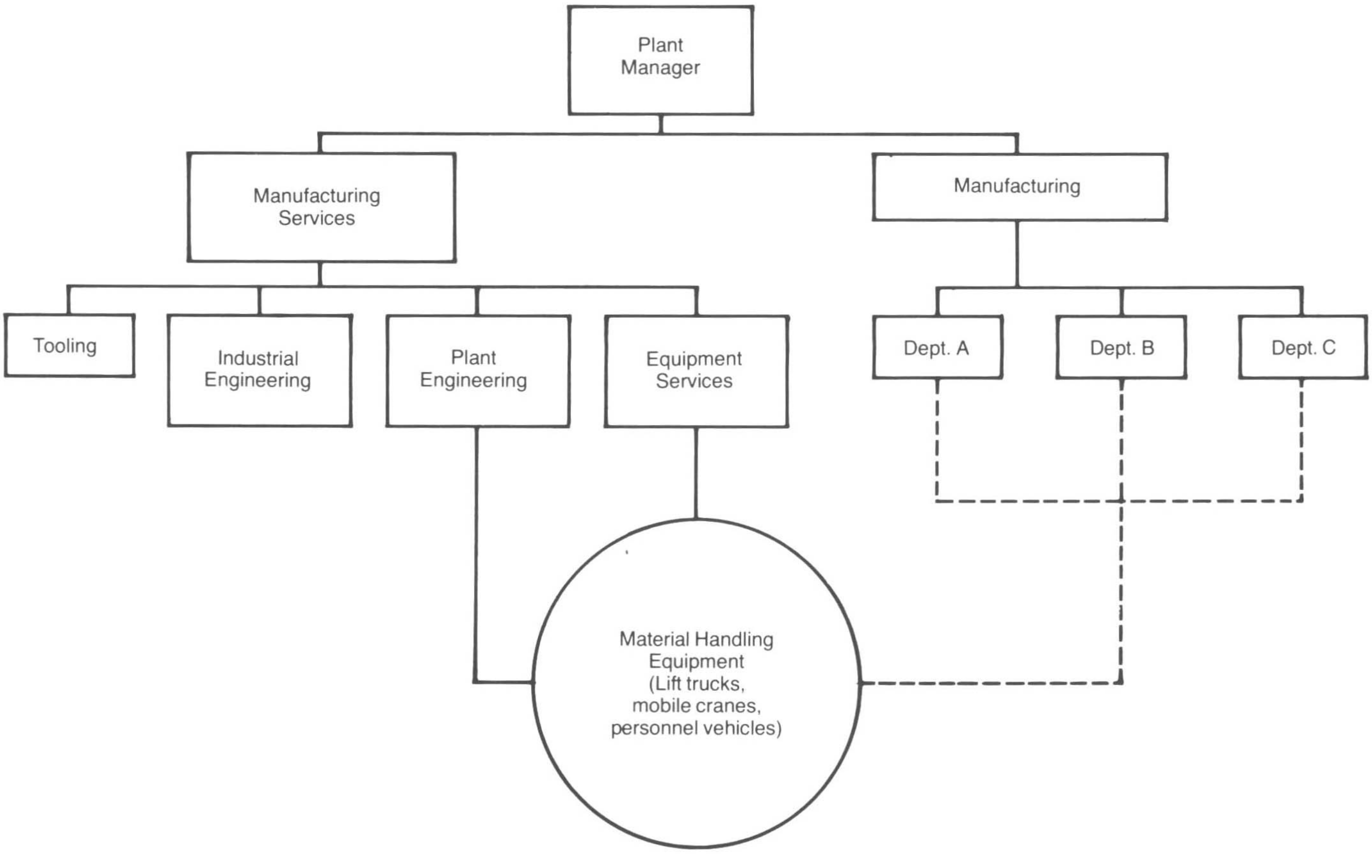


Fig. 9-4
One centralized concept places control over handling equipment under a plant-wide pool (the Equipment Services box). Equipment is assigned to departments on the basis of operating requirements, but control over the equipment rests with the pool. Preventive maintenance is scheduled and performed by Plant Engineering.

Chapter 10
Training, Safety, and Maintenance

Industry studies have shown that over one-fifth of reported industrial accidents are related to handling, particularly lifting and other types of manual effort. One of the major goals of modern material handling methods is to improve safety of industrial operations. To be successful, any safety effort must include a good combination of training, equipment selection and maintenance, proper operating practices, and a formalized program of inspection.

Training

Training is a key ingredient. Operators who are well trained in the characteristics of their equipment, and who understand their assignments, are far less prone to be involved in an accident.

Taking conveyors as an example, the location and operation of pushbutton stations should be reviewed carefully with plant personnel. In many recorded accidents involving powered conveyors, failure to shut down the unit promptly has been due to inadequate personnel training as much as to any other single factor. The results of such inadequate training can be both tragic and unnecessary.

Lift truck operation is another area involving a major training effort, for both operators and mechanics. Such training is called for in industrial facilities by the U.S. Occupational Safety and Health Administration (OSHA). It is also a good investment, because it pays off in reduced damage to products, equipment, and plant facilities. Bent rack uprights, broken pallets, and damaged walls and doors all point to a lack of proper training or supervision, or both, in many plants. The following are also indicators of inadequate lift truck operator training:

- High maintenance costs — operators may not be performing routine checks.
- Excessive product damage and customer complaints.
- High incidence of lift-truck-related accidents.
- Damage to physical plant.
- High level of fuel consumption.

Regardless of the type of equipment involved, supervisors must be trained as well as operators. In particular, supervisors should be familiar with the following items:

- Material handling requirements in the plant.
- Suitability of the equipment for the materials being handled.
- Environmental effects on equipment operations.
- Effects of equipment on the environment (carbon monoxide and exhaust fumes).
- Equipment service and repair requirements.
- Operator capabilities.
- Procedures for planned use and servicing of material handling equipment.

Many excellent training programs are available from material handling equipment manufacturers and distributors. Frequently distributors can assist in setting up training courses or even conduct them in your plant. Private firms, associations and societies such as the National Safety Council and the International Material Management Society also have developed programs that may be purchased. Some equipment manufacturers hold special training schools at their facilities, and specialized courses are available at area junior colleges and trade schools.

As far as in-plant training goes, a typical program will include a kit of printed, programmed training materials such as an instructor's guide, student workbooks, test materials, and practical exercises. Operator certificates and licenses certifying successful course completion generally are included. Slides, motion pictures, and videotape also may be used.

For example, one lift truck manufacturer recently introduced videotape training programs for use in the plant. The package includes one or more reels put together into customized packages for seminars and in-plant courses. With this approach, special equipment features, such as electronic controls or an unusual lift configuration or drive axle, can be shown — with narrative accompaniment — to a maintenance mechanic at the time that assistance is needed. Training tapes also are available to familiarize operators with the controls and techniques necessary to maneuver a truck safely and confidently.

Another program involves six self-instructional training courses on industrial crane operation and safety. They can be used individually or as a complete set for training new plant employees and material handling personnel, and for remedial study by working crane operators. Subjects include general crane safety, structural factors, and specialized study courses for operators of pendant, cab, and hot-metal cranes.

All courses consist of an audio cassette, illustrated workbook, and progress test. The subject material is presented in cassette lecture format and reinforced by related illustrations, diagrams, and questions. The tests measure progress and identify areas requiring additional study.

In all likelihood, no one standardized course or program will fill all training needs. Usually, though, one of the available standard programs can be used as a base on which to tailor a program best suited for a particular facility and its personnel.

Who should be trained? First, an operator of material handling equipment should be alert, healthy, and coordinated, have good eyesight and depth perception, and be able to read and understand directions. Simple tests can be conducted to determine mechanical capability, mental alertness, and physical suitability of potential operators. In any case, health is an important consideration.

Application and retraining. After the investment in training has been made, steps must be taken to ensure that it is not lost. Often there is a danger of a newly trained person returning to the job and laying aside everything he has learned in order to get back to his regular, day-to-day responsibilities.

Plan to use the training. Assign jobs to the trainee that will exercise his new knowledge and skills. As a last resort, even "makework" may be considered in order to see that the employee gets a chance to apply his new knowledge.

Principles of the training course should be reviewed with the operator or mechanic promptly after its completion. Pose questions that will require an application of the training. Any weaknesses in retained knowledge should be uncovered and remedied at this time.

Finally, the program should include a provision for followup training somewhere between a few months to a year after the initial course. The goal of all these efforts is to make sure that once the operator is trained, he stays trained.

Equipment design. Equipment design is aimed at achieving ever-greater levels of safety in plant and warehouse operations. Many safety features are built into a wide variety of types of equipment. Some features are standard, others are optional. The following are just a few brief examples:

Hoists. Electric hoists are equipped with at least two independent braking systems — a motor brake and a supplementary load or control brake. Other hoist features can include overload protection devices and limit switches that prevent the hoist block from coming in contact with any part of the hoist frame.

Cranes. Various types of control systems can be used on cranes to prevent excessive swinging of loads. Runways are equipped with end stops and cranes with energy-absorbing bumpers to cushion the impact of a crane stopping at the end of a runway. If more than one crane is used on a runway, various anti-collision methods — including electronic techniques — can be used to decelerate the cranes when they approach a preset distance between one another.

Lift trucks. Lift truck manufacturers design and build trucks that meet or surpass standards for safety, as set forth by the American National Standards Institute (ANSI), Occupational Safety and Health Administration (OSHA), National Fire Protection Association (NFPA), or Underwriters Laboratories (UL). Trucks are equipped with overhead guards and other safeguards prescribed by law, and must meet specific longitudinal and lateral stability standards. Units using attachments must be derated.

Overload protection systems are also available for lift trucks. One approach uses a control valve in the hydraulic system that shuts off hydraulic flow when tilt cylinder pressures exceed a preset rating. Another method also controls hydraulic system operation, using electronic sensors to detect overload conditions and activate an alarm.

Storage racks and shelving. Design standards for racks include factors for withstanding horizontal forces, and in certain areas of the country designs must take seismic forces into account. Specific criteria covering such items as floor support and shelf-beam deflection are included in ANSI or Rack Manufacturers Institute (RMI) specifications. Special fire-safety protection is provided for certain rack configurations, particularly in high-rise storage systems. Specific safety standards are followed for double-deck and mezzanine shelving systems with regard to stairways, railings, kickplates, aisles, guards, floor loading protection, and headroom.

Conveyors. A number of safety features have been built into conveyor systems. Proper location of on-off controls is essential, as is the use of warning lights and buzzers. Guards are used for enclosing drives, pulleys, and other moving components. Pinch points are covered with protective plates. Popout rollers are used on live-roll conveyors to prevent wedging between a roller and the drive belt. As is true with other classes of equipment, visual warnings are provided by signs and labels placed at critical system areas. New materials and various design approaches are being employed to reduce noise levels.

Battery handling systems. Care must be taken in planning ways to handle batteries for lift trucks and other types of electric handling equipment. Special lifting beams of various designs are frequently used, either operated from the forks of a lift truck, or as part of a permanent battery charging room system. Such methods have eliminated heavy manual hauling, and minimize the possibility of accidental spills of battery fluids. Charging rooms must be equipped with proper ventilation systems, and only authorized persons should be allowed to be in such rooms. Smoking is prohibited.

Budgeting for safety. As equipment acquisitions are being planned, make sure safety features are incorporated that will be needed in the application. However, keep in mind that safety is not "free" or automatic. In many cases, the desired safety provisions may be optional, and extra funds will have to be budgeted for them. For example, the guarding required for some types of overhead conveyor systems may be rather expensive.

It's a good idea to keep the supplier informed of the intended uses of the equipment being ordered. A qualified supplier should be able to provide safety recommendations or at least suggest that the manufacturer be consulted on certain questions. None of this advice will be forthcoming, however, if suppliers are not informed about how the equipment is to be used.

Inspections. As discussed previously, operators must be trained to perform safely. Lists of do's and don'ts provide an excellent way of emphasizing the message. Typical examples are shown here.

Formal inspection programs should be established and carried out consistently. Many inspection procedures are covered in OSHA regulations for specific classes of equipment. Record-keeping requirements also have been spelled out. Remember that in the final analysis, thorough inspections and accurate record keeping are important not only for complying with OSHA, but are also key elements of preventive maintenance. As such, they can have significant impact upon the productivity of an operation. For example, if a machine shop or fabrication area is served by just one hoist, and the hoist becomes inoperative, the entire area may have to shut down. Downtime of this kind often can be avoided through good preventive maintenance, including regular inspection.

Frequency and scope of inspections should be spelled out. They will depend on the type of equipment, how critical it is to the operation and to safety, and its frequency of use. For example, consider the following types of inspections that might typically apply to overhead cranes:

- Daily inspections are performed by an operator before the crane is put to use on the first shift.
- Weekly inspections might be performed for cranes that are used regularly, and which are rated as most critical in terms of severity of usage, effect on environment, and potential hazard.
- Monthly inspections are performed on all other active cranes in the plant, and on critical standby cranes.
- Semiannual inspections are performed on all standby cranes.
- Annual inspections covering specific items — such as checking crane hooks for cracks with sonic testing or magnetic particle testing — are performed on designated cranes.

Scope of inspection performed at different frequencies might include: limited (correcting a defect reported by an operator), regular (operating mechanisms, hydraulic system components, hooks, chains, slings, and running ropes), and major (all items included in regular inspections, plus additional items such as structural members, rivets and bolts, sheaves and drums, brake system parts and electrical apparatus.)

Duty cycles of equipment also must be considered. For hoists, for example, duty-cycle factors include lifting height, frequency of lifting, and percentage of lifts at or near rated load capacity.

Accurate record keeping is a must if the full value of an inspection program is to be realized. An identification number should be assigned to each item of equipment. File folders should be maintained, and should include items such as: manufacturer's installation and operating instructions; date of inspection, and test; documentation that the equipment complies with safety codes; inspection forms; and records of maintenance work, tests, and safety checks.

Training of inspectors is as essential as training of operators and supervisors. Permanent inspectors should be assigned for each shift. The inspectors should have authority to remove equipment from service if it does not conform to safety standards.

Often it is useful for inspectors to share findings with other employees. For example, faulty chain sections or attachments or frayed wire rope can be displayed to demonstrate the results of improper sling usage.

Maintenance

The importance of proper maintenance to safe operations cannot be overemphasized. Well-designed equipment can become unsafe to operators if improperly maintained. It also can have harmful effects on the environment. Examples include excessive exhaust fumes from industrial trucks with improperly tuned engines, and high noise levels from conveyor systems that have not been properly maintained.

Training of mechanics and service personnel must go hand in hand with a commitment to a preventive maintenance program that will be followed consistently, in spite of day-to-day operating pressures. Some firms have found a contract maintenance program, administered by the equipment distributor or other outside organization, to be an effective approach.

OSHA and Material Handling

The Occupational Safety and Health Act (OSHA) was enacted to improve safety and provide healthful working conditions. It has had a significant impact upon a variety of industrial operations, including those involving material handling. As seen in the listing at the end of this chapter, some major classes of handling equipment are covered specifically in sections of the OSHA regulations.

In many instances, equipment may not be covered directly as a category by OSHA, but portions of the regulations may affect it. For example, at the time the chapter was written, there was no section in the Federal Register dealing specifically with industrial storage shelving. However, there *are* sections that affect mezzanine shelving installations. Paragraphs 1910.21, "Walking-working surfaces," and 1910.35 and 1910.37, "Means of egress," cover stairways, railings, kickplates, aisles, guards, floor loading protection, and headroom.

Even if as yet some types of equipment are not covered specifically by OSHA, there is still a responsibility by law to provide a safe workplace. In the absence of OSHA regulations, other sources can be searched for guidelines on achieving compliance. Industry consensus standards and manufacturer specifications are among such sources, and a number are listed at the end of this chapter. Other sources include manufacturers, distributors, consultants, and other users of similar equipment.

Current OSHA Review Commission rulings also can provide some guidelines. Obviously not all citations issued are upheld when challenged. The regulation regarding overhead guards on lift trucks is an example. Some citations have been dismissed when it was clearly demonstrated that operating conditions do not permit use of a guard, as in one case involving a vast number of overhead obstructions that would be prohibitive and impractical to remove. In another case, the citation was dismissed not because of operating conditions, but because the truck did not really fall under the regulation. It was ruled that because the truck did not lift loads above the operator's head, it was not a high-lift truck and therefore did not require a guard.*

Sources of information about training, equipment, and safety and inspection practices should be continually sought and updated. As many of the following information sources should be consulted as possible:

- ANSI standards
- Consultants
- Independent testing organizations
- Industry association consensus standards
- Insurance underwriting groups
- Local codes
- Manufacturer/distributor customer service departments
- Manufacturer's literature
- Material handling textbooks and handbooks
- Short courses and seminars
- State director of safety
- U.S. Department of Labor

Various standards and regulations pertaining to safety of material handling equipment and operations are listed in the accompanying section.

Unfortunately, despite the best precautions and safety programs, accidents will still occur occasionally. It is vital that emergency procedures for dealing quickly and effectively with accidents be developed and understood by all. Establishment of an emergency plan is a necessary part of any safety and training effort.

*Information on OSHA rulings may be obtained from: Occupational Safety & Health Reporter, Published by The Bureau of National Affairs Inc., 1231 25th St., NW, Washington, DC 20037.

Typical Safety Guidelines

Hoist Warning
To Avoid Injury, Do Not:

- Lift more than rated load.
- Lift people or load over people.
- Operate with twisted, kinked, or damaged rope or chain.
- Operate damaged or malfunctioning hoist.
- Operate if rope is not seated in grooves, or chain in pockets.
- Operate unless travel limit devices function — test each shift.
- Operate hand-powered hoist except with hand power.

Do's and Don'ts For Safe Rigging

Do:

- Determine load weight.
- Check sling-leg tensions before lifting.
- Use spreader bars and shackles to balance weights.
- Minimize sharp bends and edge contacts.
- Equalize loads.

Don't:

- Wrap a rope or sling leg around a hook.
- Twist or knot a chain, or force a sling eye.
- Place severe bend on rope or chain.
- Attempt to mend or join slings.
- Make lifts with unsecured slings or chains.

Belt Conveyor Safety Tips

- Avoid overhanging loads.
- Avoid excess side forces on belt.
- Do not remove guarding.
- Do not crawl under conveyor.
- Review locations of on-off controls and power lockouts.
- Review proper startup and shutdown procedures.

Fig. 10-1

Safety-Related Standards and Regulations for Material Handling

The following listing contains standards and specifications on various major classes of material handling equipment. Where an OSHA regulation exists, it is also included. Some of the items are specifically oriented to safety. Others are equipment specifications which contain important safety-related sections. Any listing such as this must, of course, be brought up to date from time to time as new standards and regulations are established, and existing ones are updated.

Conveyors and Elevators

Safety Standard for Conveyors and Related Equipment; ANSI B20.1-1976
Safety Code for Elevators, Dumbwaiters, Escalators, & Moving Walks; ANSI A17.1-1971
Fire Protection for Belt Conveyors; FM 7-11

Cranes and Monorails

Overhead and Gantry Cranes; Federal Register; OSHA Part 1910.178
Safety Standard for Monorail Systems & Underhung Cranes; ANSI B30.11-73
Safety Code for Crawler, Locomotive, & Truck Cranes; ANSI B30.5-68
Safety Standard for Mobile Hydraulic Cranes; ANSI B30.15
Safety Standard for Overhead and Gantry Cranes; ANSI B30.20-1976
Safety Code for Derricks; ANSI B3016-1969
Specifications for Electric Overhead Traveling Cranes; CMAA No. 70
Specifications for Underhung Cranes & Monorail Systems, MMA
Specifications for Electric Overhead Traveling Cranes for Steel Mill Service; AISE No. 6
National Electrical Code; NFPA No. 70. NEC Consensus; CMAA

Hoists

Safety Standard for Overhead Hoists; ANSI B30.16
Safety Standard for Hooks; ANSI B30.10
NEC Consensus; HMI
Standard Specifications for Electric Chain Hoists; HMI-400
Standard Specifications for Wire Rope Hoists; HMI-100
Standard Specifications for Hand-Operated Chain Hoists; HMI-200
Standard Specifications for Manually Lever Operated Chain Hoists; HMI-300

Powered Industrial Trucks

Powered Industrial Trucks; Federal Register; OSHA Part 1910.178
Forks and Fork Carriers for Powered Industrial Fork Lift Trucks; ANSI MH 11.4-1973
Rough Terrain Fork Lift Trucks; ANSI B56.6-1978
Safety Standard for Electric Battery Powered Industrial Trucks; ANSI B56.3-1971
Safety Standard for Internal Combustion Engine Powered Industrial Trucks; ANSI B56.4-1971
Safety Standard for Powered Industrial Trucks; ANSI B56.1-1975
Type Designations, Areas of Use, Maintenance, & Operation of Powered Industrial Trucks; NFPA No. 505-1975, also ANSI B56.2-1975

Storage Systems and Equipment

Considerations for Planning and Installing an Automated Storage/Retrieval System; AS/RS Product Section, MHI
Indoor General Storage; NFPA 231
Outdoor General Storage; NFPA 231-A

Liquid Storage

Flammable Liquid Drum Storage & Dispensing; FM 8-5
Practices for Ventilation & Operation of Open-Surface Tanks; ANSI 29.1-1971
Storage and Handling of Liquefied Petroleum Gases; ANSI Z106.1-70
Storage Tanks for Flammable Liquids; FM 7-88
Underground Leakage of Flammable & Combustible Liquids; NFPA 329

Storage Racks

Rack Storage of Materials; NFPA 231-C
Specifications for the Design, Testing, & Utilization of Industrial Steel Storage Racks; ANSI MH16.1-74

Jacks

Safety Code for Jacks; ANSI B30.1

Rope

Lifting Crane Wire-Rope Strength Factors; SAE J959

Slings

Industrial Slings; Federal Register; OSHA Parts 1910.184
Safety Standard for Slings; ANSI B30.9
Alloy Steel Chain & Alloy Steel Chain Slings for Overhead Lifting; AISC No. 4

Key to Organizations

AISC
American Institute of Steel Construction, Inc.
Three Gateway Center, Suite 2350
Pittsburgh, PA 15222

ANSI
American National Standards Institute, Inc.
1430 Broadway
New York, NY 10018

NFPA
National Fire Protection Association
470 Atlantic Avenue
Boston, MA 02210

CMAA
Crane Manufacturers Association of America, Inc.
1326 Freeport Rd.
Pittsburgh, PA 15238

HMI
Hoist Manufacturers Institute
1326 Freeport Road
Pittsburgh, PA 15238

MHI
The Material Handling Institute, Inc.
1326 Freeport Rd.
Pittsburgh, PA 15238

SAE
Society of Automotive Engineers, Inc.
400 Commonwealth Dr.
Warrendale, PA 15096

OSHA
Occupational Safety & Health Administration
U.S. Department of Labor
Washington, DC 20210 or regional offices

FM
Factory Mutual System
1151 Boston-Providence Turnpike
Norwood, MA 02062

MMA
Monorail Manufacturers Association, Inc.
1326 Freeport Rd.
Pittsburgh, PA 15238

RMI
Rack Manufacturers Institute
1326 Freeport Rd.
Pittsburgh, PA 15238

Chapter 11
Material Handling in the Future

One of the major trends in the future of material handling will be the closer joining of information and control technology to material handling operations. The ability of an organization to properly generate, interpret, and use timely information will be critical to its efficiency, productivity, and ability to compete.

Certainly equipment developments and improvements will continue to be important, and the directions many of these developments will take can be seen today. In particular, future generations of equipment will be incorporating features involving the following:

- Increased safety of operation.
- Greater energy efficiency.
- Alternate power source capability.
- Adaptability to controls and automation.
- Self-diagnostic capability.
- Ease of servicing.
- Ease of operation.

More sophisticated methods of justifying equipment and systems expenditures also will be used, such as life cycle costing, which takes into account all costs associated with the equipment over its expected useful life. Systems planning also will be more sophisticated, and will place increasing reliance upon simulation and other quantitative techniques discussed in Chapter 4.

Management will continue to become more scientific, with decision making being based heavily on available real-time information. One yardstick of successful management will be its ability to respond effectively to rapid change, and to guide company affairs through periods of transition.

Computers and Controls

The continuing revolution in computer technology has made the use of small industrial computers, which can be dedicated to controlling specific items of equipment such as cranes, conveyors, lift trucks, and S/R machines, feasible for small users as well as large. The following are a few brief examples of applications of computing elements to material handling equipment in use today:

Boom-crane control. A microcomputer-based load-moment indicator system can be used for boom-type cranes. The system generates all load, angle, and radius data necessary for maintaining proper crane operation. It is actuated from inside the crane cab.

Automated sorting. Sorting of packages in high-volume operations is controlled with a microprocessor. An operator encodes the destination for each package into a control station keyboard. Belt conveyors move the packages away from the control station, and onto sorting lanes. Updated on package travel by photoelectric sensors, the control station automatically actuates divert mechanisms to route packages down appropriate exit lanes.

Computer-directed order picking. A man-aboard high-rise order picker has a video display and keyboard console on board. Addressing information from a minicomputer directs the vehicle along a guidewire path until it reaches the picking location, aided by an automatic shelf positioner. The minicomputer in turn receives work schedules and updated inventory information from a corporate computer.

Automated parts storage. An automated storage/retrieval machine — equipped with code-reading scanners and microprocessor controls — retracts desired coded bins and brings them to an operator station. While the operator is picking from one bin, the machine returns a previously used bin. The system can be operator-directed through a keyboard entry terminal, or it may be under computer control.

Although these logic and control devices can improve the efficiency of individual items of equipment, their greater value lies in the fact that they facilitate integration of individual activities into overall system operations.

Tying it into systems. Application of automated S/R systems got its start in inventory control and high-volume order filling in warehouses and distribution centers. However, there is now a growing trend toward applying AS/R systems in manufacturing facilities, and to link the storage systems with production-floor operations.

The system in the accompanying

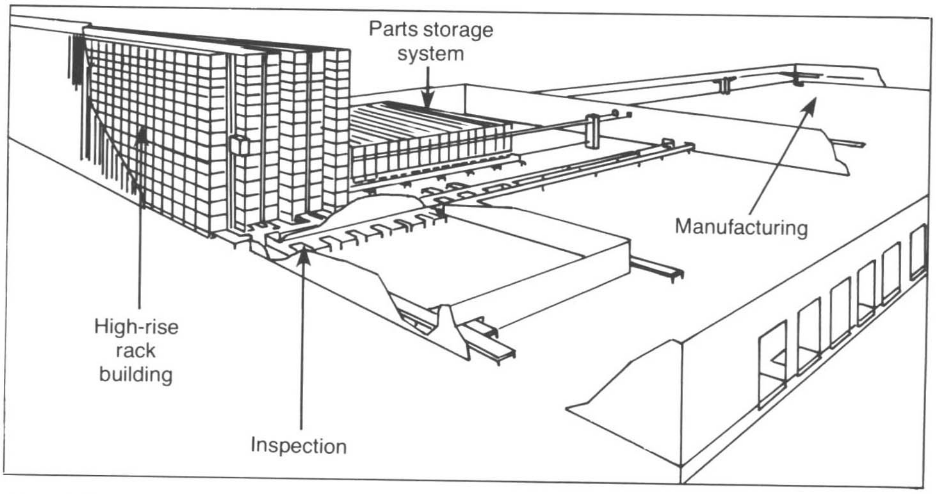


Fig. 11-1
Automated storage/retrieval systems serve manufacturing areas.

illustration is one currently in operation at a manufacturing plant. A three-aisle unit-load storage system and a six-aisle miniload system operate together to supply materials to the manufacturing floor within precise schedules. Primary function of the unit-load system is to supply materials to the miniload parts storage area, where parts to be assembled are stored in kits. Operators place retrieved parts into containers that are conveyed to the manufacturing area and automatically diverted through drop zones to work stations.

In some cases, throughput levels may not justify the use of conveyors, but other equally efficient methods of transporting materials between storage and operations are desired. Depending on the levels of automation required, alternative approaches may include transfer cars travelling along rails to work stations, or electronically controlled robot vehicles following flexible guidewire paths in the floor. Having automated forward and reverse travel and self-loading and unloading capabilities, robot vehicles can operate without operator intervention. Whatever method is used, the linking of automated storage and retrieval with manufacturing represents a new dimension in industrial operations and a major step toward the ideal of the automated factory.

Applications of Industrial Robots

Another significant step toward increased automation of handling is the use of industrial robots. Robotics, the science of designing and applying of robots, is growing quickly. Applications of industrial robots are proliferating throughout the world.

Robots vary widely in complexity and capability. However, all have several basic components in common — a mechanical manipulator, a controller that stores data and directs movement of the manipulator, and a power supply. In a sophisticated robot, control is effected by a minicomputer.

Some robots are relatively simple devices with fixed programs designed for very specific, limited tasks. Others are easily reprogrammable and can manipulate over many axes of freedom. They have built-in memories and can be led through work sequences in the field. Mechanical arms or manipulating elements of robots can be fitted with various

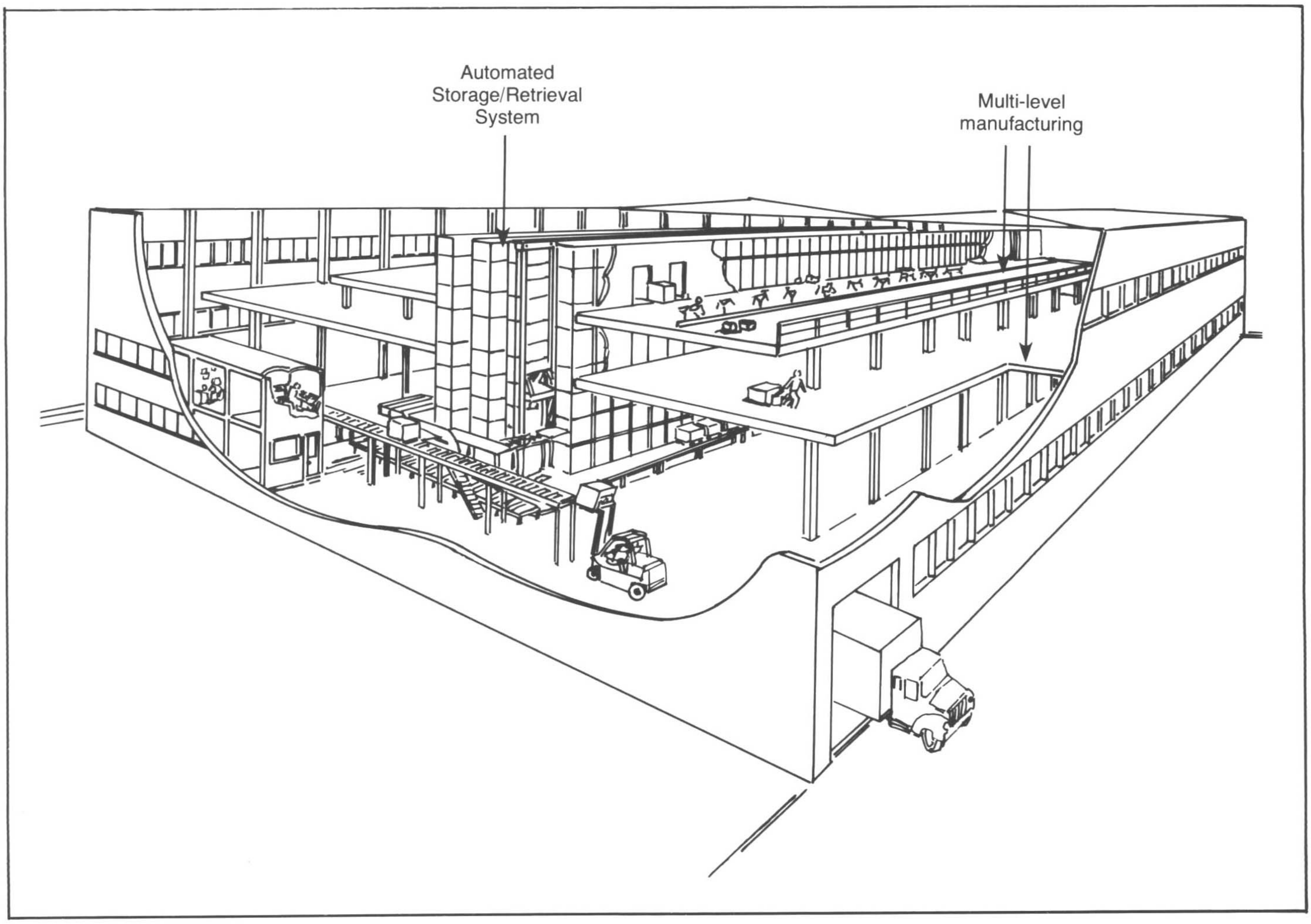


Fig. 11-2
Automated S/R system handles incoming, in-process, and finished goods, and serves manufacturing areas on multiple levels.

types of tooling, such as grasping fingers, welding heads, power tools, and paint-spraying heads. The following are some applications in which industrial robots are being used:

- Palletizing
- Die casting
- Stamping
- Machine loading
- Welding
- Plastic molding
- Forging
- Assembly
- Hazardous environments

Industrial robots are excellent tools in hazardous applications where humans should be kept away from the operating environment. They are also well-suited for rote tasks that are tedious, boring, or degrading to humans. In many cases, the introduction of robots to assembly, sorting, or manufacturing operations can provide significant jumps in productivity. As with any item of industrial equipment, robots must be carefully cost justified for the tasks at hand, except for situations where they provide obvious safety or social benefits.

Newer-generation robots are being equipped with optical sensors

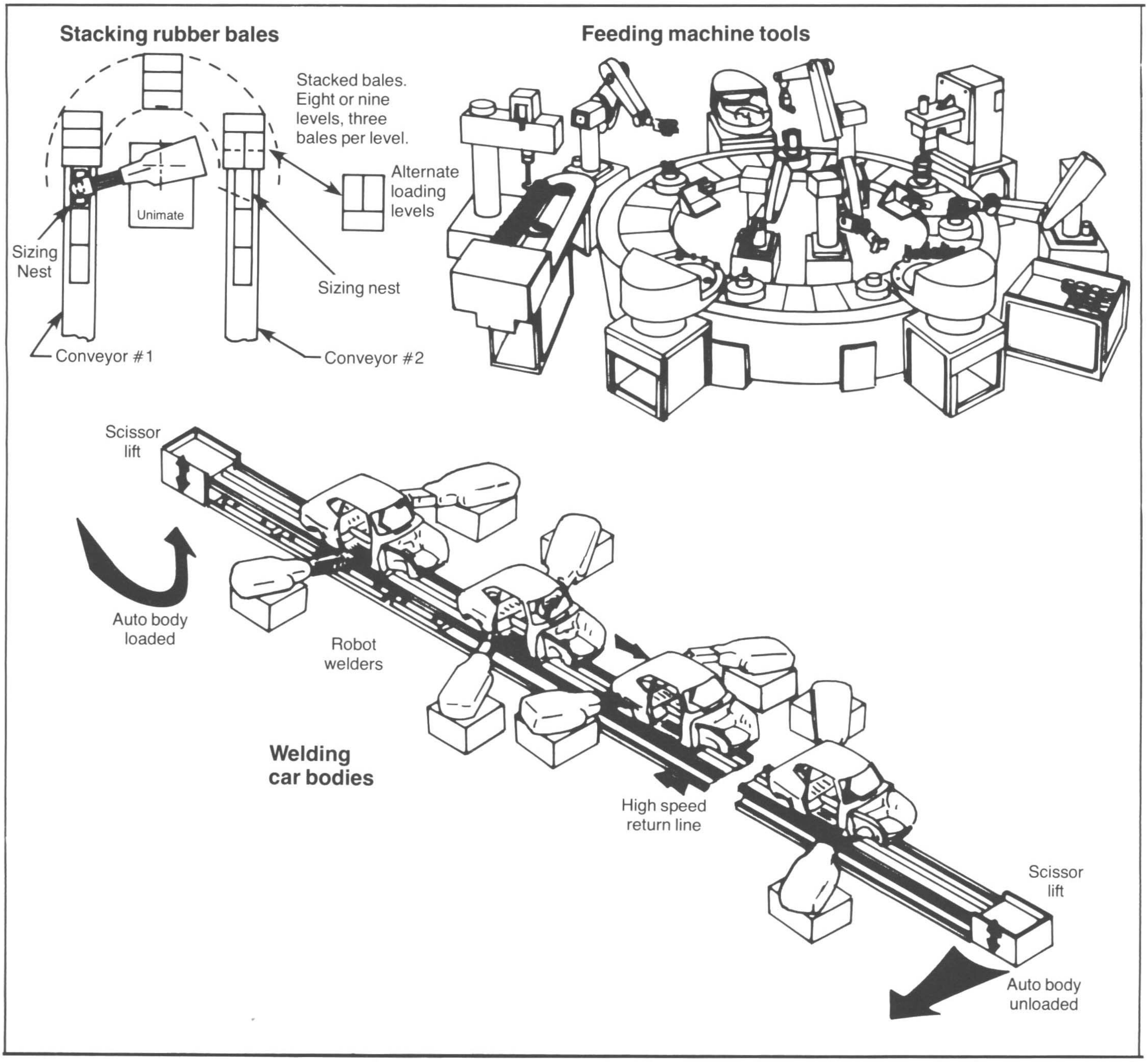


Fig. 11-3
Typical examples of industrial robot applications.

and TV cameras to provide visual inspection and analysis capabilities. Other types of sensors can be used to provide robots with tactile or "touch and feel" capability. Feedback systems can then be tied in with sensors to permit alterations in operating programs to be made automatically. The logical extension of such developments is an integrated system of operations involving sensors, actuators, manipulators, computers, and teaching and diagnostic equipment used in performing automated batch manufacturing.

The science of robotics has been called by some the "second industrial revolution." The first industrial revolution involved the development of machines to perform mechanical work that previously had been done only by humans. The second revolution — in its infancy but growing — has to do with incorporating intelligence functions into these working machines. (A familiar example is the use of numerically controlled — NC — machines in place of older units that required manual turning of hand cranks to control removal of metal or wood.) There is little doubt that robots will be broadly used as handling tools in the future.

The Information Explosion

To be properly utilized, all the equipment, systems, controls, and planning techniques discussed in this and previous chapters depend, in the final analysis, on one unifying element — appropriate information available at the right time and place. Effective material handling of the future will be more dependent on real-time, on-line information than ever before.

In the coming years, the ability of a company to generate, interpret, and act upon relevant information will be as important, if not more so, as its ability to properly apply equipment and systems on the plant floor. Energy shortages, productivity demands, growth of world markets, and other pressures are requiring companies to become increasingly efficient in order to maintain their competitive positions or even to survive. Hence, the need for accurate, timely

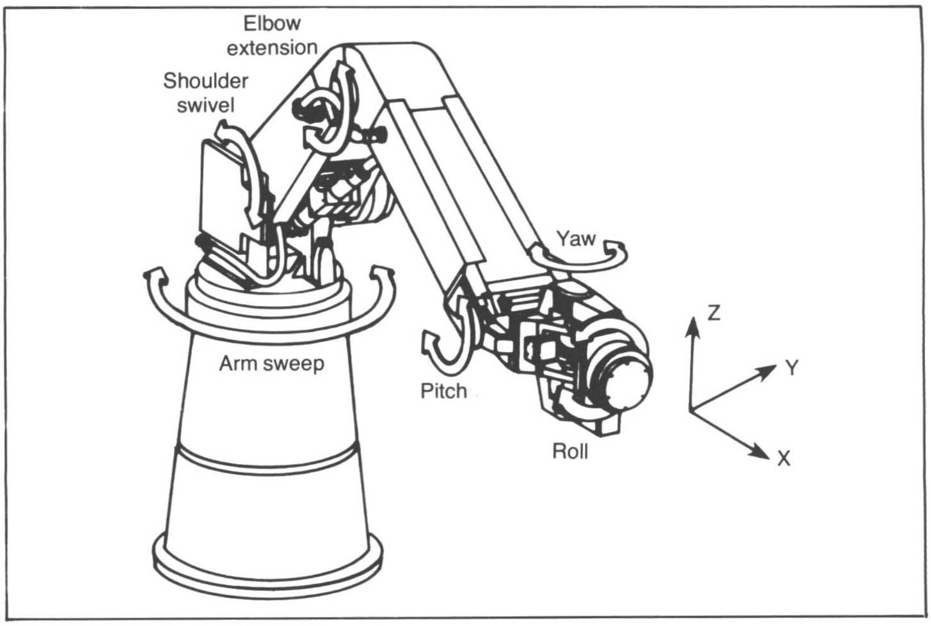


Fig. 11-4
General-purpose robot. Termination of arm can be fitted with various types of grippers or tools.

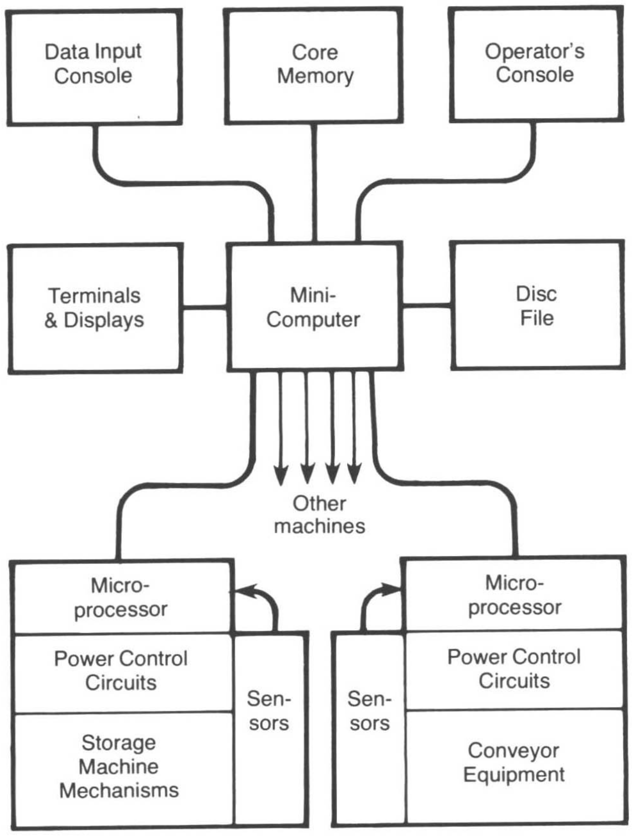


Fig 11-5
Distributive control system.

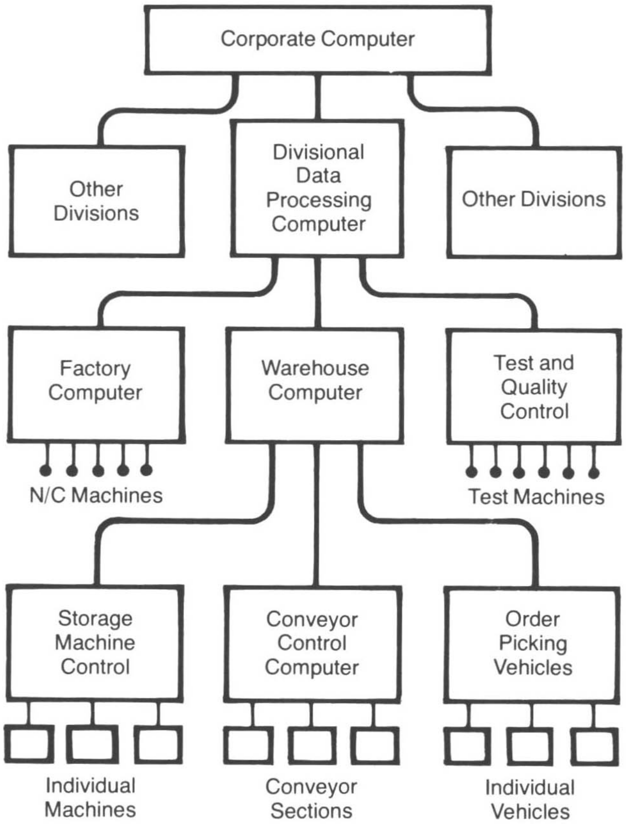


Fig. 11-6
Hierarchic control system.

data is becoming more and more critical.

The availability of improved and more economical computers and peripheral readout and display equipment has been a major factor in spurring the growth of the information sciences field. And, the use of distributive computer systems — in which information handling tasks are shared by two or more computers — has made industrial data processing and system control more reliable than before, because a computer failure need not affect an entire operation. Distributive systems are also capable of responding quickly to changes in operating conditions.

A related concept that will see increased usage is that of hierarchic control — whereby computers operating at different levels of the enterprise are linked through communications systems. An example might be a microprocessor used to control a single S/R machine, tied to a minicomputer that controls an entire AS/R system, tied in turn to a larger plant data-processing computer. The latter is, in turn, linked to a corporate computer supervising corporate-wide marketing, management services, production and inventory control systems.

The need for rapid, on-the-spot data will increase the use and importance of automatic identification equipment in material handling systems. Machine-readable codes will be used to far greater degree, not just on packages, pallets, and containers, but also on parts — shafts, gears, axles, and various assembly components. And, uniform code systems will be used more widely throughout the distribution process, with brokers, distributors, manufacturers, customers, and others being links in the overall system chain.

Obviously, in such an environment, material handling cannot operate as an isolated activity. The need for timing material flow processes with delivery and shipment schedules will be greater than ever before, and more organizations will be making use of material requirements planning (MRP) techniques and formalized material management systems.

In summary, the future of material handling will include a continuing evolution of more efficient and effective types of handling equipment, operating within integrated systems to achieve maximum productivity and energy efficiency in manufacturing plants, warehouses, distribution centers, terminals, hospitals and other institutions, airports, and a variety of other facilities. Tied to this systems concept will be a continuing series of developments in controls, automation, and information processes to make material handling systems effective tools for meeting the goals of the organization. Above all, professionals with a variety of technical, business, and information science backgrounds and skills will be needed to successfully plan, design, and implement material handling systems of the future.

Appendix I — Acknowledgments

Fig. 2-2	PLANT ENGINEERING Magazine, Technical Publishing, a company of The Dun & Bradstreet Corporation, Barrington, IL.
Fig. 3-7	"Considerations for Planning and Installing an Automated Storage/Retrieval System", prepared by the AS/RS Product Section of The Material Handling Institute, Inc., Pittsburgh, PA, 1977.
Figs. 4-3 through 4-10 and Fig. 4-13	Courtesy of Dr. Thomas Cullinane, University of Notre Dame.
Fig. 4-11	*Material Handling Systems Design*, J. M. Apple, Ronald Press, New York, 1972.
Figs. 4-14 and 4-15	MODERN MATERIALS HANDLING Magazine, Cahners Publishing Co., Boston, MA.
Fig. 4-16	*Modern Production Management*, E. S. Buffa, John Wiley & Sons, Inc., New York, 1963.
Chapter 5	Productivity ratios are in the format followed in "Yale Management Guide to Productivity," published by Industrial Truck Division, Eaton Corporation, Philadelphia, PA, 1979.
Figs. 6-1 through 6-3	Reproduced by permission from "The ABC's of Warehousing," Copyright 1978, Marketing Publications, Inc., Washington, DC.
Figs. 6-4a, b and c	*Material Handling Systems Design,* J. M. Apple, Ronald Press, New York, 1972.
Tables 6-I through 6-III	Taken from "Financial Facts Affecting Equipment Changes," presented by Bernard Dusenberry, Main Hurdman & Cranstoun, at the 1978 National Material Handling Forum, Detroit, MI.
Fig. 9-1	MATERIAL HANDLING ENGINEERING Magazine, Penton/IPC, Inc., Cleveland, OH.
Fig. 11-2	"Proceedings" 1977 SME/MHI Material Handling Seminar.
Fig. 11-3	IRON AGE Magazine, Chilton Company, Radnor, PA, and MATERIAL HANDLING ENGINEERING Magazine, Penton/IPC, Inc., Cleveland, OH.
Fig. 11-4	Courtesy Cincinnati Milacron, Inc.
Figs. 11-5 and 11-6	MATERIAL HANDLING ENGINEERING Magazine, Penton/IPC, Inc., Cleveland, OH.

Appendix II — Sources of Information

The following listing provides references to literature and other sources for those interested in obtaining additional information about material handling:

Books

Facility Layout and Location: An Analytical Approach, White, J. A., Prentice-Hall, 1974.
Material Handling Systems Design, Apple, J. M., Ronald Press, New York, 1972.
Planning and Managing Materials Flow, Sims, E. R., Jr., Industrial Education Institute, 1968.
Plant Layout and Materials Handling, 3rd Ed., Apple, J. M., Ronald Press, New York, 1977.
Principles of Engineering Economic Analysis, White, J. A., Agee, M. H., and Case, K. E., John Wiley and Sons, New York, 1977.
Systematic Handling Analysis, Muther, R., and Haganas, K., Management and Industrial Research Publications, Kansas City, MO, 1969.
Systematic Layout Planning, 2nd Ed., Muther, R., Cahners Books, Boston, 1973.

Catalogs and Directories

Material Handling Engineering Handbook & Directory, Penton/IPC, Inc., 614 Superior Ave. West, Cleveland, OH 44113.
MHI Literature Catalog, The Material Handling Institute, Inc., 1326 Freeport Rd., Pittsburgh, PA 15238.
Plant Engineering Directory and Specifications Catalog, Technical Publishing, a company of The Dun & Bradstreet Corporation, 1301 S. Grove Ave., Barrington, IL 60010.

General Literature

Lesson Guide Outline, College-Industrial Council on Material Handling Education, 1326 Freeport Rd., Pittsburgh, PA 15238.
Material Handling Review and Certification Guide, International Material Management Society, 3310 Bardaville Dr., Lansing, MI 48906.
Plant Engineering Material Handling Library, Technical Publishing, a company of The Dun & Bradstreet Corporation, 1301 S. Grove Ave., Barrington, IL 60010.

Periodicals

Distribution/Warehouse Cost Digest, Marketing Publications Inc., 217 National Press Building, Washington, DC 20045.
Engineer's Digest, Walker-Davis Publications, Inc., 2500 Office Center, Willow Grove, PA 19090.
Handling & Shipping, Penton/IPC, Inc., 614 Superior Ave. West, Cleveland, OH 44113.
Industrial Engineering, 25 Technology Park/Atlanta, Norcross, GA 30071.
Industry Equipment News, Thomas Publishing Co., One Penn Plaza, 250 W. 34th St., New York, NY 10001.
Industry Week, Penton/IPC, Inc., 614 Superior Ave. West, Cleveland, OH 44113.
Material Handling Engineering, Penton/IPC, Inc., 614 Superior Ave. West, Cleveland, OH 44113.
Material Handling Product News, Gordon Publications, Inc., 20 Community Place, Morristown, NJ 07960.
Materials Management & Distribution, Maclean-Hunter Publishing Co., 481 University Ave., Toronto, M5W 1A7, Ont., Canada.
Modern Materials Handling, Cahners Publishing Co., 221 Columbus Ave., Boston MA 02116.
New Equipment Digest, Penton/IPC, Inc., 614 Superior Ave. West, Cleveland, OH 44113.
Plant Engineering, Technical Publishing, a company of The Dun & Bradstreet Corporation, 1301 S. Grove Ave., Barrington, IL 60010.
Production Engineering, Penton/IPC, Inc., 614 Superior Ave. West, Cleveland, OH 44113.
Traffic Management, Cahners Publishing Co., 221 Columbus Ave., Boston, MA 02116.

Professional Societies and Trade Associations

The following organizations serve as sources of information on material handling subjects. Many sponsor educational seminars, and publish brochures, monographs, or standards related to material handling:

American Institute of Industrial Engineers, Inc., 25 Technology Park/Atlanta, Norcross, GA 30092.
American Institute of Plant Engineers, 3975 Erie Ave., Cincinnati, OH 45208.
American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.
American Production and Inventory Control Society, Watergate Office Bldg., Suite 504, 2600 Virginia Ave., N.W., Washington, DC 20037.
Caster and Floor Truck Manufacturers Association, 3525 W. Peterson Ave., Chicago, IL 60645.
Conveyor Equipment Manufacturers Association, 1000 Vermont Ave., N.W., Washington, DC 20005.
Institute of Electrical & Electronic Engineers, 345 East 47th St., New York, NY 10017.
International Material Management Society, 3310 Bardaville Dr., Lansing, MI 48906.
Material Handling Equipment Distributors Association, 102 Wilmot Road, Suite 210, Deerfield, IL 60015.
The Material Handling Institute, Inc. (MHI), 1326 Freeport Rd., Pittsburgh, PA 15238.

Affiliated organizations:

- **Crane Manufacturers Association of America, Inc.**
- **Hoist Manufacturers Institute**
- **The Industrial Truck Association**
- **Monorail Manufacturers Association, Inc.**
- **Rack Manufacturers Institute**

National Wooden Pallet and Container Association, 1619 Massachusetts Ave., N.W., Washington, DC 20036.
Packaging Institute, Inc., 342 Madison Ave., New York, NY 10017.
Society of Packaging and Handling Engineers, 14 E. Jackson St., Chicago, IL 60604.
Society of Manufacturing Engineers, 20501 Ford Rd., P.O. Box 930, Dearborn, MI 48128.
Warehousing Education and Research Council, Suite 375, 5725 East River Rd., Chicago, IL 60631.

Appendix III — About The Material Handling Institute, Inc.

The Material Handling Institute, Inc. (MHI), is a national trade association incorporated in 1945. Active member companies make and market industrial material handling equipment and systems or user specified components for such equipment in facilities maintained by the member in the United States. Associate membership is held by business publications.

The Material Handling Institute, Inc., provides an aggressive legally constituted and administered forum whereby concerted actions necessary to maintain and stimulate the continuing growth of the industry nationally and internationally are formulated and undertaken on an ongoing basis.

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