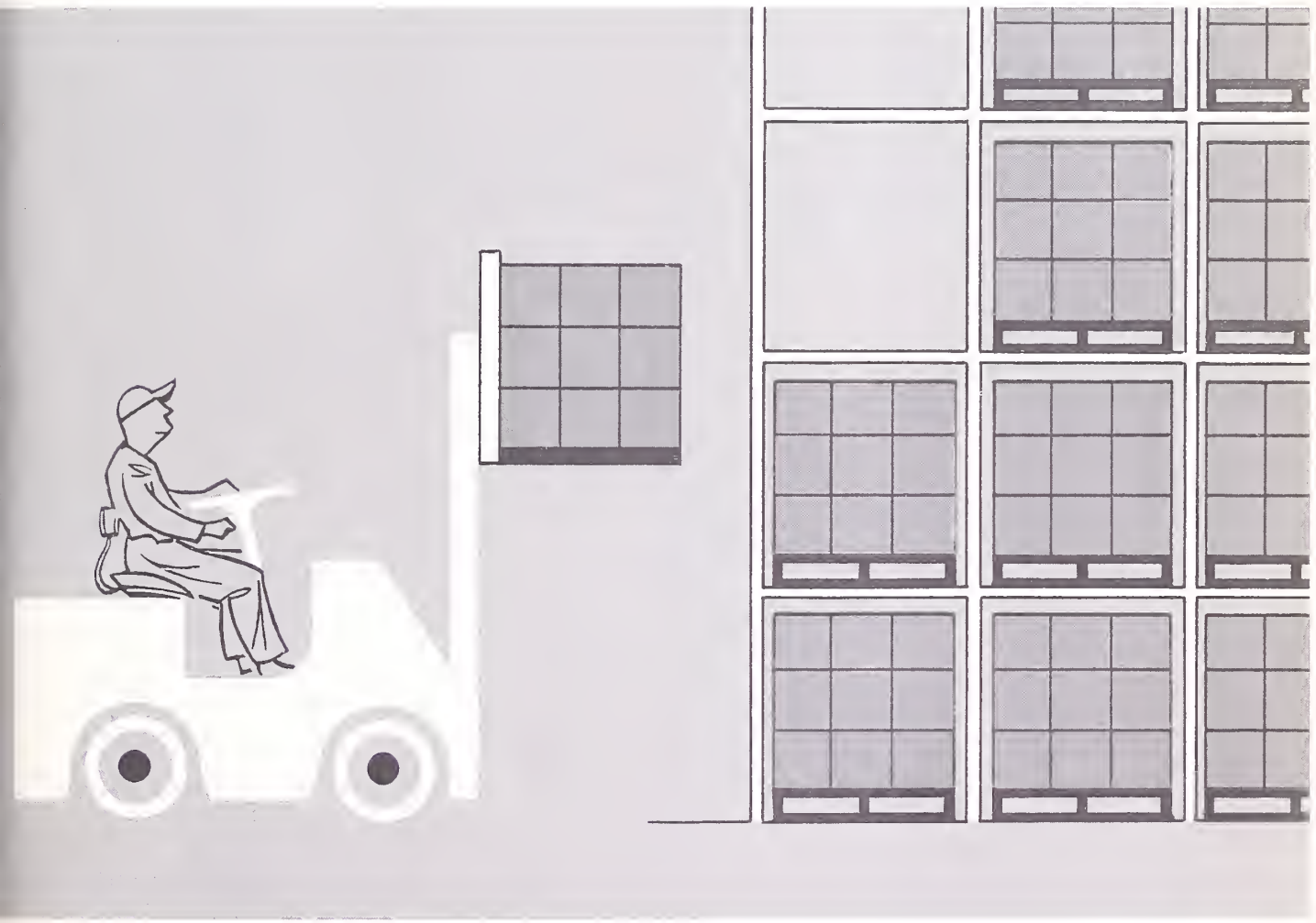
STORING FRUITS and VEGETABLES on PALLETS in WHOLESALE WAREHOUSES



UNITED STATES DEPARTMENT OF AGRICULTURE
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Transportation and Facilities Research Division

PREFACE

The research on which this report is based was part of a larger project to increase efficiency in the physical handling of agricultural products in various stages of the marketing system. The work was conducted under the direction of Joseph F. Herrick, Jr., research marketing analyst, Handling and Facilities Research Branch, Transportation and Facilities Research Division, Agricultural Marketing Service.

The authors thank the many companies in the fruit and vegetable industry that made their facilities available for study of storage and handling operations.

Other reports of interest to wholesalers on the handling of perishable food products issued by the United States Department of Agriculture are:

Materials Handling in Public Refrigerated Warehouses. Mktg. Res. Rpt. No. 145, June 1957.

Loading Out Fruits and Vegetables in Wholesale Warehouses. Mktg. Res. Rpt. No. 282, March 1959.

Mechanically Processing Wholesale Frozen Food Orders. AMS–317, June 1959.

Wholesale Fruit and Vegetable Warehouses; Guides for Layout and Design. Mktg. Res. Rpt. No. 467, August 1961.

Receiving Fruits and Vegetables in Wholesale Warehouses. Mktg. Res. Rpt. No. 478, October 1961.

Methods, Equipment, and Facilities for Receiving, Ripening, and Packing Bananas. Mktg. Res. Rpt. No. 92, June 1955.

Some Improved Methods of Handling Frozen Food in Wholesale Plants. Mktg. Res. Rpt. No. 107, November 1955.

The last two publications listed are not available from the Department of Agriculture, but may be consulted at major libraries.

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Washington, D.C. February 1964

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price 25 cents

SUMMARY

Pallet tiering devices, which can store loaded pallets in three or four tiers, offer wholesale distributors of fresh fruits and vegetables a means to better use storage capacity than is possible with the conventional storage system. When pallet loads are stored in the conventional manner, only one-fourth of an inventory is usually placed in a second tier, because the packages of produce must bear the weight of the loads.

The most efficient system of tiering pallets studied—a drive-in pallet rack system with three tiers—required a storage area of about 3,700 square feet, 3,400 square feet less than the conventional system. Handling and storage costs were about $13 per carlot equivalent, compared to nearly $16 for the conventional system. The study was based on a service wholesaler handling an annual volume of 1,000 carlot equivalents (about 31 million pounds) of fresh produce. Both the conventional and drive-in rack systems used 40- by 48-inch pallets and counterbalanced forklift trucks for handling.

A service wholesaler handling an annual volume of 1,000 carlot equivalents could reduce costs for a new warehouse by as much as $25,000 if he designed his facility around three-tiered drive-in pallet racks instead of using the conventional storage system. Storage and handling costs would be cut by at least $2,500 annually.

Another three-tiered drive-in rack system, which used extendible-fork lift trucks for handling, also had lower storage and handling costs than the conventional system. Storage and handling costs for four other tiering systems studied were about equal to or higher than those of the conventional system, ranging up to nearly $21.50 per carlot.

The three-tiered drive-in pallet rack systems would also have the lowest costs at annual volumes up to 3,000 carlots.

Wholesalers can use the data in this report to determine how much storage capacity can be increased in an existing warehouse by installing tiering devices. As an example, a wholesaler now using the conventional storage system, 40- by 48-inch pallets, and counterbalanced forklift trucks, could increase storage capacity by as much as two-thirds by installing three-tiered drive-in pallet racks. A clear, unobstructed ceiling height of 18 feet would be required.

STORING FRUITS AND VEGETABLES ON PALLETS IN WHOLESALE WAREHOUSES

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BACKGROUND

The generally used method of storing palletized fruits and vegetables in wholesale warehouses (called the conventional method in this report) does not make full use of vertical storage space. Pallet loads of produce in containers that are strong enough are placed directly atop one another, but many commodities cannot be tiered in this manner, and valuable storage space is lost.

A number of devices are available that provide for stacking loaded pallets in two, three, or four tiers. Precise information was lacking, however, as to: (1) How much reduction in floor area requirements or increase in storage capacity is gained by the use of tiering devices; and (2) how the use of tiering devices affects the costs of owning and maintaining a warehouse and the costs of handling commodities in and out of storage.

To assist wholesalers planning to build new warehouses or to increase the capacity of their present facilities, a study was made to compare the requirements and costs of storage by the conventional method with three general types of tiering devices—self-supporting pallets, standard pallet racks, and drive-in pallet racks. These are described in the following section, "Storage Systems."

Data were collected, under commercial operating conditions, in the warehouses of six wholesale distributors of fruits and vegetables.

The warehouses studied varied in size, shape, and layout. Some had separate rooms for dry-cold (85–90 percent relative humidity) and wet-cold (90–95 percent relative humidity) storage, and some had all cold storage in one room. All the warehouses had the general storage area in a single room. In this study, area requirements are based on separate rooms for dry-cold, wet-cold, and general storage. The merits of combining the two cold-storage areas in one room are also discussed.

Cost comparisons are based on a service wholesale warehouse handling 1,000 carlot equivalents (approximately 31 million pounds) of fruits and vegetables annually. Service wholesalers take orders through their salesmen and make deliveries to retail foodstores. Bananas, which account for 156 carlots,[2] are stored in special ripening rooms. The general, dry-cold, and wet-cold storage rooms therefore provide for an annual volume of 844 carlots. Banana handling and storage problems have been discussed in another report.[3]

In handling operations, it is assumed that commodities are palletized in the railroad car or truck and moved to the warehouse receiving platform, where a forklift truck operator moves them to storage. Commodities are assembled for orders by pallet loads in an order assembly area and loaded on delivery trucks by a conveyor extended into the truck. Loading out and receiving are the subjects of previous research reports.[3]

The type of forklift truck used has an effect on floor area requirements as well as the time required for handling. The counterbalanced truck (fig. 1) requires aisles 10½ feet wide. The straddle forklift truck (fig. 2) can operate in aisles only 6½ feet wide. This truck has outriggers that straddle the load as it is lifted. Because the weight of the load is behind the wheels on the outriggers, a much shorter truck is possible, and a right-angle turn can be made in a narrow aisle.

[1] Mr. Ferris and Mr. Bogardus have resigned from the Agricultural Marketing Service.

[2] The distribution of commodities is based on national averages drawn from studies by the U.S. Department of Agriculture and surveys made by the Service Wholesale Division of the United Fresh Fruit & Vegetable Association. For additional details see table 1, page 2, Bogardus, Robert K., Wholesale Fruit and Vegetable Warehouses—Guides for Layout and Design, Marketing Research Report No. 467, 41 pages, 1961.

[3] See list of reports in preface.

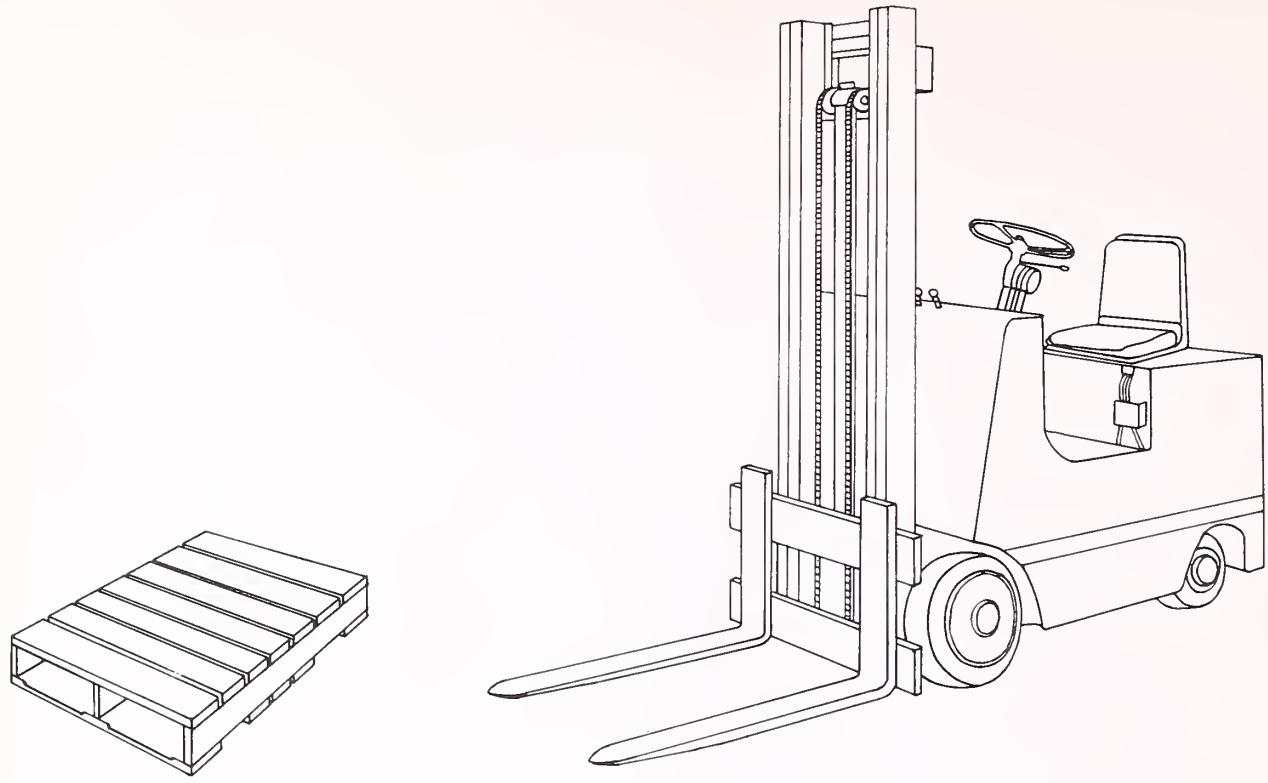

FIGURE 1.—A counterbalanced forklift truck and pallet.

The extendible-fork truck has forks mounted on a scissor-like mechanism so they may be extended beyond the outriggers (fig. 3). This enables the truck to "reach" out to pick up or set down loads without the outriggers having to straddle the load. The outriggers permit turning in a narrower aisle (7½ feet wide) than counterbalanced trucks because the load, when withdrawn to the upright, need not be counterbalanced by weight far back of the front axle. Thus the extendible-fork truck combines the advantage of the counterbalanced truck of not having to straddle the load with the advantage of the straddle truck of being able to operate in narrow aisles. The counterbalanced trucks were the fastest of the three types observed.

Because of various combinations of pallet size, number of tiers, and type of forklift truck used, seven storage systems were studied. The seven systems are:

The research methods and techniques used to measure the characteristics of storage method and handling that affect the costs of operation are in the appendix.

The costs analyzed in this report are: The costs of owning and maintaining the warehouse and any tiering devices used; and the costs of handling loaded and empty pallets in receiving and loading out. Managerial, clerical, and delivery-truck costs, and the like, are not included.

It was assumed that the labor rate was $2.25 per hour for forklift truck operators. This figure includes the base hourly rate plus the cost of such items as social security, workmen's compensation, paid vacations, and unemployment compensation.

The labor requirements include the productive time for the job plus additional allowances for unavoidable delays and job changeover. These allowances are described in the appendix.

Storage method	*Number of tiers*	*Pallet size (inches)*	*Type of forklift truck*
Conventional	Half the pallet loads are in single tiers and half are in 2 tiers.	40 x 48	Counterbalanced.
Self-supporting pallets:			
Tubular frame	3	40 x 48	Do.
Do	3	40 x 32	Straddle.
Standard pallet racks	3	40 x 32	Do.
Drive-in pallet racks:			
4-tiered	4	40 x 48	Counterbalanced.
3-tiered	3	40 x 48	Do.
Do	3	40 x 48	Extendible fork.

Conventional Storage

In conventional storage, use of vertical space is severely limited. Gentleness is required in both handling and storage of fresh fruits and vegetables. Many commodities are packaged in bags and other containers that offer little or no protection from externally applied forces, and they cannot bear the weight of loaded pallets (fig. 4). Also, it is difficult to build these commodities into pallet loads with a surface stable enough to form a base for another load. Indiscriminate stacking of pallet loads of fresh fruits and vegetables would result in crushed merchandise and toppled stacks.

In a typical general line of fruits and vegetables, about half the palletized commodities in storage can be stacked. One-half of the loads that can be tiered, or about 25 percent of the total, would be stored in the second tier atop the other half of the tierable loads.

The conventional storage system studied used 40- by 48-inch pallets and a counterbalanced forklift truck for handling.

Self-Supporting Pallets

Self-supporting pallets have superstructures attached to support superimposed loads so that packages on the pallets do not have to bear the weight. Some limitations on tiering loads are removed, but more pallet loads are required to store a given quantity, because of the room taken up by the supports. Loading patterns that fully utilize the pallet area cannot be used. The height to which packages can be loaded is also limited by the support structure or because sufficient clearance must be allowed for the pallet load that is to be set on top. The maximum loading height permitted by self-supporting pallets is 46 inches. In conventional storage, packages may be loaded up to a height of 72 inches or more, depending on the commodity and the type of package.

One type of self-supporting pallet was observed in use in fruit and vegetable warehouses. This was a tubular-frame assembly which could be attached to standard pallets (fig. 5). There were two pieces to each assembly, each piece consisting of two corner posts connected by a horizontal brace which was bent in toward the center of the pallet. When both pieces were assembled on a pallet, the superstructure consisted of posts at each corner connected at the top by a brace shaped like an "X". This type of self-supporting pallet is termed the "tubular-frame" pallet.

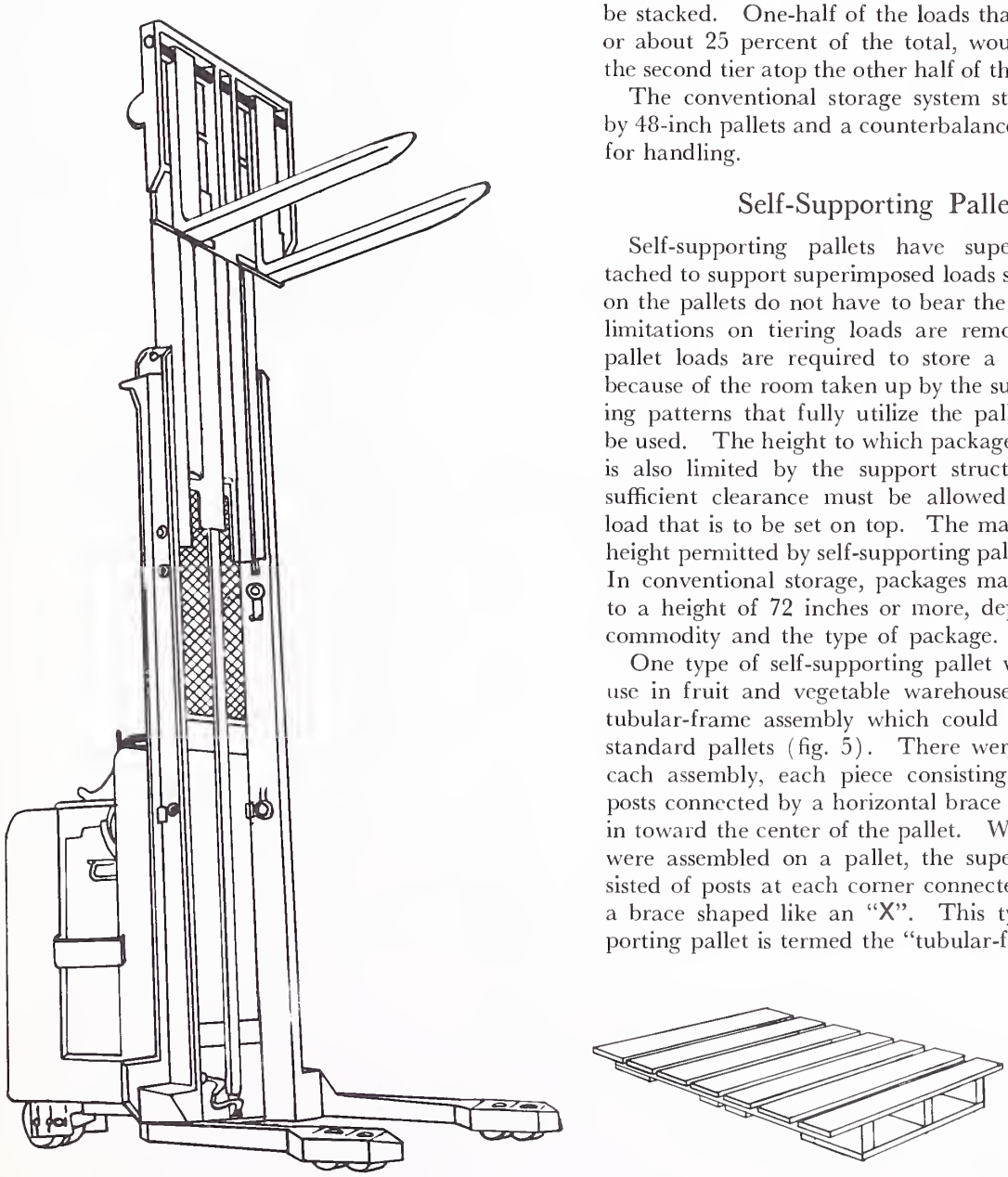

FIGURE 2.—A straddle forklift truck and a single-wing pallet.

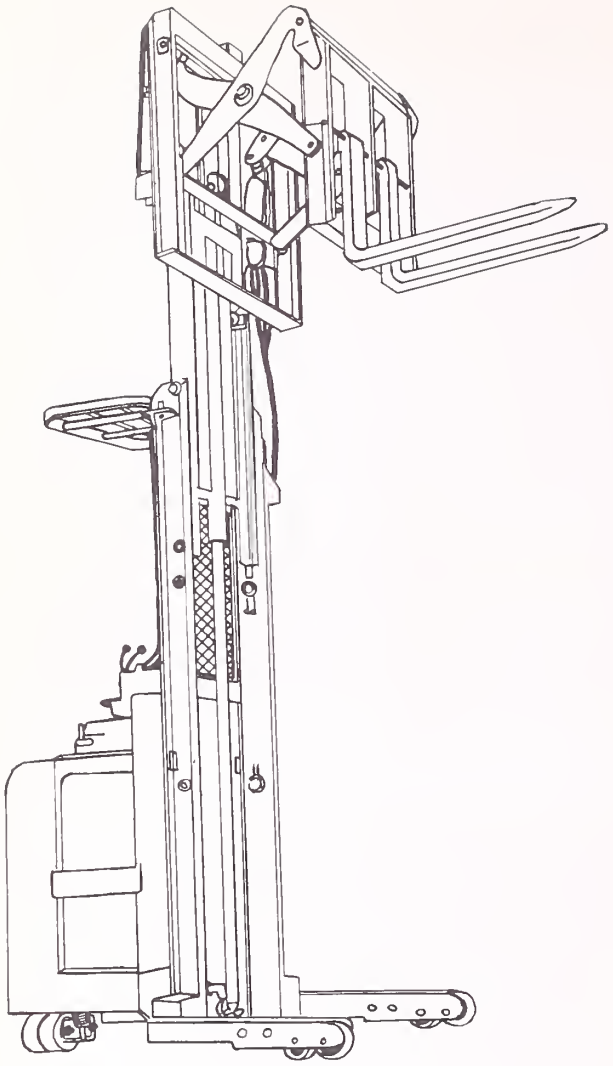

FIGURE 3.—An extendible forklift truck.

Two systems using tubular-frame pallets were observed. One system used 40- by 48-inch pallets, tiered three high, with handling by counterbalanced forklift truck, and the other used 40- by 32-inch pallets, tiered three-high, with handling by straddle truck.

When supports are used, the average load per pallet is about 40 percent less with 40- by 48-inch pallets and 53 percent less with 40- by 32-inch pallets than with conventional storage on 40- by 48-inch pallets.

Standard Pallet Racks

A pallet rack is a steel framework upon which pallets may be stored, one over the other, in the warehouse. The most important components are horizontal beams upon which the pallets rest, and vertical columns to support the horizontal beams and transmit the load to the warehouse floor. "Standard" pallet racks are so named to distinguish them from "drive-in" pallet racks. The terms "pallet rack" and "drive-in pallet rack" are often used.

A row of standard pallet racks consists of a number of upright frames connected by horizontal beams. Each upright frame has two columns, one at the front of the row and one at the back; the horizontal beams are parallel to the aisle (fig. 6).

The beams block access into the storage bay by handling equipment. Therefore, the depth of the storage bay is restricted to one row deep with an access aisle on one side, or two rows deep with an access aisle on each side of the bay. This limitation on storage bay depth with standard pallet racks is a disadvantage from the space utilization standpoint. In the conventional and self-supporting pallet methods of storage, there is no such restriction. The result is that more aisles are needed when standard pallet racks are used. Storage is less dense because bay depth per access aisle is less.

Pallet racks have a potential advantage over self-supporting pallets in that loading patterns on the pallets can be more efficient because there are no obstructing corner posts. This advantage applies only if the vertical space available for packages remains the same.

The standard pallet rack installation observed used 40- by 32-inch single-wing pallets (fig. 2) tiered three high. Handling was by straddle forklift trucks. The racks provided 48-inch vertical clearance in each tier. Allowing 6 inches for the pallet and 2 inches clearance for moving loads in and out of the racks, 40 inches is available for loading packages on the pallets—6 inches less than on the comparable self-supporting pallet.

Drive-In Pallet Racks

Drive-in pallet racks eliminate the disadvantage of low storage density found with standard pallet racks.

Drive-in pallet racks have many of the same components that standard pallet racks have—that is, upright frames and horizontal beams upon which the pallets rest. The horizontal beams, however, are arranged at right angles to the aisle rather than parallel to it, so that they do not block access into the bay (fig. 7). Storage bays can be as deep as other considerations permit, and bay depths of up to five rows are common.

Drive-in pallet racks are braced laterally in the center of the bay. With access aisles on each side of the bay, two rows of pallets are accessible from one aisle, and three rows from the other aisle. There is a special variation on the drive-in pallet rack where even this limitation on movement through the bay is removed. The rack is tied into the floor and ceiling of the warehouse, and handling equipment can be moved all the way through the storage bay to the aisle on the other side. This is called the "drive-through" pallet rack. One of the systems studied employed

BN–18692

FIGURE 4.—Pallet storage by the conventional method. Note the lack of overhead space utilization.

BN–18691

FIGURE 5.—Tubular-frame pallets in storage.

BN–18695

FIGURE 6.—Storage on standard pallet racks.

BN–18690

FIGURE 7.—Commodities stored on drive-in pallet racks.

drive-through pallet racks, but they were not being used as such. For this reason, they are referred to as drive-in pallet racks in the analysis.

Space use with drive-in pallet racks is potentially better than with self-supporting pallets because of greater freedom in designing pallet patterns. The drive-in feature permits storage bay depths as great as with self-supporting pallets and the fact that the pallets have no corner stanchions permits heavier pallet loading.

Three different systems using drive-in pallet racks were analyzed. One used four tiers in conjunction with counterbalanced forklift trucks, and the other two had three tiers, one used with counterbalanced forklift trucks and the other with extendible-fork lift trucks. The 40- by 48-inch pallet was used in all three systems.

In each of the warehouses where studies were made, the net clear ceiling height was approximately the same, so that the four-tiered racks held smaller unit loads than the three-tiered. Vertical space available per tier in the three-tiered racks was 65 inches, and in the four-tiered racks, only 45 inches. Subtracting 6 inches for the pallet and 4 inches vertical clearance for moving loads in and out leaves only 35 inches of loading height for packages in the four-tiered racks.

A service wholesaler handling 1,000 carlot equivalents annually of a general line of fruits and vegetables would need space enough to store approximately 15 carlots, excluding bananas. This would provide for an inventory turnover 80 times during the year, or slightly more than a 4½-day supply during the busy season (an 8-month period when the major volume of business occurs). The 15 carlots would be divided among the 3 storage areas in this way:

General	7 carlots
Dry cold	5 carlots
Wet cold	3 carlots

Floor area requirements are based, first of all, on the number of *pallet stacks* (number of pallet loads divided by the number of tiers) used to store 15 carlots. The numbers of pallet loads and stacks required in each system, by commodity and storage area, are given in appendix table 15. The number of pallet loads required by the systems are determined by: The size of pallet used—40 by 48 inches or 40 by 32 inches; the loading height available per pallet; and the usable horizontal space available per pallet. All tiering devices reduced the loading height available per pallet over the conventional storage method, and the systems using self-supporting pallets reduced the horizontal space available.

The problem of overall warehouse layout is dealt with by considering only the area required for storage and access to storage. All layouts follow the same general pattern: parallel storage bays separated by access aisles. If a room requires two or more access aisles, they are connected by a service aisle (fig. 8) at right angles. For all systems except that using standard pallet racks, the maximum number of rows in a bay is five. When standard pallet racks are used, bays are only two rows deep.

Specific floor area requirements for each storage system were determined from basic layout patterns developed for the various systems (appendix p. 25 and figs. 15 and 16) and from the dimensions of pallets, the clearances allowed between pallets or structural members, and the aisle width required by the type of forklift truck used. These dimensions, as well as the total vertical space required, are given in appendix figures 17–21.

In developing layouts for individual storage rooms, it was not possible to fit the exact required capacities into rooms with uniform rectangular shape. The layouts in this report are regularly shaped rooms with at least the required capacity and the smallest possible area requirements, subject to the restriction that no room is more than three times longer than it is wide, or

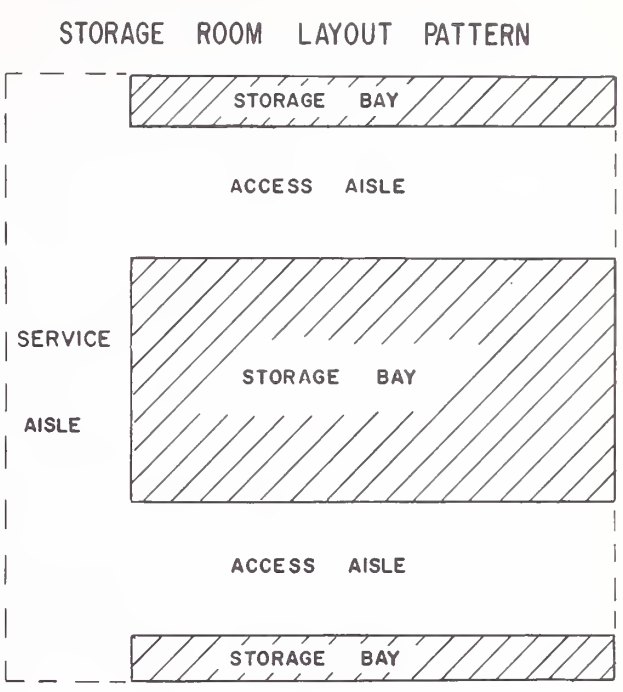

FIGURE 8.

vice versa. As a result, the actual capacities of the storage areas are usually slightly higher than the required capacities.

The smallest floor area requirements, those of the three-tiered drive-in rack system, using extendible-fork trucks (table 1), are less than half of those of the conventional system using counterbalanced trucks. Good use of vertical space, combined with the narrow aisles required by extendible-fork trucks, make floor area requirements low. Less than 30 percent of the total storage area is required for aisles. The three-tiered drive-in rack system, using counterbalanced trucks, requires 389 square feet more aisle space, but the total area required is only a little more than half as much as that of the conventional system.

A self-supporting pallet system has the third lowest area requirement. Although the number of pallet loads (720) is high for the tubular-frame system, the small floor area required by 40- by 32-inch pallets and the narrow aisles (6½ feet) used by straddle trucks do save space. Compared to conventional storage, the number of aisles required, and therefore the percent of floorspace aisles occupy, are reduced.

Area requirements of the four-tiered drive-in rack system are higher than those of the three-tiered systems for several reasons. All these systems were constructed in warehouses with ceiling heights that were

TABLE 1.—*Floor area requirements for storing 15 carlots of palletized fruits and vegetables by seven storage systems*

Storage system and storage areas	Capacity		Area required for—		Total
	Pallet loads	Pallet stacks	Storage	Aisles	
			Sq. ft.	*Sq. ft.*	*Sq. ft.*
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks:					
General		60	990	414	1, 404
Dry cold		50	826	345	1, 171
Wet cold		30	498	207	705
Total	420	140	2, 314	966	3, 280
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks:					
General		60	990	580	1, 570
Dry cold		50	826	484	1, 310
Wet cold		30	498	291	789
Total	420	140	2, 314	1, 355	3, 669
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks:					
General		100	1, 131	411	1, 542
Dry cold		85	961	349	1, 310
Wet cold		55	621	225	846
Total	720	240	2, 713	985	3, 698
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks:					
General		65	1, 111	651	1, 762
Dry cold		55	941	551	1, 492
Wet cold		35	600	352	952
Total	620	155	2, 652	1, 554	4, 206
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks:					
General		70	1, 126	660	1, 786
Dry cold		80	1, 287	754	2, 041
Wet cold		40	642	376	1, 018
Total	570	190	3, 055	1, 790	4, 845
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks:					
General		114	1, 281	1, 509	2, 790
Dry cold		102	1, 147	1, 381	2, 528
Wet cold		48	535	703	1, 238
Total	792	264	2, 963	3, 593	6, 556
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks:					
General		130	2, 090	1, 822	3, 912
Dry cold		65	1, 046	612	1, 658
Wet cold		60	965	565	1, 530
Total	340	255	4, 101	2, 999	7, 100

approximately equal. When pallets were tiered four high, the number of packages per pallet had to be reduced, because the depth of the additional pallet, plus its required vertical clearance, had to be deducted from the total vertical height available. The loss of vertical space significantly reduced storage density (tons stored per 100 square feet).

Moreover, in the warehouses where the studies were made, greater clearances were provided between vertical rack members for racks constructed to tier four pallets than were provided for the systems in which pallets were tiered three high. As a result, pallet stacks in the four-tiered arrangement required approximately 18.3 square feet of floorspace, while the three-tiered arrangement required approximately 16.5 square feet of floorspace.

The tubular-frame pallet system using counterbalanced trucks and 40- by 48-inch pallets requires a little more than two-thirds of the floor area of conventional storage.

The most significant disadvantage of standard pallet racks, low storage density, shows up in aisle space requirements. Because storage bays are only two rows deep, storage space must be increased by increasing

the number of bays per storage room and by making the rows longer than in other storage systems. Both these factors add to the amount of aisle space required. The general and dry-cold storage rooms each require three access aisles; the wet-cold storage room, two access aisles; and all three rooms require service aisles. Because the straddle truck is used, access aisles are only 6½ feet wide; service aisles are 7 feet wide to accommodate two-way traffic.

Of the total 7,100 square feet of warehouse area required for the conventional system, the space required for loaded pallet stacks accounts for approximately 56 percent. The 4,101 square feet required for pallet stacks include clearances for package overhang, air circulation, and to facilitate handling loads into and out of storage. Aisles are 10½ feet wide—adequate for a counterbalanced truck to make a right-angle turn to pick up or deposit a load, including 12 inches clearance.

The dry- and wet-cold storage rooms each have two storage bays and one access aisle. The general storage area has three storage bays, two access aisles, and a service aisle across the end of the area connecting the access aisles.

THE COST OF STORAGE SPACE

Storage space costs consist of the cost of owning and maintaining the warehouse, plus the cost of tiering devices if they are used. Annual warehouse costs include depreciation, interest, insurance, taxes, and maintenance for the structure and the basic electrical and mechanical equipment, including the required refrigeration system. The annual costs of tiering devices also include depreciation, interest, insurance, taxes, and maintenance. In the case of pallet racks, the cost includes the expense of their installation as well as their purchase price. For self-supporting pallets, the costs are for the tubular frames only. The cost of pallets is included in handling costs.

Storage space costs range from a high of about $9 per carlot for the standard pallet rack system to a low of about $5 for three-tiered drive-in pallet racks with the extendible-fork truck (table 2). The cost for the conventional system is nearly the same as the highest cost system.

Selection of a storage system cannot be made on the basis of storage space cost alone. Some of the advantage of low cost of storage space in tiering systems is lost in the higher handling costs that result from the greater number of pallets that must be handled, lifted, and placed in or on the tiering devices.

TABLE 2.—*Costs of storage space for a 1,000-carlot annual volume*

Storage system	Area required	Annual storage space costs			Total storage space costs per carlot [2]
		Warehouse facility [1]	Tiering devices	Total	
	Square feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	3, 280	3, 542	884	4, 426	5. 24
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	3, 669	3, 963	884	4, 847	5. 74
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	4, 206	4, 542	1, 299	5, 841	6. 92
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks	3, 698	3, 994	[3] 2, 036	6, 030	7. 14
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks	4, 845	5, 233	[4] 1, 600	6, 833	8. 10
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks	7, 100	7, 668	.....	7, 668	9. 09
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks	6, 556	7, 080	612	7, 692	9. 11

[1] Based on an average cost of $1.08 per square foot per year. See table 13 in the appendix.

[2] Based on an annual volume of 844 carlot equivalents moving through general, dry-cold, and wet-cold storage.

[3] Based on tubular frames for 897 pallets.

[4] Based on tubular frames for 705 pallets.

Labor

The most significant factor in comparing labor requirements of the seven systems is the average number of pallet loads required to handle the same volume of commodities. Next in importance are the speed of the forklift truck used and the average transport distance required by the system. The average number of pallet loads per carlot equivalent and average transport distance for the seven systems are given in table 3.

TABLE 3.—*Pallet-handling operations (excluding bananas): Average number of pallet loads per carlot equivalent and average transport distances*

Storage system	Average transport distance	Average pallet loads per carlot
	Feet	*Number*
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks	150	21.5
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	120	25.8
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	120	25.8
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks	130	35.8
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	130	37.4
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks	120	45.9
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks	190	50.4

The number of pallet loads per carlot equivalent is at its lowest with conventional storage, because no restrictions are set by pallet supports or rack installations, and the largest practical pallet loads are used. The transportation distances are affected by the overall dimensions of the storage areas and the number of aisles required. The compact areas with a high storage density (tons stored per 100 square feet of storage area) have the lowest transport distance.

Other factors affecting handling requirements are the amount of space into which a load must be fitted, and the height to which loads must be lifted. It takes longer to put a load in storage when the clearance is tight and if the load has to be lifted very high. Some of the time required to elevate loads can be eliminated by beginning the elevation while the forklift truck is moving (fig. 9), but there is a practical limit to the height at which a load can be safely transported.

Forklift truck operators perform the following work in handling loaded and empty pallets:

Receiving: (1) Pick up loaded pallets on the receiving platform, transport them to the storage location, deposit them in storage, and return to the receiving platform; and (2) rehandle pallet loads for stock rotation when necessary.

Order assembly: (1) Pick up pallet loads of commodities in storage, transport them to an order-assembly area, deposit the loads, and return to storage; and (2) transport empty pallets from order-assembly area to the receiving platform.

Table 4 shows labor requirements per carlot equivalent for pallet-handling operations for the seven storage systems. Requirements for receiving are based on an annual volume of 844 carlots, and, for order assembly, on 1,000 carlots. The 156 carlots of bananas are handled on pallets during the order-assembly operation. Labor requirements were determined by time studies. They include allowances for unavoidable delays and changing jobs, as described in the appendix.

At 1.73 man-hours per carlot equivalent, requirements of conventional storage are 10 percent less than the lowest of any of the high-tiering systems and less than half as much as the standard pallet rack system.

The savings in labor with conventional storage compared to the next lowest system—three-tiered drive-in racks and a counterbalanced truck—are almost entirely attributable to the larger loads handled. Although picking loads up and setting them down is considerably less time consuming in conventional stor-

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FIGURE 9.—Elevating a load while transporting.

TABLE 4.—*Pallet-handling operations: Labor requirements per carlot equivalent for a service wholesaler handling an annual volume of 1,000 carlots*

Storage system	Labor required for receiving (excluding bananas)				Labor required for assembly				Grand total
	Moving loads to storage	Rehandling	Allowances [1]	Total	Assembling loads	Returning empty pallets	Allowances	Total	
	Man-min.	*Man-min.*	*Man-min.*	*Man-min.*	*Man-min.*	*Man-min.*	*Man-min.*	*Man-min.*	*Man-hours*
Conventional 40- x 48-inch pallets, counterbalanced trucks	26. 44	1. 35	24. 38	52. 17	28. 34	2. 59	[2] 20. 52	51. 45	1. 73
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	30. 19	4. 28	24. 38	58. 85	32. 98	2. 98	[2] 20. 52	56. 48	1. 92
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	40. 51	5. 51	24. 38	70. 40	47. 69	4. 14	[2] 20. 52	72. 35	2. 38
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	43. 01	6. 30	24. 38	73. 69	48. 81	4. 04	[2] 20. 52	73. 37	2. 45
Tubular-frame 40- x 48-inch pallets, counterbalanced trucks	43. 68	4. 18	24. 38	72. 24	44. 58	19. 49	[2] 20. 52	84. 59	2. 61
Tubular-frame 40- x 32-inch pallets, straddle trucks	61. 51	3. 74	24. 38	89. 63	63. 34	30. 55	[3] 32. 43	126. 32	3. 60
Standard pallet racks, 40- x 32-inch pallets, straddle trucks	94. 75	0	24. 38	119. 13	98. 15	6. 63	[4] 21. 54	126. 32	4. 09

[1] Includes 15 man-minutes per carlot unavoidable delay allowance and 9.38 man-minutes per carlot job changeover allowance (see appendix).

[2] Includes 12.63 man-minutes per carlot unavoidable delay allowance and 7.89 man-minutes per carlot job changeover allowance (see appendix).

[3] Includes 12.63 man-minutes per carlot unavoidable delay allowance and 19.80 man-minutes per carlot idle time (see appendix).

[4] Includes 12.63 man-minutes per carlot unavoidable delay allowance and 8.91 man-minutes per carlot idle time (see appendix).

age (fig. 10), this advantage is partly offset by a longer transport distance (150 feet compared to 120 feet in the three-tiered rack system).

Labor requirements of the system using three-tiered drive-in racks and a counterbalanced truck are 27 percent less than the lowest achieved with self-supporting pallets, and over 53 percent less than those of standard pallet racks and straddle forklift trucks. The advantages of larger unit loads, shorter transport distances, and the greater speed of the counterbalanced truck combine to bring this about.

Most of the saving in labor with the three-tiered racks and counterbalanced truck compared to the four-tiered rack and the same truck (fig. 11) is due to the difference in the number of unit loads handled. The average number of pallet loads per carlot for three-tiered racks is 25.8, and four-tiered racks, 37.4. The labor required per pallet load is pretty much the same with either storage method and the difference in average transport distance is only 10 feet.

Labor requirements for the three-tiered rack system using an extendible-fork truck (fig. 12) are 24 percent higher than those for the system using the counterbalanced truck, because of the difference in operating speed of the two types of trucks.

Handling empty pallets is a problem when tubular-frame pallets are used. Though the superstructures are demountable, they were left attached to the pallets in the warehouse observed. This meant that only two empty pallets at a time were returned to the receiving platform. Five times as many trips were required compared to the other storage systems, where empty pallets can be handled in loads of 10 pallets.

When 40- by 48-inch, tubular-frame, self-supporting pallets are used for storage and counterbalanced forklift trucks for handling, the labor required per carlot is 27 percent less than with the smaller tubular-frame pallets and straddle trucks (fig. 13). The larger unit loads handled on the 40- by 48-inch pallets reduce by over 20 percent the number of trips required to move a given volume, compared to the smaller tubular-frame pallets. An additional factor in the lower labor requirements with 40- by 48-inch tubular-frame pallets is the greater speed of the counterbalanced forklift truck. The work involved in picking up and setting down loads is the same because the height the loads are lifted is identical.

The greatest disadvantage of the self-supporting pallets studied is the restriction on pallet patterns imposed by the frames fitted to each corner of the pallets.

BN–18688

FIGURE 10.—Depositing a load in the second tier when the conventional storage method is used.

The resulting high number of pallet loads per carlot equivalent raises the labor requirements.

The labor requirements for all handling operations were highest when standard pallet racks and straddle forklift trucks were used. The two factors primarily responsible are that the average size of the unit loads handled is the smallest of any of the systems observed and the average distance transported is the greatest. The relatively long transportation distance is due to the large number of aisles required because every pallet must be adjacent to an aisle.

Standard pallet racks have one advantage from the handling standpoint over all the other systems studied. Because every pallet load in storage is next to an aisle, there is no need to rehandle loads for stock rotation. In warehouses where orders are selected directly from storage, rather than from an order-assembly area, the greater accessibility of pallet loads stored on standard racks could be advantageous.

Equipment

The materials-handling equipment included in the comparisons consist of forklift trucks, batteries, battery chargers, and pallets. Two batteries and one battery charger are required for each forklift truck. During the day shift, one battery powers the truck while the other battery is being charged. At the end of the day shift, the battery is connected to the charger; the other battery furnishes power during the night shift.

At a given level of annual volume, the number of forklift trucks required is determined by the daily time requirements to perform the work in the operation that requires the most time.[4] The number of pallets required is determined by the size of the unit load.

The analysis of labor requirements (see appendix p. 29) shows that one forklift operator for receiving and one for assembly would be adequate to handle the volume for each of the seven storage systems. Because one operator works the day shift and the other works the night shift, only one lift truck is required.

The number of pallets required to handle the volume is the number required to store the 15-carlot representative inventory, plus enough to receive an additional 4-carlot equivalents. The extra pallets are provided to take care of those days when commodities are received and none have been shipped during the previous night. The average daily volume received on pallets is 3.2 carlots at the 1,000-carlot annual volume; this was increased to 4 to provide a small safcty margin.

[4] Note that the most time-consuming operation with all systems analyzed is order assembly, including returning pallets.

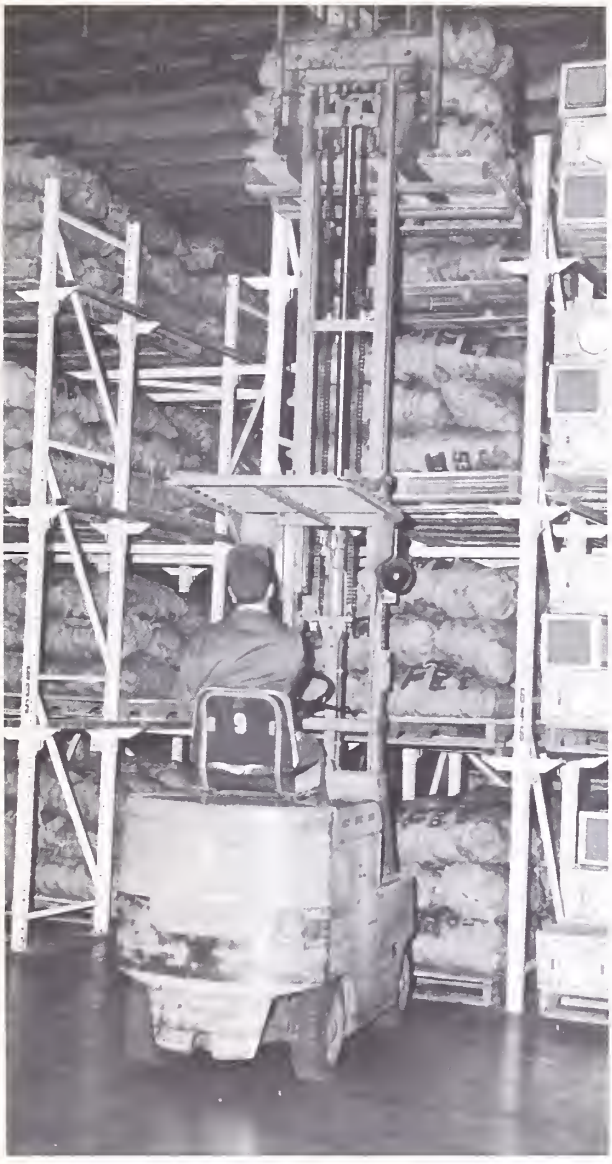

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FIGURE 11.—Placing a pallet load in storage in four-tiered drive-in pallet racks with a counterbalanced forklift truck.

In addition, 25 pallets are added to handle palletized boxes of bananas. An average of 37.5 pallet loads of boxed bananas constitutes 1 carlot for all systems, because the same number of boxes are loaded on each pallet with all systems. The average daily volume of bananas shipped is slightly over 0.5 carlot.

The pallet requirements in table 5 are based on the needs during the assumed 8-month busy season when 80 percent of the total annual volume is handled.

Costs

Labor costs cover the time forklift operators spend on pallet-handling operations, including allowances for unavoidable delays and changing jobs. The cost of time spent on other warehouse activities is not included in this study. Equipment costs include the costs of depreciation, interest, taxes, insurance, maintenance, and electrical energy (details in appendix).

Conventional storage and a counterbalanced truck result in the lowest handling costs of all the systems observed (table 6). Labor and handling equipment costs are 7 percent less than the lowest achieved with any of the high-tiering methods of storage, and 45 percent less than with the standard pallet racks. The most economical handling when drive-in pallet racks are used is achieved with three-tiered racks and a counterbalanced forklift truck. This system results in handling costs 41 percent lower than with storage on the standard pallet racks. Tubular frame 40- by 48-inch pallets result in the lowest handling cost of the self-supporting pallets, with costs 27 percent lower than with the standard pallet racks.

Labor costs account for a larger portion of the total cost, and labor costs are much more variable than the handling equipment costs.

TABLE 5.—*Pallet requirements for an annual volume of 1,000 carlots*

Storage system	Average pallet loads per carlot [1]	Pallets required:		
		To store representative inventory	To receive 4 carlots	Total [2]
	Number	*Number*	*Number*	*Number*
Conventional 40- x 48-inch pallets, conterbalanced trucks	21. 5	322	86	433
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	25. 8	387	103	515
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	25. 8	387	103	515
Tubular-frame 40- x 48-inch pallets, counterbalanced trucks	35. 8	537	143	705
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	37. 4	561	150	736
Tubular-frame 40- x 32-inch pallets, straddle trucks	45. 9	688	184	897
Standard pallet racks, 40- x 32-inch pallets, straddle trucks	50. 4	756	202	983

[1] Excluding bananas.

[2] Includes 25 pallets for banana assembly.

BN–18689

FIGURE 12.—Setting a load down in storage with an extendible-fork lift truck.

TABLE 6.—*Comparable handling costs per carlot equivalent when specified storage and handling systems are used for an annual volume of 1,000 carlots*

Storage system	Labor cost [1]	Equipment cost [2]	Total handling cost
	Dollars	*Dollars*	*Dollars*
Conventional 40- x 48-inch pallets, counterbalanced trucks	3. 89	2. 85	6. 74
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	4. 32	2. 93	7. 25
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	5. 36	2. 66	8. 02
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	5. 51	3. 15	8. 66
Tubular-frame 40- x 48-inch pallets, counterbalanced trucks	5. 87	3. 12	8. 99
Tubular-frame 40- x 32-inch pallets, straddle trucks	8. 10	3. 01	11. 11
Standard pallet racks, 40- x 32-inch pallets, straddle trucks	9. 20	3. 11	12. 31

[1] Based on an assumed cost of $2.25 per hour for forklift operators.
[2] Based on total annual cost of handling equipment required divided by 1,000 carlots handled per year.

STORAGE AND HANDLING COSTS COMBINED

The total costs in table 7 represent the storage and handling costs on a per-carlot-equivalent basis.

When three-tiered drive-in pallet racks are used for storage, total costs per carlot are 16 to 18 percent less

BN—18684

FIGURE 13.—Transporting a load to storage on a straddle forklift truck.

than when conventional storage is used. The cost comparison indicates that a slight advantage exists for the counterbalanced truck over the extendible-fork truck when used with three-tiered drive-in pallet racks. For all practical purposes they can be considered equivalent. Four-tiered racks and a counterbalanced truck resulted in costs about the same as with conventional storage.

The high cost of handling, added to storage costs that are about the same as those for conventional storage, resulted in a high total cost for standard pallet racks and a straddle forklift truck. This system resulted in the highest costs of all the systems studied. The two systems employing tubular-frame pallets show considerable improvement compared to standard pallet racks. However, costs are still higher than with conventional storage and a counterbalanced truck. Conventional storage is competitive with these systems despite high storage costs because handling costs are the lowest observed.

TABLE 7.—*Comparable storage and handling costs per carlot equivalent when specified storage and handling systems are used for an annual volume of 1,000 carlots*

Storage system	Storage		Handling		Total comparable cost
	Area required	Cost [1]	Labor [2] required	Cost [3]	
	Sq. ft.	*Dollars*	*Man-hours*	*Dollars*	*Dollars*
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	3, 669	5. 74	1. 92	7. 25	12. 99
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	3, 280	5. 24	2. 38	8. 02	13. 26
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	4, 206	6. 92	2. 45	8. 66	15. 58
Conventional 40- x 48-inch pallets, counterbalanced trucks	7, 100	9. 09	1. 73	6. 74	15. 83
Tubular-frame 40- x 48-inch pallets, counterbalanced trucks	4, 845	8. 10	2. 61	8. 99	17. 09
Tubular-frame 40- x 32-inch pallets, straddle trucks	3, 698	7. 14	3. 60	11. 11	18. 25
Standard pallet racks, 40- x 32-inch pallets, straddle trucks	6. 556	9. 11	4. 09	12. 31	21. 42

[1] Includes costs of warehouse area plus tiering devices allocated over 844 carlots per year moving through general and cold storage.

[2] Includes labor required for receiving, rehandling, assembly, and returning empty pallets.

[3] Includes labor cost plus handling equipment cost allocated over 1,000 carlots per year shipped out.

INITIAL INVESTMENT

Table 8 is a tabulation of the initial costs of the plant and equipment for the 7 storage systems at an annual volume of 1,000 carlots. The systems requiring the lowest initial investment are the two that use three-tiered drive-in pallet racks. The saving compared to conventional storage amounts to almost $26,000 with a counterbalanced truck and to over $31,000 with an extendible-fork truck.

TABLE 8.—*Initial investment requirements when specified storage and handling systems are used for an annual volume of 1,000 carlots*

Storage system	Warehouse area [1]	Tiering devices [2]	Handling equipment [3]	Total investment
	Dollars	*Dollars*	*Dollars*	*Dollars*
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	32, 800	8, 100	9, 902	50, 802
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	36, 690	8, 100	11, 548	56, 338
Tubular-frame 40- x 32-inch pallets, straddle trucks	36, 980	10, 316	11, 016	58, 312
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	42, 060	11, 900	12, 321	66, 281
Tubular-frame 40- x 48-inch pallets, counterbalanced trucks	48, 450	8, 108	12, 212	68, 770
Conventional 40- x 48-inch pallets, counterbalanced trucks	71, 000	0	11, 260	82, 260
Standard pallet racks, 40- x 32-inch pallets, straddle trucks	65, 560	5, 600	11, 274	82, 434

[1] Includes only the area required for storage and aisles providing access to storage.

[2] Includes installation of pallet racks.

[3] Includes forklift trucks, batteries, battery chargers, and pallets.

INTERNAL WAREHOUSE EXPANSION

Wholesalers currently using 40- by 48-inch pallets, counterbalanced forklift trucks, and conventional storage can increase the storage capacity in their warehouses, for all fruits and vegetables except bananas, two-thirds or more by installing drive-in racks in which pallets can be tiered three-high. Eighteen feet of clear vertical space would have to be available in order to tier pallets three-high in racks. In the discussion of the conventional method given earlier, it was established that a combined total of 7,100 square feet of floorspace would be required for the general, wet-cold, and dry-cold storage areas. Because these areas were sized for the conventional storage system, the dimensions do not fully meet the needs of a rack installation, and some space cannot be fully used. Even so, converting from the conventional method to racks would provide a two-thirds increase in storage capacity. In some warehouses this increase could be greater, in others it could be less, depending upon the dimensions and shape of the storage areas and the service aisles that might be required.

A wholesaler whose annual business volume increases from 1,000 to 1,300 carload equivalents would be crowded for storage space if he used the conventional pallet storage system. If the ceiling height in his warehouse was adequate, the needed storage capacity could be provided by installing three-high pallet racks in place of the conventional storage system. In addition, as much as 2,100 square feet of floorspace would be released for other warehouse operations. (This figure would be reduced by any aisle space required.) This would make sufficient space available for an additional banana-ripening room, supply storage, or for packaging operations, if the shape and location of the released space was suitable.

ANNUAL VOLUMES OF 2,000 AND 3,000 CARLOTS

Handling and storage costs for the 3-tiered drive-in rack systems were compared to those of the conventional system at annual volumes of 2,000 and 3,000 carlots.

In estimating costs at annual volumes of 2,000 and 3,000 carlot equivalents, it was assumed that the volume handled is the only business characteristic that is changed. The rate of turnover is still approximately 80 times per year, and the representative inventory remains a constant percentage of the annual volume. The required storage capacities would be 30 carlots for 2,000 carlots per year, and 45 carlots for 3,000 carlots.

Warehouse area requirements were determined in the same manner used in the basic comparisons at the 1,000-carlot-equivalent annual volume. Room layouts were developed for each storage area, and the total area of these rooms represented the area required for storing 84.4 percent of the total volume (commodities other than bananas). For storage on pallet racks, the annual cost of the racks per pallet stack of capacity was assumed to be relatively constant at annual volumes of 1,000-carlot equivalents and above. Warehouse area costs were computed at the assumed rate of $1.08 per square foot per year.

In estimating the handling costs at the higher volumes, it was assumed that the productive labor required per carlot equivalent would be the same as at the 1,000-carlot annual volume. Allowances for unavoidable delay and changing jobs, however, are divided by larger average daily volumes,[5] so that labor requirements per carlot equivalent at annual volumes of 2,000 and 3,000 carlots are lower than 1,000 carlots.

At 2,000 carlots per year, 2 forklift operators (one for receiving and one for assembly) can handle the volume. The same is true of the two systems employing counterbalanced forklift trucks when the volume is 3,000 carlots per year. When the extendible-fork lift truck is used, a second forklift operator is required for order assembly.

Total storage and handling costs per carlot equivalent for annual volumes of 2,000 and 3,000 carlots are given in tables 9 and 10. The ranking of the 3 storage systems is the same at the 2 higher volumes as at 1,000 carlots per year. Storage on three-tiered drive-in pallet racks results in substantial savings compared to conventional storage, with little difference between use of counterbalanced or extendible-fork trucks. Savings over the conventional storage system amount to 18 percent at both the higher volumes when counterbalanced trucks are used.

At annual volumes of 2,000 and 3,000 carlots, the total costs for storage and handling per carlot equivalent for all 3 systems are lower than costs for 1,000 carlots. Labor and handling equipment costs are less because they are spread over larger annual volumes. The additional truck required for 3,000 carlots in the system using extendible-fork trucks still does not raise the equipment cost per carlot to the level incurred at the 1,000-carlot volume. Storage costs of the rack systems are about 6 to 8 percent higher per carlot equivalent at the higher volumes because a greater proportion of aisle space is required as the storage areas are increased in size.

[5] In allocating allowances on a per carlot-equivalent basis, the following average daily volumes during the busy season were used: (1) 2,000 carlots per year—6.4 carlots received and 7.6 carlots assembled; (2) 3,000 carlots per year—9.6 carlots received and 11.4 carlots assembled. Palletized boxed bananas account for the added volumes assembled.

TABLE 9.—*Total storage and handling costs per carlot equivalent on annual volume of 2,000 carlots*

Storage system	Total area required	Storage costs			Labor required	Handling costs			Total cost
		Area	Tiering devices	Total		Labor	Equipment	Total	
	Sq. ft.	*Dollars*	*Dollars*	*Dollars*	*Man-hours*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	7,987	5.11	1.03	6.14	1.54	3.47	1.95	5.42	11.56
3-tiered drive-in racks 40- x 48-inch pallets, extendible-fork trucks	7,202	4.61	1.03	5.64	2.02	4.54	1.79	6.33	11.97
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks	14,293	9.14	.....	9.14	1.35	3.04	1.86	4.90	14.04

TABLE 10.—*Total storage and handling costs per carlot equivalent on annual volume of 3,000 carlots*

Storage system	Total area required	Storage costs			Labor required	Handling costs			Total cost
		Area	Tiering devices	Total		Labor	Equipment	Total	
	Sq. Ft.	*Dollars*	*Dollars*	*Dollars*	*Man-hours*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
3-tiered drive-in racks, 40 x 48-inch pallets, counterbalanced trucks	11,909	5.08	1.02	6.10	1.41	3.17	1.48	4.65	10.75
3-tiered drive-in racks 40 x 48-inch pallets, extendible-fork trucks	10,347	4.41	1.02	5.43	2.07	4.66	2.21	6.87	12.30
Conventional 40 x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks	20,583	8.89	.....	8.89	1.29	2.90	1.39	4.29	13.18

SELECTING A SYSTEM

Storage on three-tiered drive-in pallet racks is the most economical system studied for a fruit and vegetable wholesale warehouse with characteristics similar to those used in making these analyses. At annual volumes of 1,000 and 2,000 carlot equivalents per year, the difference in cost between using a counterbalanced or an extendible-fork truck (for handling) is small. Savings, compared to conventional storage, amount to approximately 18 percent in total cost per carlot. At a volume of 3,000 carlots per year, the use of counterbalanced trucks results in similar savings, but the extendible-fork truck results in savings of less than 10 percent.

The savings realized when three-tiered drive-in pallet racks are used might be improved with racks designed to hold larger loads. Greater vertical clearances between tiers and greater horizontal clearances between upright frames would permit unit loads closer to the capacity of the handling equipment than with the rack installation observed. This would result in fewer pallet loads being stored and fewer trips being required to handle the volume. These two advantages would have to be measured against the disadvantage that each stack of pallets would require more space.

Analysis of the costs and of the methods of estimating them points up the need for choosing an effective storage and handling system before constructing the warehouse. Through advance planning, the fruit and vegetable wholesaler can cut storage and handling costs by as much as 18 percent with the use of drive-in pallet racks for storage as opposed to the use of a conventional storage system.

The final decision as to which storage and handling system will be used should be based on careful estimates of the results to be expected from each system. All recommendations should be viewed within the circumstances surrounding the particular warehouse involved. Using the methods given in this report, adjustments can be made in the handling costs to reflect different wage rates. The area requirement could be estimated for storage volumes or pallet sizes other than the ones used here. The differences and similarities between individual businesses and the conditions assumed in this report should be considered carefully. The effects of the differences should be estimated and included in drawing conclusions.

ADDITIONAL FACTORS THAT CAN AFFECT COSTS

Elimination of Rehandling

In the preceding basic cost comparisons the cost of rehandling for stock rotation was included in handling costs. Rehandling would be necessary when space in a partially filled lane in a storage bay is needed to store incoming fresh commodities. (Lane, in this report, means a single line of pallets running the depth of the bay; see fig. 15.) The older stock already in the lane would be removed, the new stock placed in the lane, and the old stock replaced in the lane in the spaces nearest the aisle where it would be used first.

When there are enough empty lanes available to store all incoming stock there would be no need for stock rotation. Therefore, rehandling can be practically eliminated by providing enough storage space so that partially filled lanes would not be needed. Labor requirements for rehandling were based on one lane for each carlot received. (See appendix.) The minimum numbers of additional lanes required to eliminate rehandling would be seven in general storage, six in dry-cold storage, and four in wet-cold storage. Whether or not the minimum number of lanes or more than the minimum is added to the layout depends on the number required and the number of access aisles.

A comparison between the costs of the additional warehouse area required and the labor required for rehandling was made to determine which alternative is more economical. Handling equipment costs do not enter into the analysis because only one forklift truck is required for each system. Eliminating rehandling cannot reduce equipment requirements and costs any further.

For all the storage and handling systems observed, it was found that, at an annual volume of 1,000 carlots, rehandling for stock rotation is more economical than providing additional storage area to eliminate rehandling (table 11). At most, rehandling costs only $0.22 per carlot, whereas the cost of additional storage space ranges from $0.89 to $1.98 per carlot.

Rehandling should be avoided, of course, if it is possible to do so without increasing other costs. In planning a new warehouse, an operator may find that components of the warehouse other than storage areas need to be larger than the minimum. Then it may be possible to work into the warehouse design, without increasing the cost of construction, storage area layouts that provide sufficient capacity to eliminate rehandling.

TABLE 11.—*Comparison of cost of rehandling with cost of additional storage space required to eliminate rehandling (annual volume 1,000 carlots)*

Storage system	Rehandling		Storage space required to eliminate rehandling			
	Labor required per carlot [1]	Cost per carlot [2]	Area required [3]	Annual cost of area [4]	Annual cost of tiering devices	Total cost per carlot [5]
	Man-hrs.	*Dollars*	*Sq. ft.*	*Dollars*	*Dollars*	*Dollars*
Tubular-frame 40- x 32-inch pallets, straddle trucks	0.06	0.14	696	752	.....	0.89
Tubular-frame 40- x 48-inch pallets, counterbalanced trucks	.07	.16	1,152	1,244	.....	1.47
Conventional 40- x 48-inch pallets, counterbalanced trucks	.02	.05	1,151	1,243	.....	1.47
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	.09	.20	1,048	1,132	284	1.68
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	.07	.16	1,172	1,266	284	1.84
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	.10	.22	1,215	1,312	361	1.98

[1] See tables 18 and 23, appendix.
[2] Based on a labor cost of $2.25 per man-hour.
[3] See appendix for details.
[4] Based on average cost of $1.08 per square-foot per year.
[5] Based on 844 carlot equivalents moving through general and cold storage.

Combined Cold Storage

Most present-day fruit and vegetable wholesale warehouses have cold storage separated into at least two distinct categories: Dry cold and wet cold. Recently, there has been a trend to combine all cold storage into a single room with a view toward lowering construction costs and simplifying the overall warehouse layout. Modern packaging, short storage periods, and accurate control of temperature at 32° F. make such consolidation of cold-storage areas practical from the standpoint of product quality maintenance.

An analysis of area requirements for separate versus combined cold storage, based on three-tiered drive-in pallet rack storage with a counterbalanced forklift truck, indicates that, when efficient layouts are used, no significant reduction in area is achieved by combining the two rooms (table 12). The total wall area, however, would be reduced by 588 square feet by eliminating the wall separating the rooms, and the number of doors required would be reduced from four to two (fig 14). The volume stored is the same, and the outer wall surface exposed to higher temperature air in adjacent areas is about the same in either case. Because in the separate rooms the temperatures maintained are the same and the humidity levels are within 5 percent of each other, there would be no difference in refrigeration requirements. Some saving in piping might be possible with the combined cold-storage room, but this was not investigated.

TABLE 12.—*Area requirements for separate and combined cold storage when 3-tiered drive-in pallet racks and a counterbalanced forklift truck are used for an annual volume of 1,000 carlots*

Cold storage arrangement	Storage capacity	Width	Depth	Area
	Pallet stacks			*Square feet*
Separate:				
Dry-cold room	50	46′1″	28′5″	1,310
Wet-cold room	30	27′9″	28′5″	789
Total	80	.....	.....	2,099
Combined single cold room	80	73′7″	28′5″	2,091

Pallet Orientation

The pallets used in the storage and handling systems observed that used counterbalanced or extendible-fork lift trucks were 40 inches long (stringer length) by 48 inches wide (deck board length). This pallet is termed 40- by 48-inch and is in general use now. The reverse of these dimensions is termed a 48- by 40-inch pallet.

When 40- by 48-inch pallets are placed in storage, the longer dimension is parallel to the access aisles. So, aisles are longer with this pallet than for the 48- by 40-inch pallet.

In storage and handling systems where counterbalanced forklift trucks (10.5-foot aisles) are used, access-aisle area can be reduced by as much as 6 square

SEPARATE AND COMBINED COLD STORAGE ROOMS
WHEN 3-TIERED DRIVE-IN PALLET RACKS ARE USED
IN A WHOLESALE FRUIT AND VEGETABLE WAREHOUSE

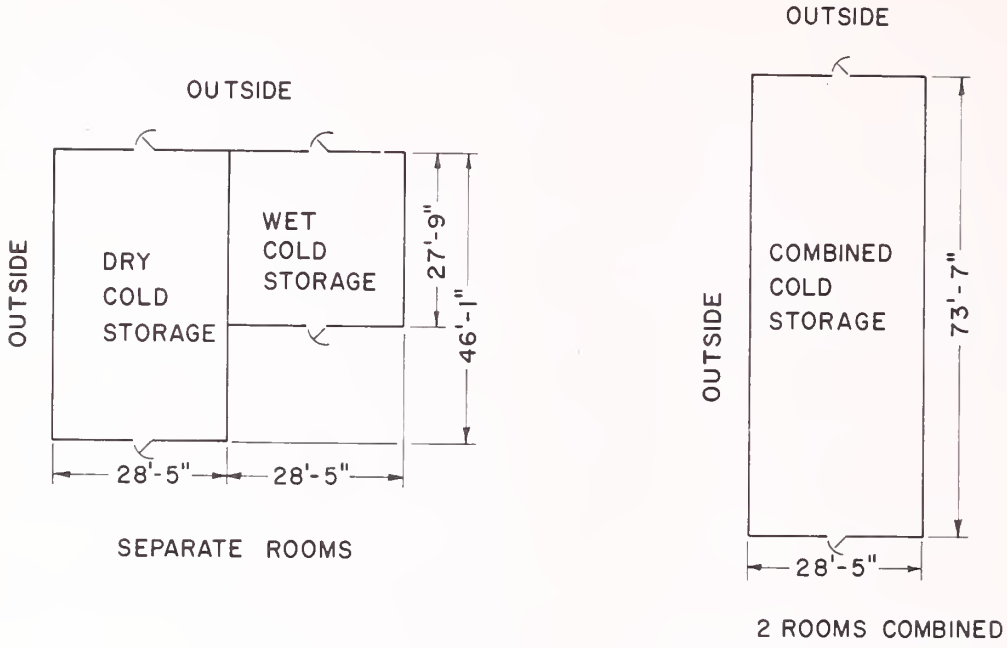


FIGURE 14

feet per lane by using 48- by 40- rather than 40- by 48-inch pallets. The floor area required for pallet storage would be unchanged, but dimensions of the area would change.

The room width would decrease, thus reducing the aisle length by 8 inches for each lane required. The aisle width is increased to 11 feet because of the increased pallet length, but the total aisle area per lane is reduced. This can be illustrated by the fact that for each 48-inch pallet width 42 square feet of aisle area is required. With the 40-inch width parallel to the aisle, 36 square feet of aisle area is required. This reduction of 6 square feet in aisle space would apply to each lane needed, since the same clearances would be required for either pallet orientation.

When pallet orientation is changed for the conventional method the floor area required would be 306 square feet less than the 7,100 square feet originally required. This would represent a reduction in the investment in storage space of $3,050. In addition to the advantage of reduced aisle area when 48- by 40-inch pallets are used, it would also be possible to place four more pallets on each of the two order-selection lines adjacent to an 80-foot-long belt conveyor, thus making a greater variety of items, in pallet quantities, available to the order selectors. Twenty pallets 48 inches wide could be positioned beside an 80-foot conveyor while 24 of the 40-inch width could be positioned in the same space.

APPENDIX

Research Methods and Techniques

The methods and equipment analyzed in this report were studied in six wholesale fruit and vegetable warehouses during normal working hours under actual operating conditions. Data were collected to measure the warehouse area required for storage, and the labor and handling equipment required for moving loads into and out of storage.

Dimensions of pallet loads, pallet racks, self-supporting pallets, and clearances in storage are based on actual physical measurements taken in the warehouse. Sales records, inventory statistics, and records of receipts were studied to gain knowledge of turnover rates and storage periods. Pallet-loading data for conventional storage and commodity distribution data were adapted from other research studies.[6]

[6] See preface.

Patterns for pallet racks and self-supporting pallets were developed from published data.[7]

Time study was used to measure labor and handling equipment inputs. As the handling operation progressed, a trained observer recorded the elapsed time for each element of work. An estimate of the worker's effort level was made to reduce the chance for bias, because workers observed in one location might work at a consistently faster rate than workers in another location. The effort level was recorded as a percent of the normal pace. The normal pace, assigned a value of 100 percent, is the rate at which a trained, conscientious worker would be expected to perform his assigned duties under good working conditions. An effort level greater than 100 percent meant that the worker was working faster than the normal pace, and an effort level less than 100 percent indicated that he was working at a rate slower than normal. The percentage of the effort level was multiplied by the observed time to arrive at the "base" time. An allowance was added to determine the "productive" time. The allowance was added to provide time for personal needs and to recover from fatigue. Cost calculations were made using labor and equipment requirements based on the productive times.

Storage and Tiering Device Cost Data

Annual storage space costs (table 13) are based on those of a typical modern service wholesale warehouse. The warehouse is a single-story, steel-frame building. Exterior walls are masonry. Interior partitions are concrete masonry and wood stud. Floors are concrete with a nonskid finish. Exterior and interior walls around refrigerated rooms and rooms with controlled temperature or humidity are insulated.

TABLE 13.—*Annual cost to own and maintain a warehouse with an initial cost of $10* [1] *per square foot and an expected life of 30 years*

Item	Cost per square foot
	Dollars
Depreciation [2]	0. 33
Average interest at 5 percent	. 25
Insurance and taxes at 4 percent	. 40
Maintenance at 1 percent	. 10
Total	1. 08

[1] Based on experience of members of United Fresh Fruit & Vegetable Association.
[2] Straight-line depreciation.

[7] Goldweitz, Saul. The Palletizer—Pallet Pattern Selection Guide. Modern Materials Handling, 12 pp., illus., 1951.

Refrigerated rooms account for approximately 12 percent and conditioned rooms about 8 percent of the total warehouse space. An estimate, based on the experience of wholesale distributors, indicates an initial cost of about $10 per square foot. This figure includes facility construction, and refrigerating, heating, and electrical equipment. It does not include the purchase price of the land, site preparation, the materials-handling equipment, or the cost of tiering devices.

The pallet racks studied were constructed of commercially available standard rack components. Typical rack components are upright frames, shelves, horizontal beams or "runners," brackets for attaching horizontal members to uprights, top bars for connecting upright frames, and row connectors. The quantity and size of each component were determined from the layout data in the following section. The cost figures in table 14 represent the total cost of each pallet rack installation for all three storage areas (general, dry cold, and wet cold).

Costs of pallet racks in 1962 were obtained from equipment manufacturers, distributors, and manufacturers' associations. The depreciation period (expected useful life) was suggested by the manufacturers, and also reflects the depreciation periods usually used in computing Federal taxes.

The cost of the racks and their installation (table 14) should be considered average, because these costs can vary widely for different quantities and from one location to another. Warehousemen can obtain more specific cost estimates from local distributors.

The annual cost of tubular frames for 40- by 48-inch or 40- by 32-inch pallets is based on an initial cost of $1,150 for 100 frames, an expected useful life of 10 years, and the following annual ownership and maintenance costs, per 100 frames:

Depreciation	$115. 00
Interest at 5 percent	31. 62
Insurance and taxes at 4 percent	46. 00
Maintenance	34. 50
Total	227. 12

Determining Floor Area Requirements

The number of square feet of storage space required in a wholesale warehouse depends on several factors. The more important of these are:

- the amount of inventory planned;
- the size of the unit loads;
- the height to which commodities are tiered;
- the widths of the aisles needed; and
- the clearances provided for ease of handling.

In determining the amount of inventory to be provided for in storage, a number of assumptions were made. They are:

TABLE 14.—*Annual cost to own and maintain specified types of pallet rack installations for an annual volume of 1,000 carlot equivalents when the expected useful life is 30 years*

Pallet rack installation	Initial cost			Annual cost				
	Materials	Installation	Total	Depreciation	Interest 5%	Insurance and taxes 4%	Maintenance	Total
3-tiered standard pallet racks for 40- by 32-inch pallets	$5,300	$300	$5,600	$187	$145	$224	$56	$612
4-tiered drive-in pallet racks for 40- by 48-inch pallets (rehandling for stock rotation)	11,445	455	11,900	397	307	476	119	1,299
3-tiered drive-in pallet racks for 40- by 48-inch pallets (rehandling for stock rotation)	7,840	260	8,100	270	209	324	81	884
4-tiered drive-in pallet racks for 40- by 48-inch pallets (additional space to eliminate rehandling)	14,710	490	15,200	507	393	608	152	1,660
3-tiered drive-in pallet racks for 40- by 48-inch pallets (additional space to eliminate rehandling)	10,290	410	10,700	357	276	428	107	1,168

1. Inventory turnover was 80 times per year or approximately once each 4½ days.
2. Space was provided to store a 4½-day inventory (15 carlots). The inventory was assumed to be a composite of all commodities handled. The quantities of each commodity in the inventory were based on the ratio of the annual volume for that commodity to the total annual volume for all commodities. It was also assumed that as the seasons changed, the space allocated to an out-of-season item would be required for those in-season items that were being handled in greater than average quantities.
3. Eighty percent of the total volume was handled in an 8-month "busy" season.
4. In analyzing different business volumes, the volume of each commodity remained the same in relation to the total volume. For example, potatoes always accounted for 25 percent of the carlot equivalents handled per year.
5. The volume of each commodity making up the equivalent inventory for a business volume of 1,000 carlots per year is shown in table 15.

Because bananas are stored in special banana-ripening rooms, they are excluded from the area requirements calculations that follow. Bananas account for 15.6 percent, or 156 carlot equivalents, when the annual volume is 1,000 carlot equivalents.

Eighty percent of the 844 carlot equivalents stored on pallets are handled in the 8-month busy season (35 weeks). The average weekly volume during this period is 19 carlot equivalents, excluding bananas. With a 6-day workweek, the equivalent inventory (4½-day supply) to be provided for would be 4½

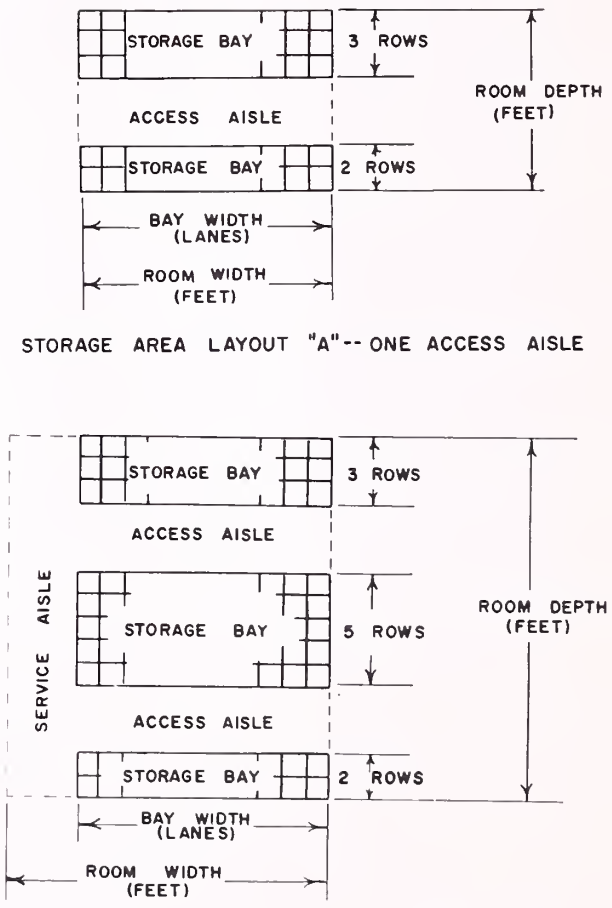


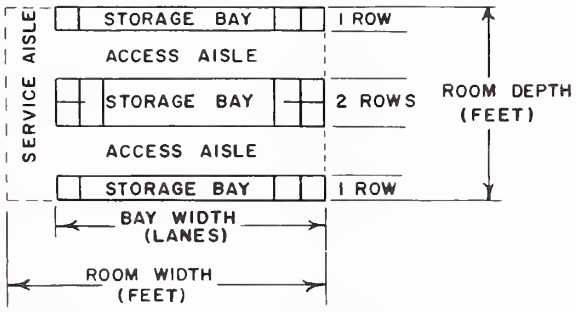
FIGURE 15.—Storage area layout patterns for conventional, self-supporting pallet, and drive-in pallet rack storage.

times one-sixth of the weekly volume, or 14.3 carlots. This figure was increased to 15 carlot equivalents to provide for upward fluctuations over the average inventory.

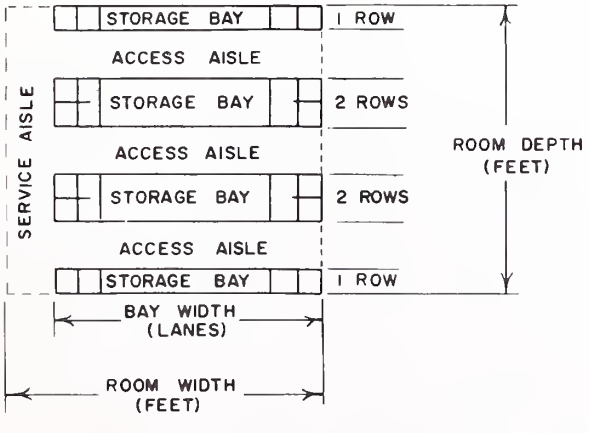
Pallet patterns were designed to fit within the restrictions imposed by each storage method. The number of pallet loads required to store the representative inventory was divided by the tiering height to determine the number of pallet "stacks" required. (A vertical column of pallet loads is referred to as a pallet "stack," even though in some storage methods the loads are not actually stacked atop one another.) The number of pallet stacks for annual volumes other than the 1,000-carlot-per-year volume can be determined by raising or lowering the numbers of pallet spaces required in the same proportion as the change in annual volume.

After the numbers of pallet stacks required had been decided, criteria were chosen to determine corresponding floor area requirements. It was decided that each of the three storage areas would occupy a single room in the warehouse and that only the areas of these rooms would be included. A layout pattern to be used within the storage rooms was chosen to be applied to all storage methods. A further restriction was that no room would be more than three times as long as it was wide, or vice versa. This restriction was added to prevent storage area requirements from being based on storage room layouts that are excessively long and narrow. Otherwise, all storage rooms would have but one access aisle with all pallets lined up along either side of it, because this pattern would always result in the minimum area required. If some restrictions were not placed on how long and narrow storage areas could be, one room would be 13 feet deep by 185 feet wide. The layout patterns used for conventional storage, self-supporting pallets, and drive-in pallet racks are shown in figure 15. Storage area layout A was used if the required number of pallet stacks was low enough to permit a room width no greater than three times the room depth. If the number of pallet stacks required was higher than this, storage area layout B was used. Bay depth for each access aisle averages five rows.

The layout patterns used for storage on standard pallet racks are shown in figure 16. Storage area layout C was used when the number of lanes needed to provide the required number of pallet stacks was such that room width was no more than three times the room depth. When this capacity was exceeded, storage area layout D was used to bring the shape of

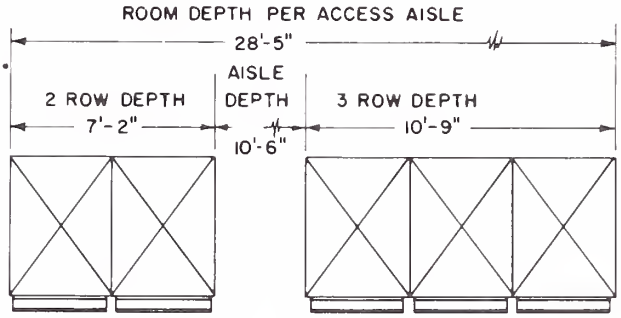


STORAGE AREA LAYOUT "C"-- 2 ACCESS AISLES



STORAGE AREA LAYOUT "D"-- 3 ACCESS AISLES

FIGURE 16.—Storage area layout patterns for standard pallet rack storage.



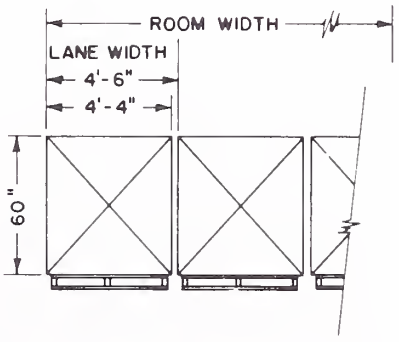


FIGURE 17.—Basic dimensions for conventional and 40- by 48-inch self-supporting pallet storage.

TABLE 15.—*Pallet stacks required to store a 4½-day inventory (15 carlot equivalents) of*

	Commodity and storage area	Commodity volume [1]	Conventional storage on 40- x 48-in. pallets				Storage on 40- x 48-in. self-supporting pallets (3 tiers)		
			Weight per pallet	Pallet loads required	Tiering height	Pallet stacks required	Weight per pallet	Pallet loads required	Pallet stacks required
	General:	*Pounds*	*Pounds*	*Pallets*	*Pallet loads*	*Pallet stacks*	*Pounds*	*Pallets*	*Pallet stacks*
1	Cantaloups	8, 415	1, 700	5	2	3	1, 020	8	3
2	Lemons	7, 200	1, 600	5	2	3	800	9	3
3	Onions	13, 500	2, 000	7	1	7	750	18	6
4	Potatoes	165, 600	2, 000	83	1	83	1, 500	110	37
5	Sweetpotatoes	6, 600	1, 100	6	1	6	660	10	4
6	Tomatoes	9, 280	1, 536	6	2	3	1, 120	8	3
7	Watermelons	12, 672	1, 200	11	2	6	908	14	5
8	Other [2]	16, 960	1, 200	14	1	14	908	19	7
9	Subtotal	240, 227	.....	137	.....	125	.....	196	68
	Dry cold:								
10	Apples	31, 200	1, 750	18	2	9	1, 000	31	11
11	Grapefruit	21, 600	1, 600	14	2	7	800	27	9
12	Grapes	8, 448	1, 536	6	2	3	960	9	3
13	Lettuce	55, 356	1, 260	44	2	22	504	110	37
14	Oranges	26, 000	1, 600	16	2	8	800	33	11
15	Peaches	4, 620	1, 100	4	1	4	660	7	3
16	Other [2]	15, 729	1, 500	10	1	10	1, 135	14	5
17	Subtotal	162, 953	.....	112	.....	63	.....	231	79
	Wet cold:								
18	Cabbage	22, 000	1, 000	22	1	22	600	37	13
19	Carrots	17, 850	1, 750	10	2	5	1, 000	18	6
20	Celery	20, 160	1, 080	19	2	10	720	28	10
21	Corn	7, 250	1, 200	6	2	3	1, 000	7	3
22	Other [2]	16, 050	1, 000	16	1	16	757	21	7
23	Subtotal	83, 310	.....	73	.....	56	.....	111	39
24	Total	486, 490	[3] 1, 511	322	.....	244	[3] 904	538	186

[1] Inventory data for a wholesale fruit and vegetable business with an annual volume of 1,000 carlot equivalents with an average turnover rate of 80 times per year. For additional details on the development of these figures, see Bogardus, R. K., Wholesale Fruit and Vegetable Warehouses: Guides for Layout and Design. U.S. Department of Agriculture Marketing Research Rept. 467, 41 pp., illus. 1961.

[2] Average data.

the storage area within the 3-to-1 limitation. The average storage bay depth in layouts C and D is two rows per access aisle.

These standardized layout patterns were used to determine the exact layout for each storage room that would provide the required capacity within the minimum area, subject to the limitation on shape. Dimensions of storage rooms are based on the dimensions of rows, access aisles, and lanes shown in figures 17–21 for the various storage systems. If a room contains a service aisle, the width of the aisle is: (1) 10 feet 6 inches if a counterbalanced truck is used; (2) 7 feet if a straddle truck is used; and (3) 9 feet 6 inches if an extendible-fork truck is used.

As an example, the layout for the general storage room for the conventional system was determined by the following method. The required storage capacity is 125 pallet stacks. Dividing this figure by the total number of rows (5) in storage area layout A (fig. 15) indicates that storage bays 25 lanes wide would provide this capacity. Lane width (fig. 17) is 4 feet 6 inches (pallet load width is 4 feet 4 inches), so the room would be 112 feet 4 inches wide and 28 feet 5 inches deep. (Room depth per access aisle shown in fig. 17.) This results in a room more than three times as wide as it is deep, so storage area layout B was used. Dividing the total of 10 rows in storage area layout B into the 125 pallet stacks required indicates that storage bays 13 lanes wide would provide the required capacity. Room width is then 68 feet 10 inches, including 10 feet 6 inches for the service aisle, and room depth is 56 feet 10 inches.

fruits and vegetables, by commodities and storage areas, when specified storage methods are used

Storage on 40- x 32-in. self-supporting pallets (3 tiers)			Storage on 3-tiered standard pallet racks—40- x 32-in. pallets			Storage on 4-tiered drive-in pallet racks—40- x 48-in. pallets			Storage on 3-tiered drive-in pallet racks—40- x 48-in. pallets			
Weight per pallet	Pallet loads required	Pallet stacks required	Weight per pallet	Pallet loads required	Pallet stacks required	Weight per pallet	Pallet loads required	Pallet stacks required	Weight per pallet	Pallet loads required	Pallet stacks required	
Pounds	*Pallets*	*Pallet stacks*	*Pounds*	*Pallets*	*Pallet stacks*	*Pounds*	*Pallets*	*Pallet stacks*	*Pounds*	*Pallets*	*Pallet stacks*	
765	11	4	765	11	4	850	10	3	1,700	5	2	1
800	9	3	600	12	4	960	8	2	1,600	5	2	2
500	27	9	600	23	8	1,000	14	4	1,250	11	4	3
1,000	167	56	800	207	69	1,200	138	35	1,500	110	37	4
660	10	4	660	10	4	440	15	4	880	8	3	5
800	12	4	1,152	8	3	960	10	3	1,344	7	3	6
603	21	7	507	25	9	695	18	5	1,100	12	4	7
603	28	10	507	35	12	695	24	6	1,100	15	5	8
.....	285	97	.....	331	113	.....	237	62	.....	173	60	9
800	39	13	750	42	14	1,050	30	8	1,750	18	6	10
800	27	9	600	36	12	960	23	6	1,600	14	5	11
768	11	4	960	9	3	960	9	3	1,152	7	3	12
504	110	37	462	120	40	630	88	22	840	66	22	13
800	33	11	600	43	15	960	27	7	1,600	16	6	14
660	7	3	440	11	4	440	11	3	660	7	3	15
754	21	7	633	25	9	869	18	5	1,375	11	4	16
.....	248	84	.....	286	97	.....	206	54	.....	139	49	17
400	55	19	500	44	15	600	37	10	1,000	22	8	18
800	22	8	1,000	18	6	1,050	17	5	1,750	10	4	19
540	37	13	720	28	10	720	28	7	1,080	19	7	20
800	9	3	650	11	4	900	8	2	1,200	6	2	21
502	32	11	422	38	13	579	28	7	917	18	6	22
.....	155	54	.....	139	48	.....	118	31	.....	75	27	23
[3] 707	688	235	[3] 644	756	258	[3] 867	561	147	[3] 1,257	387	136	24

[3] Overall average.

Table 16 shows the overall dimensions of each storage area for each system.

The last two columns in table 16 show the additional lanes that would be needed to eliminate rehandling of commodities for stock rotation. Lanes were added to each storage bay according to the following rules: In general storage, four lanes were added to storage area layout A, or two lanes were added to storage area layout B; in dry-cold storage, three lanes were added to layout A, or two lanes were added to layout B; and in wet-cold storage two lanes were added to layout A, or one lane was added to layout B. These rules provide for addition of at least one lane for each commodity listed in table 15 except those in the "other" categories.

Labor Requirements

The labor rate used to analyze all storage and handling systems is $2.25 per hour for forklift truck operators. This includes base wages plus fringe benefits such as social security, workmen's compensation insurance, and paid vacations.

Work Element Descriptions

Handling operations were divided into work elements. The element titles and description follow.

PICK UP LOAD ON PLATFORM.—Begins when forks start to enter loaded pallet. Includes inserting forks, lifting and tilting pallet, and moving load clear of original position. Ends when load clears original position.

TRANSPORT LOADED.—Begins when load clears original position or when load has been lowered to height suitable for travel. Includes completing, raising, or retracting load while in motion, and transporting to desired location, starting to raise or extend load while in motion, and decelerating for position to set down. Ends when truck starts to turn for positioning to set down.

SET DOWN LOAD IN STORAGE.—Begins when truck starts to turn for positioning. Includes maneuvering truck to aline load horizontally and raising load to desired height, driving into storage bay when necessary, positioning and depositing load, withdrawing forks from loaded pallet, and backing truck until forks clear face of storage bay. Ends when forks clear face of storage bay.

TRANSPORT EMPTY.—Begins when forks clear face of storage bay or pallet in order-assembly area. Includes lowering forks while in motion, moving to desired location, starting to raise or extend forks if necessary, and decelerating for positioning to pick up. Ends when forks start to enter loaded pallet on platform or when truck starts to turn for positioning to pick up load in pallet rack.

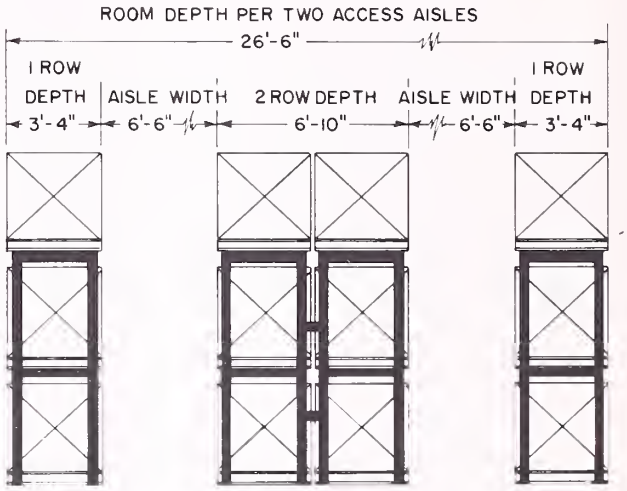
PICK UP LOAD IN STORAGE.—Begins when truck starts to turn for positioning. Includes maneuvering truck to aline forks horizontally and raising forks to desired height, driving into storage bay when necessary, inserting forks, lifting and tilting pallet, backing truck until load clears face of storage bay, and lowering load to height suitable for travel. Ends when load is in position to travel.

SET DOWN LOAD IN ASSEMBLY AREA.—Begins when truck starts to turn for positioning. Includes maneuvering truck into position to deposit load, extending load when necessary, lowering pallet into position in assembly area, and withdrawing forks. Ends when forks clear loaded pallet.

SET DOWN EMPTY PALLETS ON PLATFORM.—Begins when truck starts to turn for positioning. Includes maneuvering truck into position to deposit load; extending load when necessary, lowering pallets into position on the platform, and withdrawing forks. Ends when forks clear bottom pallet.

Productive Times

Allowances to provide for personal needs and recovery from fatigue were added to the base times to determine productive times for each element of work. The personal and fatigue allowances are each 5 percent of the base time. Productive times for work



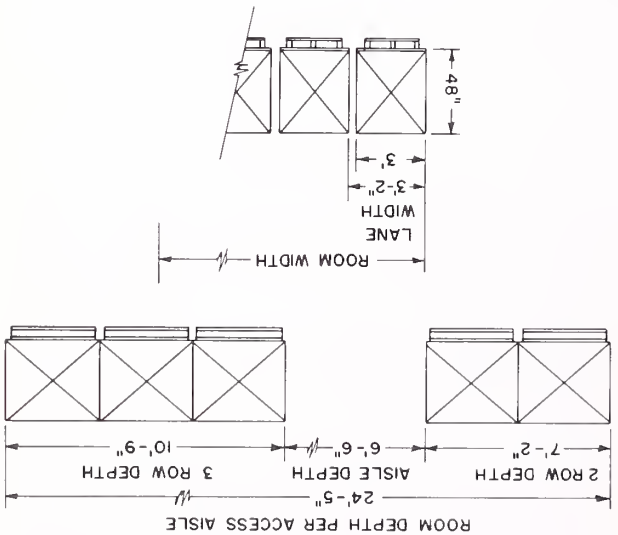


FIGURE 18.—Basic dimensions for 40- by 32-inch self-supporting pallets.

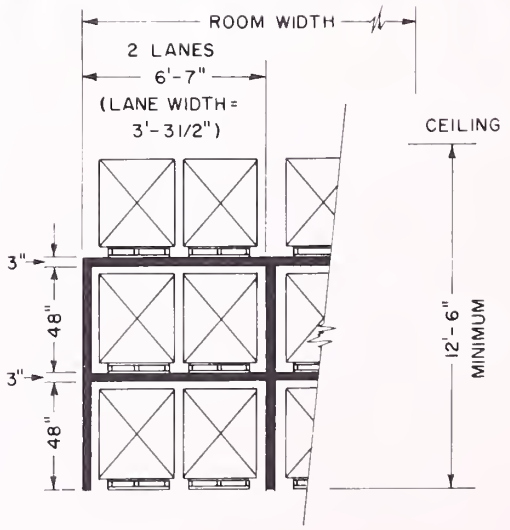


FIGURE 19.—Basic dimensions for standard pallet racks.

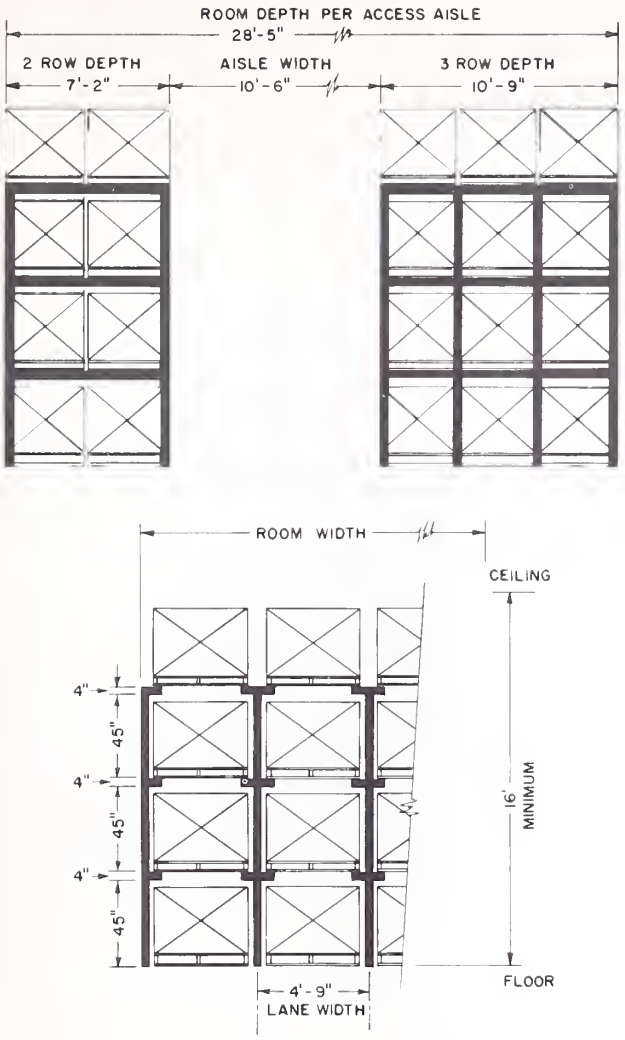


FIGURE 20.—Basic dimensions for four-tiered drive-in pallet racks.

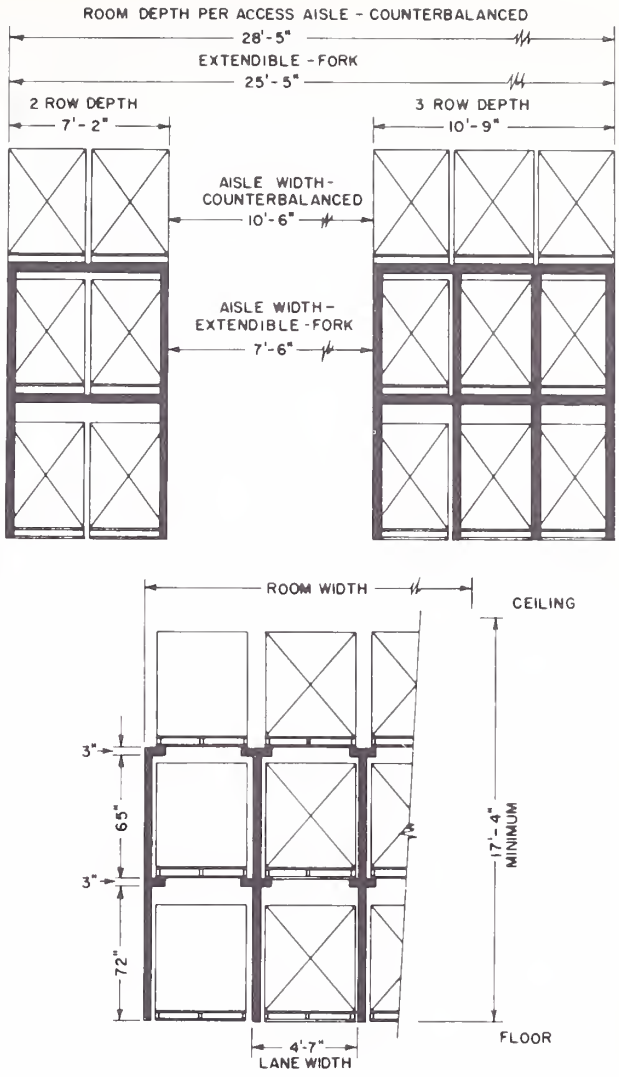


FIGURE 21.—Basic dimensions for three-tiered drive-in pallet racks.

elements were summed to determine productive labor requirements for: (1) Moving loads into storage (table 17); (2) rehandling commodities for stock rotation (table 18); (3) assembling commodities stored in general and cold storage along a belt conveyor (table 19); (4) assembling palletized bananas along a belt conveyor (table 20); and (5) returning empty pallets from the order-assembly area to the receiving platform (table 21). Table 22 presents labor requirements for transportation over distances not covered in other tables.

Rehandling for Stock Rotation

It was assumed that rehandling of pallet loads in one lane would be necessary for each carlot received. Rehandling would therefore occur 844 times per year at the 1,000-carlot-per-year volume. The number of pallet loads rehandled each time would depend on the storage method used. It was assumed that each possible number of pallet loads to be rehandled was equally likely. Thus, if the storage lane were three loads high (tiers) and three loads deep (rows), the number of pallet loads to be moved could be any number from zero to eight. (If the lane were full, containing nine loads, it would not be used for new commodities.) The average number of loads moved per receipt would be four. When the lane is three loads high and two loads deep, any number of loads from zero to five would be possible. The average is 2.5 pallet loads. Combining the two averages, according to their weight, results in an average 3.4 pallet loads to be moved when the storage method consists of storage bays three tiers high and five rows deep per access aisle. The number of loads to be rehandled was determined for all methods of storage in this manner (table 23).

TABLE 16.—*Room dimensions required for specified storage systems to store a representative inventory for an annual volume of 1,000 carlots*

Storage system	Storage area	Layout pattern [1]	Storage bay width	Storage capacity [2]	Room width	Room depth	Rehandling eliminated—	
							Lanes added	Addition to room width
	Name	*Letter*	*Lanes*	*Pallet-stacks*			*Number*	
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks.	General	B	13	130	68′10″	56′10″	2	9′0″
	Dry cold	A	13	65	58′ 4″	28′ 5″	3	13′6″
	Wet cold	A	12	60	53′10″	28′ 5″	2	9′0″
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks.	General	A	14	70	62′10″	28′ 5″	4	18′0″
	Dry cold	A	16	80	71′10″	28′ 5″	3	13′6″
	Wet cold	A	8	40	35′10″	28′ 5″	2	9′0″
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks.	General	A	20	100	63′ 2″	24′ 5″	4	12′8″
	Dry cold	A	17	85	53′ 8″	24′ 5″	3	9′6″
	Wet cold	A	11	55	34′ 8″	24′ 5″	2	6′4″
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks.	General	D	19	114	70′ 1″	39′10″	.....	.....
	Dry cold	D	17	102	63′ 6″	39′10″	.....	.....
	Wet cold	C	12	48	46′ 9″	26′ 6″	.....	.....
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks.	General	A	13	65	62′ 0″	28′ 5″	4	19′0″
	Dry cold	A	11	55	52′ 6″	28′ 5″	3	14′3″
	Wet cold	A	7	35	33′ 6″	28′ 5″	2	9′6″
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks.	General	A	12	60	55′ 3″	28′ 5″	4	18′4″
	Dry cold	A	10	50	46′ 1″	28′ 5″	3	13′9″
	Wet cold	A	6	30	27′ 9″	28′ 5″	2	9′2″
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks.	General	A	12	60	55′ 3″	25′ 5″	4	18′4″
	Dry cold	A	10	50	46′ 1″	25′ 5″	3	13′9″
	Wet cold	A	6	30	27′ 9″	25′ 5″	2	9′2″

[1] For diagrams of layout patterns, see figs. 15 and 16.
[2] To determine storage capacity in pallet loads multiply pallet stacks by tiering height (1.333 loads for conventional, 4 for 4-tiered racks, and 3 for all other storage methods).

TABLE 17.—*Labor requirements per pallet load for storing 1 pallet load, with observed storage systems*

[In man-minutes]

Storage system	Productive labor requirements [1]				
	Pick up load on receiving platform	Transport loaded	Set down load in storage	Transport empty	Total
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks [2]	0.11	0.46	[3] 0.27	0.39	1.23
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks [4]	.11	.41	[5] .36	.34	1.22
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks [6]	.09	.48	[5] .35	.42	1.34
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks [7]	.09	.75	[5] .40	.64	1.88
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks [4]	.11	.41	[8] .29	.34	1.15
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks [6]	.11	.37	[5] .37	.32	1.17
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks [6]	.19	.47	[5] .46	.45	1.57

[1] Productive times include 10-percent allowance for fatigue and personal needs.
[2] Average distance transported is 150 ft.
[3] 75 percent of loads in 1st tier and 25 percent in 2d tier.
[4] Average distance transported is 130 ft.
[5] Loads are equally divided between 3 tiers.
[6] Average distance transported is 120 ft.
[7] Average distance transported is 190 ft.
[8] Loads are equally divided between 4 tiers.

TABLE 18.—*Labor requirements per pallet load for rehandling for stock rotation for observed storage systems*

[In man-minutes]

Storage system	Productive labor requirements [1]							
	Pick up load in storage	Transport loaded	Transport empty [2]	Pick up load in storage	Transport loaded	Set down load in storage	Transport empty	Total
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks [3]	0.17	0.09	0.10	0.11	0.09	0.27	0.10	0.93
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks [3]	.32	.11	.11	.11	.11	.36	.11	1.23
Tubular-frame 40- x 48-inch pallets, 3 tiers, straddle trucks [4]	.32	.08	.09	.09	.08	.35	.09	1.10
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks [5]	.40	.14	.13	.11	.14	.29	.13	1.34
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks [3]	.34	.11	.11	.11	.11	.37	.11	1.26
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks [3]	.57	.10	.10	.19	.10	.46	.10	1.62

[1] Productive times include 10-percent allowance for fatigue and personal needs.

[2] No time required to set load down when it is removed from storage because forklift operator merely lowers pallet to the floor as he reverses direction to begin transport empty back to the next load.

[3] Average transport distance is 22 feet.

[4] Average transport distance is 13 feet.

[5] Average transport distance is 32 feet.

TABLE 19.—*Labor requirements per pallet load for assembling commodities along a conveyor, for observed storage systems*

[In man-minutes]

Storage system	Productive labor requirements [1]				
	Pick up load in storage	Transport loaded	Set down load in assembly area	Transport empty	Total
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks [2]	[3] 0.17	0.46	0.20	0.39	1.22
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks [4]	[5] .32	.41	.20	.34	1.27
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks [6]	[5] .32	.48	.22	.42	1.44
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks [7]	[5] .52	.75	.22	.64	2.13
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks [4]	[8] .40	.41	.20	.34	1.35
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks [6]	[5] .34	.37	.20	.32	1.23
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks [6]	[5] .57	.47	.30	.45	1.79

[1] Productive times include 10-percent allowance for fatigue and personal needs.

[2] Average distance transported is 150 ft.

[3] 75 percent of loads in 1st tier and 25 percent in 2d tier.

[4] Average distance transported is 130 ft.

[5] Loads are equally distributed between 3 tiers.

[6] Average distance transported is 120 ft.

[7] Average distance transported is 190 ft.

[8] Loads are equally distributed between 4 tiers.

TABLE 20.—*Labor requirements per pallet load for assembling palletized bananas [1] along a conveyor with forklift trucks*

[In man-minutes]

Time item	Productive labor requirements		
	Counterbalanced truck	Straddle truck	Extendible-fork truck
Pick up load on platform	0. 11	0. 09	0. 19
Transport loaded [2]	. 41	. 53	. 52
Setdown load in assembly area	. 20	. 22	. 30
Transport empty [2]	. 34	. 45	. 48
Total	1. 06	1. 29	1. 49

[1] Twelve boxes, each containing 40 pounds of bananas, loaded on each pallet. There are an average of 37.5 pallet loads per carlot equivalent of bananas.
[2] Transport distance—130 ft.

TABLE 21.—*Labor requirements per load of pallets for 1 man to return empty pallets to the receiving platform with forklift truck*

[In man-minutes]

Forklift truck	Productive labor requirements [1]				
	Pick up load on platform	Transport loaded [2]	Set down empty pallets on platform	Transport empty [2]	Total
Counterbalanced	0. 11	0. 41	0. 22	0. 34	1. 08
Straddle	. 09	. 53	. 30	. 45	1. 37
Extendible-fork	. 19	. 52	. 31	. 48	1. 50

[1] Productive times include 10-percent allowance for fatigue and personal allowances.
[2] Average distance transported is 130 ft.

Unavoidable Delay and Job Changeover Allowances

In addition to the fatigue and personal allowances, allowances were made for unavoidable delays and for changing jobs when a worker with time available is assigned to other work. An allowance of 10 percent per day (0.8 hour) to cover unavoidable delays was added to the elapsed time required to perform the productive work. The allowance for changing jobs is 0.5 hour, or 30 minutes per forklift operator per day.

Because of the nature of the work assigned to the forklift truck operator, an allowance for unavoidable delays is included to account for the times when the operator is on a standby basis to be available on call to service unloading crews, to rearrange storage areas, or to service an order assembly line. The delay intervals are interspersed throughout the periods in which he is productively engaged. Although these delays are estimated to be a significant amount of time (48 minutes), it is not possible to use that time productively, because of the irregularity of their occurrence and their short duration.

The unavoidable-delay allowance must be added to the time of each forklift operator for all systems. This has the effect of reducing the time each worker has available for productive work from 8 hours to 7.2 hours each day. The number of operators required is one if the productive labor requirements for 1 day are less than 7.2 man-hours, and two if the productive labor required should be between 7.2 and 14.4 man-hours. For all the systems analyzed, 2 forklift operators are adequate (one for receiving and one for assembly) for the 1,000-carlot annual volume.

The job changeover allowance of one-half hour per man per day is added to the labor requirements, if, after

TABLE 22.—*Labor requirements per trip for 1 man transporting fruits and vegetables on forklift trucks*

[In man-minutes]

Transport distance (feet)	Productive time requirements [1]					
	Counterbalanced truck		Straddle truck		Extendible-fork truck	
	Transport loaded [2]	Transport empty [3]	Transport loaded [4]	Transport empty [5]	Transport loaded [6]	Transport empty [7]
50	0.19	0.18	0.22	0.20	0.21	0.20
60	.21	.19	.25	.23	.25	.24
70	.24	.21	.30	.26	.29	.27
80	.26	.23	.33	.30	.33	.31
90	.30	.25	.37	.33	.36	.34
100	.32	.27	.41	.36	.40	.37
110	.35	.30	.45	.39	.44	.41
120	.37	.32	.48	.42	.47	.45
130	.41	.34	.53	.45	.52	.48
140	.43	.36	.56	.48	.55	.51
150	.46	.39	.59	.52	.59	.55
160	.48	.41	.64	.54	.63	.58
170	.52	.43	.67	.57	.67	.63
180	.54	.45	.71	.61	.70	.66
190	.57	.47	.75	.64	.75	.69
200	.59	.49	.79	.67	.78	.73

[1] Productive times include 10-percent allowance for fatigue and personal needs.

[2] To estimate time required at intermediate distances, use the equation: Productive time (minutes) = 0.00273 x distance (feet) + 0.050.

[3] To estimate time required at intermediate distances, use the equation: Productive time (minutes) = 0.00216 x distance (feet) + 0.063.

[4] To estimate time required at intermediate distances, use the equation: Productive time (minutes) = 0.00381 x distance (feet) + 0.029.

[5] To estimate time required at intermediate distances, use the equation: Productive time (minutes) = 0.00312 x distance (feet) + 0.046.

[6] To estimate time required at intermediate distances, use the equation: Productive time (minutes) = 0.00383 x distance (feet) + 0.019.

[7] To estimate time required at intermediate distances, use the equation: Productive time (minutes) = 0.00350 x distance (feet) + 0.027.

it is added, there remains at least 1 hour for which the worker can be assigned to other work. Otherwise, the total day is charged to the pallet handling activities included in these analyses. It can be seen that in receiving there is at least one hour that can be charged to other activities with all the systems analyzed (table 24). The maximum productive labor required is 5.05 hours. Adding 0.8-hour unavoidable delay allowance and 0.5-hour job changeover leaves 1.65 hours that can be charged to other work.

In the assembly operation there would be less than 1 man-hour available for other work in two of the systems studied after adding the unavoidable-delay and job-changeover allowances. When standard pallet racks are used, the total would be 7.94 man-hours, leaving only 0.06 man-hour. With 40- by 32-inch tubular-frame pallets the total would be 7.25, leaving

TABLE 23.—*Numbers of pallet loads to be rehandled when specified storage methods are used for an annual volume of 1,000 carlot equivalents*

Storage system	Average number of loads rehandled per carlot	Average number of loads rehandled per year [1]
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers	1.45	1,224
Tubular-frame 40- x 48-inch or 40- x 32-inch pallets, 3 tiers	3.40	2,870
4-tiered drive-in racks, 40- x 48-inch pallets	4.70	3,967
3-tiered drive-in racks, 40- x 48-inch pallets	3.40	2,870

[1] Based on 844 receipts per year of commodities stored on pallets.

TABLE 24.—*Daily labor requirements for receiving and assembly when specified storage and handling systems are used for an annual volume of 1,000 carlots*

Storage system	Receiving [1]			Assembly [2]			
	Productive	Allowances [3]	Other work	Productive	Allowances [3]	Idle [4]	Other work
	Man-hours	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks	5.05	1.30	1.65	6.64	[5] 0.80	0.56	0
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks	3.48	1.30	3.22	5.95	[5] .80	1.25	0
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks	2.55	1.30	4.15	4.06	1.30	0	2.64
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	2.63	1.30	4.07	3.35	1.30	0	3.35
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	2.45	1.30	4.25	3.28	1.30	0	3.42
3-tiered drive-in racks 40- x 48-inch pallets, counterbalanced trucks	1.84	1.30	4.86	2.28	1.30	0	4.42
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks	1.48	1.30	5.22	1.96	1.30	0	4.74

[1] 1 forklift operator receiving an average of 3.2 carlots per day.
[2] 1 forklift operator assembling an average of 3.8 carlots per day.
[3] Includes 0.8 hr. for unavoidable delay allowance and 0.5 hr. for job changeover allowance except where noted by other footnotes.
[4] Time that cannot be assigned to other work because there would be less than 1 hr. available after subtracting the 0.5-hr. job-changeover allowance.
[5] Job-changeover allowance not included because the forklift operator cannot be assigned to other work.

only 0.75 man-hour. With these two methods the entire time (8 hours) of the forklift operator is charged to the assembly operations included in the analyses.

The figures in table 24 are average daily requirements and would be divided by the average daily volumes to get the requirements per carlot equivalent.

The unavoidable-delay and job-changeover allowances are divided by different daily volumes for receiving and assembling operations to determine their contribution to labor required per carlot. In receiving, only 844 carlots are moved into storage with forklift trucks. In the 8-month busy season, during which 80 percent of the total annual volume is handled, the average volume received daily by forklift truck is therefore 3.2 carlot equivalents.

The job-changeover allowance for receiving is 30 man-minutes divided by 3.2 carlots, or 9.38 man-minutes per carlot for all systems.

In assembly operations, after bananas are cut and packed in 40-pound boxes, they are palletized along the truck-loading conveyor. Therefore, 80 percent of the total 1,000 carlots are assembled by forklift truck during the 8-month busy season. The average daily volume assembled during this period would be 3.8 carlots. The productive labor required per carlot for assembling bananas and other commodities, and the total productive labor required per day, are shown in table 25. With all systems, except the standard pallet rack and 40- by 32-inch tubular-frame pallets, the job-changeover allowance is 7.89 man-minutes per carlot assembled.

Time available for job changeover for the standard pallet rack storage system would be 33.6 man-minutes divided by 3.8 carlots, or 8.8 man-minutes per carlot, and for the tubular-frame pallet storage system in which a straddle truck is used the time available would be 75 man-minutes divided by 3.8 carlots, or 19.7 man-minutes per carlot.

Equipment Cost Data

The initial cost figures in table 26 were furnished by equipment manufacturers, distributors, and manufacturers' associations. They were current in 1962. Equipment prices can vary widely from one location to another and for different quantities. The figures used should be considered average. Wholesalers considering purchasing equipment can get more specific cost estimates from local distributors. The depreciation periods reflect those usually used in computing Federal taxes, as well as the depreciation periods recommended by the manufacturers. The cost of having capital tied up in equipment was computed as interest on average investment at the rate of 5 percent.

TABLE 25.—*Average daily productive labor requirements for assembly and returning empty pallets for observed storage systems, for an annual volume of 1,000 carlots*

Storage system	Labor required per carlot					Labor required per day
	Assembling, nonbananas	Assembling, bananas	Assembling, weighted average [1]	Returning pallets	Total	
	Man-minutes	*Man-minutes*	*Man-minutes*	*Man-minutes*	*Man-minutes*	*Man-hours*
Standard pallet racks, 40- x 32-inch pallets, 3 tiers, straddle trucks	107. 35	48. 38	98. 15	6. 63	104. 78	6. 64
Tubular-frame 40- x 32-inch pallets, 3 tiers, straddle trucks	66. 10	48. 38	63. 34	30. 55	93. 89	5. 95
Tubular-frame 40- x 48-inch pallets, 3 tiers, counterbalanced trucks	45. 47	39. 75	44. 58	19. 49	64. 07	4. 06
4-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	50. 49	39. 75	48. 81	4. 04	52. 85	3. 35
3-tiered drive-in racks, 40- x 48-inch pallets, extendible-fork trucks	46. 18	55. 88	47. 69	4. 14	51. 83	3. 28
3-tiered drive-in racks, 40- x 48-inch pallets, counterbalanced trucks	31. 73	39. 75	32. 98	2. 98	35. 96	2. 28
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers, counterbalanced trucks	26. 23	39. 75	28. 34	2. 59	30. 93	1. 96

[1] This figure is obtained by adding the products of 844 carlots times the man-minutes for assembling produce other than bananas and 156 carlots times the man-minutes for assembling bananas and dividing by 1,000 carlots.

TABLE 26.—*Annual cost to own and maintain certain materials handling equipment*

Equipment	Expected useful life	Initial cost	Ownership costs				Maintenance	Total annual cost
			Depreciation	Interest (5 percent)	Insurance and taxes (4 percent)	Total ownership		
	Years							
1 counterbalanced forklift truck with overhead guard (2,000-lb. capacity)	8	$6, 050	$756. 25	$170. 16	$242. 00	$1, 168. 41	$181. 50	$1, 350
2 batteries for counterbalanced truck (15 cell, 504 amp.-hr. capacity) [1]	5	2, 970	594. 00	89. 10	118. 80	801. 90	89. 10	891
1 charger for 15-cell batteries	8	725	90. 62	20. 39	29. 00	140. 01	21. 75	162
Total	.....	9, 745	1, 440. 87	279. 65	389. 80	2, 110. 32	292. 35	2, 403
1 straddle forklift truck with overhead guard (2,000-lb. capacity)	8	4, 655	581. 88	130. 92	186. 20	899. 00	279. 30	1, 178
2 batteries for straddle truck (6-cell, 725 amp.-hr. capacity) [1]	5	3, 120	624. 00	93. 60	124. 80	842. 40	93. 60	936
1 charger for 6-cell batteries	8	550	68. 75	15. 47	22. 00	106. 22	16. 50	123
Total	.....	8, 325	1, 274. 63	239. 99	333. 00	1, 847. 62	389. 40	2, 237
1 extendible-fork forklift truck with overhead guard (2,000-lb. capacity)	8	5, 550	693. 75	156. 09	222. 00	1, 071. 84	333. 00	1, 405
2 batteries for extendable-fork truck (12-cell, 455 amp.-hr. capacity) [1]	5	2, 000	400. 00	60. 00	80. 00	540. 00	60. 00	600
1 charger for 12-cell batteries	8	550	68. 75	15. 47	22. 00	106. 22	16. 50	123
Total	.....	8, 100	1, 162. 50	231. 56	324. 00	1, 718. 06	409. 50	2, 128
Pallets:								
100 40- by 48-inch flush-stringer	6	350	58. 33	10. 21	14. 00	82. 54	10. 50	93
100 40- by 32-inch single-wing	6	300	50. 00	8. 75	12. 00	70. 75	9. 00	80

[1] 1 battery to be used during the day shift and the other during the night shift.

The cost of electrical energy is not included in the handling-equipment cost table because it would be different for different combinations of storage method and handling equipment. The energy required to move commodities depends on the type of truck used, weight of load, transport distance, and tiering height. Total energy required would be determined by these factors and the total quantity handled. Energy requirements were computed for each storage system (table 27) using handbook data.[8] Energy costs are based on a rate of $0.027 per kilowatt-hour (kw.-hr.). This rate, a national average for commercial users, was obtained from statistics published by the Federal Power Commission.

[8] Handbook of Material Handling with Industrial Trucks. The Electric Industrial Truck Association. 71 pp., illus. 1950.

TABLE 27.—*Costs of electrical energy when specified storage systems are used for an annual volume of 1,000 carlot equivalents*

Storage system	Forklift truck used	Total energy required per year	Electrical energy cost per year	Electrical energy cost per carlot
		Kw.-hr.		
Conventional 40- x 48-inch pallets, ½ in 1 tier, ½ in 2 tiers	Counterbalanced	1, 611	$43	$0. 04
Tubular-frame 40- x 48-inch pallets, 3 tiers	Counterbalanced	2, 317	63	. 06
Tubular-frame 40- x 32-inch pallets, 3 tiers	Straddle	2, 005	54	. 05
Standard pallet racks 40- x 32-inch pallets, 3 tiers	Straddle	3, 124	84	. 08
4-tiered drive-in racks, 40- x 48-inch pallets	Counterbalanced	2, 482	67	. 07
3-tiered drive-in racks, 40- x 48-inch pallets	Counterbalanced	1, 853	50	. 05
3-tiered drive-in racks, 40- x 48-inch pallets	Extendible-fork	1, 984	54	. 05

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