The Effect of

APPLE HANDLING METHODS

on Storage Space Utilization

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This is the fourth of five reports to be published by the Agricultural Marketing Service from data submitted by the Washington State Apple Commission in fulfillment of its contract with the U.S. Department of Agriculture. The first three reports are Marketing Research Report No. 49, "Apple Handling Methods and Equipment in Pacific Northwest Apple Packing and Storage Houses," Marketing Research Report No. 68, "Innovations in Apple Handling Methods and Equipment," and Marketing Research Report No. 71, "Handling Empty Apple Boxes in Pacific Northwest Apple Packing and Storage Houses." The fifth report in this series is expected to cover plantwide materials-handling costs. After this report is issued, a summary is planned.

"Methods and Costs of Loading Apples in the Orchard in the Pacific Northwest," Marketing Research Report No. 55, published by the Agricultural Research Service of the Department in January 1954, summarizes another phase of the study.

Some of the results of this research are now available in summary form through the U. S. Department of Agriculture film entitled "Apple Handling Methods." A print of this film may be obtained on a loan basis from:

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PREFACE

The research which is the basis for this report was conducted by the former research department of the Washington State Apple Commission under a contract with the United States Department of Agriculture. This contract was administered by William H. Elliott, head, Handling and Facilities Research Section, Transportation and Facilities Branch, Marketing Research Division, Agricultural Marketing Service. The study was made under authority of the Agricultural Marketing Act of 1946.

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SUMMARY

Storage space utilization is an important consideration to the operators of apple storages because it affects their returns for performing all operations in connection with storing and packing apples. Different types of materials-handling equipment which handle unit loads of different sizes govern to a great extent the volume of apples that can be stored in a given space. In this study three sizes of storage rooms were selected. Two of these rooms are of conventional design; they are typical of many found in older multiple-story plants in which clamp-type 2-wheel hand trucks are used for performing handling operations. One room is of modern design, suited for industrial trucks.

Important variables considered in determining the amount of storage space that could be utilized in these rooms are: (1) Size of unit load; (2) aisle space; (3) stacking height; (4) type and kind of refrigeration; (5) air circulation used; and (6) spacing and size of posts and girders.

In storage rooms with relatively low ceilings and supporting columns set on 16-foot centers, more piling space can be utilized by use of clamp-type 2-wheel hand trucks than by use of industrial lift trucks. However, in rooms that have relatively high ceilings and roofs supported by trusses rather than columns, a substantially greater number of boxes can be stored by industrial lift trucks than by clamp-type 2-wheel hand trucks, even though the industrial lift trucks need more operating space. The following tabulation indicates the range in the net storage capacities of three storage rooms when specified types of equipment are used and when boxes are stacked at heights conforming to present industry practices:

When a clamp-type 2-wheel hand truck is used in a room measuring 50 x 80 x 13 1/2 feet, the boxes are stacked 12 high and the net storage capacity of the room is 21,400 boxes. When a 48-box forklift truck is used in the same room, the boxes are stacked 11 high and the net storage capacity is only 15,000 boxes.

Using a 2-wheel hand truck in a room measuring 50 x 110 x 12 1/2 feet (boxes stacked 12 high) the net storage capacity would be 28,850 boxes; this compares with 15,300 boxes by use of 48-box industrial forklift truck (boxes stacked 11 high).

When a clamp-type 2-wheel hand truck is used in a storage room of modern design, measuring 80 x 90 x 20 feet, the net storage capacity--boxes stacked 12 high--of the room is 36,000 boxes, or 37 percent less than the net capacity of 57,000 boxes when using 24- or 36-box industrial clamp lift trucks and 36-box industrial forklift truck.

A storage plant operator contemplating a change in handling method and equipment should consider all the advantages and disadvantages as well as the effect on total gross revenue. Some of the advantages of the more mechanized methods in use today include: (1) Smaller labor costs, (2) smaller crews, and (3) less bruising and damage to fruit. Some of the disadvantages are: (1) Greater capital investment and (2) a substantial reduction in usable storage space. A decision to change from one handling method to another should not be made solely on the basis of gross revenue considerations.

THE EFFECT OF APPLE HANDLING METHODS ON STORAGE SPACE UTILIZATION

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BACKGROUND OF THE STUDY

Most of the older apple packing and storage houses in use in the Pacific Northwest were designed for the use of certain types of materials-handling equipment. Because of their design, the adoption and efficient use of newer types of materials-handling equipment has created problems for these houses both in the movement of products between floors and the utilization of storage space. The modern one-story apple storage plant has little resemblance to plants constructed 20 or 25 years ago. The old-type multistoried plant usually was designed in terms of square feet of floor space rather than cubic feet of stacking space and for extensive manual handling rather than for the efficient use of modern materials-handling equipment.

The introduction of modern equipment in these houses in recent years has had a decided impact on the utilization of space in cold storage rooms. Today, boxes of apples are moved into, within, and out of storage rooms by many types of mechanical equipment. Each type or combination of types of equipment affects the number of boxes that can be stored in a given area because each requires different aisle widths and other operating space. Moreover, the heights to which boxes can be stacked and the ability to use space in confined areas, around columns, and under coils vary with different types of equipment. The use of some types of equipment also results in more airspace around boxes than is required for other types. This spacing not only affects space utilization, it also affects the air circulation around the boxes, which in turn has a bearing on the maintenance of optimum storage conditions for the fruit.[2]

Utilization of storage space also is influenced by the size of unit loads, which vary from single stacks consisting of 5 or 6 boxes to as many as eight 6-high stacks, or a total of 48 boxes, and on the height to which unit loads are stacked. A small unit load is more maneuverable and enables irregular space to be filled more readily, whereas a large unit load may result in loss of space, or require manual methods for adjustments of unit loads to fit irregular space. Because of their maneuverability, some of the older types of materials-handling equipment permit more effective use of space in the old-type storage plants than some of the newer types of equipment.

Sizes and shapes of containers used for apple storage also influence the utilization of storage space. However, in the Pacific Northwest, fruit is stored in the standard Northwest apple box. To some extent this standardization simplifies the space utilization problem. The outside dimensions of the standard wooden box are as follows: Width, 12 inches; depth, 11 inches; and length, 19 1/2 inches. After it is packed, the standard apple box has a bulge on the top and bottom which adds about 2 inches to the depth, so that it measures roughly 12 inches by 13 inches by 19 1/2 inches. Thus, the space required to store a packed box is slightly greater than that for a box of loose fruit. Some growers store apples in field boxes which have external dimensions identical to the standard box. Field boxes frequently are used when fruit is to be packed in cartons.

[1] Transferred to the Fruit Industries Research Foundation, Yakima, Wash.

[2] Air circulation and other considerations involved in maintaining optimum storage conditions will be covered in other reports on apple storage.

The more important factors affecting the utilization of storage space are size of unit load, aisle space, stacking height, kind of refrigeration and air circulation, and spacing and size of columns, posts, and girders.

Total gross plant revenue for a given season usually has a direct relationship to the total number of boxes of apples stored. Therefore, possible savings that may be gained through shifts to lower unit-cost methods of handling cannot be considered as net savings if these methods reduce the total number of boxes that can be handled and stored and the consequent revenue received (assuming, of course, that the plant is not already operating at a loss). To illustrate this point, assume that a plant with a capacity of 100,000 boxes shifts to a lower unit-cost method of handling and reduces its storage capacity to 90,000 boxes. By shifting to the lower unit-cost method it reduces handling costs from $5 to $2.50 per thousand boxes. The reduction in costs would amount to $275 per season. However, if the loss of net storage revenue on the 10,000 boxes for this hypothetical plant amounted to 3 cents per box or $300 for the season, the plant would suffer a net loss of $25 by shifting to a lower unit-cost handling method.

This report presents illustrations showing how various factors can be used to estimate the amount of space lost through use of different types and combination of types of materials-handling equipment under certain stated conditions found in older plants. In these illustrations, direct comparisons are not made between space lost or gained or the effect on the quality of the fruit.

In some plants a change in the type of equipment might facilitate faster handling of the fruit during the harvest period. Faster handling might, in turn, aid in maintaining the quality of the fruit for a longer period. With respect to space gained or lost through changing the type of materials-handling equipment used and the consequent maintenance of fruit quality, each plant presents a separate problem.

FACTORS AFFECTING STORAGE SPACE UTILIZATION

In attaining maximum utilization of storage space, consideration should be given to: Providing optimum storage conditions for the fruit; maintaining the identity of grower lots; using time, labor, and equipment effectively; and moving the fruit into, within, and out of storage rapidly and gently. Otherwise, maximum space utilization could result in a net loss of revenue.

The principal factors that affect the utilization of storage space in rooms of different designs or different dimensions are: (1) The size and spacing in storage of unit loads; (2) the number, width, and layout of aisles; (3) ceiling and stacking heights; (4) type and location of refrigeration and air circulation equipment; and (5) the size and spacing of posts or height of girders.

In the Pacific Northwest, the more important types and combination of types of materials-handling equipment used for moving apples into storage rooms and stacking them are: (1) Clamp-type 2-wheel hand trucks; (2) belt conveyors and clamp-type 2-wheel hand trucks; (3) floor chain conveyors and clamp-type 2-wheel hand trucks; (4) elevators and clamp-type 2-wheel hand trucks; (5) industrial forklift trucks and pallets; and (6) industrial clamp-type lift trucks. The amount of cube or gross piling space that can be utilized in rooms of different dimensions varies considerably between these different equipment combinations because some of them require more operating space than others. Moreover, the heights to which boxes can be stacked efficiently differ, especially in confined areas.

Unit Loads

The size of unit loads handled by different types of equipment is an important factor in storage space utilization, particularly when unit loads are to be maintained throughout the stacking operation. Clamp-type 2-wheel hand trucks usually handle a unit load consisting of a single stack of 6 boxes of loose fruit or a 5- or 6-high stack of packed boxes

(fig. 1-A). For industrial truck handling, these 5- or 6-high stacks are grouped into 2, 4, 6, or 8 stacks, as shown in figure 1-B through 1-E, the exact number depending on the type and capacity of the equipment. If total plant volume justifies equipment ownership costs, it is of course more efficient to handle larger unit loads, as more boxes are moved at one time and individual boxes are handled fewer times. However, inefficiencies may result from the handling of larger unit loads in some of the older plants which have relatively low ceilings and close column spacing.

Table 1 shows the storage space occupied by unit loads handled by specified types of materials-handling equipment. More space between unit loads is required for some types of equipment than for others. For example, more space must be provided between loads for the outriggers of a straddle-type industrial truck than for a counterbalanced truck.

When unit loads consisting of two or more individual stacks are handled by industrial trucks, the need for space between individual stacks is eliminated. Only enough space is left between unit loads to permit adequate clearance for handling and air circulation. Single stacks, for handling by clamp-type 2-wheel hand trucks, must be stored so that space is provided on both sides of the boxes. Therefore the size of the unit loads and space required between loads to insure safe, rapid, and smooth handling and storage operations are important factors in space utilization.

Table 1.--Comparison of space occupied by boxes of unpacked apples in 6-box-high unit loads of specified sizes when stacked for handling with specified types of materials-handling equipment

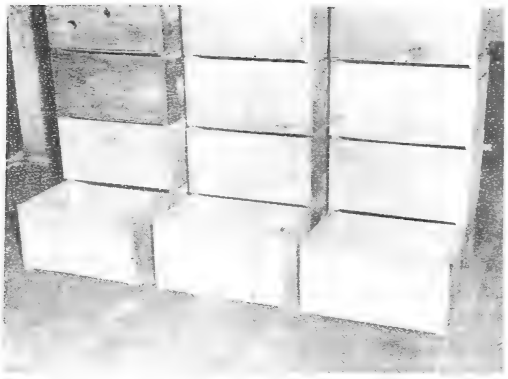
Size of load and type of equipment	Dimensions of load plus other allowable space[1]			Space occupied by 1 unit load	Space occupied by 1,000 stacked boxes
	Depth	Width	Height		
	Inches	*Inches*	*Inches*	*Cubic feet*	*Cubic feet*
6 boxes--clamp-type 2-wheel hand truck	12 1/4	22	66	10.29	1,715.53
12 boxes--industrial clamp-type truck	12 1/4	43	66	20.12	1,676.66
24 boxes--industrial clamp-type lift truck	25	44	67	42.65	1,777.08
36 boxes--industrial clamp-type lift truck	37 1/2	44	67	63.98	1,777.24
36 boxes--industrial forklift truck	37 1/2	43	71	66.25	1,840.28
48 boxes--industrial forklift truck	49 1/2	43	71	87.46	1,821.99

[1] Allowable space for clamps, pallets, and air circulation.

Aisle Space

The principal factors that determine the number, width, and layout of aisles and the consequent amount of storage space lost to aisles in apple storage rooms are: (1) Size of lots which must be segregated by ownership, variety, and grade; (2) type of materials-handling equipment used; (3) location of doors; (4) shape or dimensions of rooms; (5) overhead obstructions; and (6) State or local fire regulations.

The aisles in a storage room serve to move fruit in and out of the room. They also facilitate segregation of the fruit by ownership, variety, and grade. The segregation and storage pattern may either simplify or complicate the aisle layout in individual rooms. For instance, if large blocks of fruit for only a few growers were stored in a room, the



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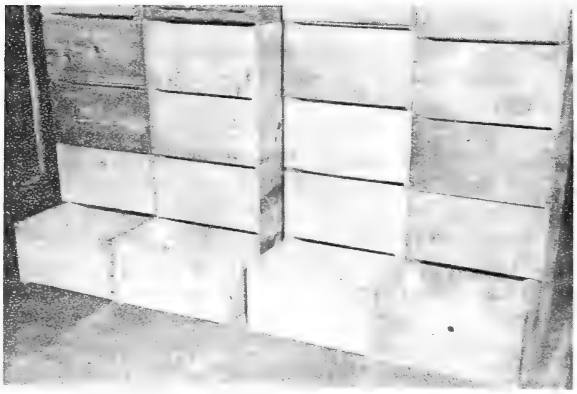

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Figure 1.--Patterns of stacking used for different types of handling equipment. A.--Stacked for handling by two-wheel hand truck. B.--For 12-box industrial clamp truck. C.--For 24-box industrial clamp-lift truck. D.--For 36-box industrial clamp-lift truck. E.--For 36-box and 48-box industrial forklift trucks.

storage pattern would be relatively simple; only 1 or 2 aisles would be needed. However, a greater number of aisles would be needed in a room of the same dimensions if it were used to store a large number of small lots and if each grower's lot were stored so that it would face or adjoin an aisle. This storage arrangement is necessary if boxes are to be broken out of stacks with a minimum amount of handling.

The need for ready access to each grower's lot is associated not only with the requirements or needs of the growers but also to good storage practices. Good storage management includes constant observation of all lots to check on maturity and provides a basis for deciding when various lots should be packed and marketed. Therefore, in laying out aisles in a storage area, accessibility to individual lots is a consideration which affects both handling costs and the amount of space required to store a given quantity of fruit.

The following tabulation shows the width of aisles required for efficient operation of specified types of materials-handling equipment:

Equipment	Aisle width
	Feet
Clamp-type 2-wheel hand truck	4
Clamp-type 2-wheel hand truck and belt conveyor	4
Floor chain conveyor	4
12-box industrial clamp truck	5
24-box industrial clamp truck	[1] 9
36-box industrial clamp truck	[1] 10
36-box pallet and forklift truck	[1] 10
48-box pallet and forklift truck	[2] 12

[1] Straddle-type truck requires only a 6 1/2-foot aisle.
[2] Straddle-type truck requires only a 7-foot aisle.

The size of the materials-handling equipment and the overall dimensions of unit loads handled are the key determinants of aisle width. Although straddle-type industrial trucks can be operated in narrower aisles than those shown above, this type of truck requires a smooth floor, free of big cracks, holes, and other rough places, on which to operate.

In a storage room 100 feet wide and 150 feet deep, in which 2-wheel clamp-type hand trucks are used for handling fruit, two 4-foot aisles usually run the depth of the room. Boxes of fruit are stacked at right angles to the aisles. If an industrial forklift truck is used in this room, only 1 aisle, 9 to 12 feet wide, down the center (150 feet long) is needed. In a conventional plant which uses clamp-type 2-wheel hand trucks, the depth of the rows of boxes from the aisles usually does not exceed 30 feet.

A room 50 feet by 150 feet usually requires more aisle space than a room 75 feet by 100 feet, even though they contain the same amount of floor space. In the wide, small-depth room, at least one aisle will have to run the full width of the room. If rows of stacked boxes become relatively long, a second aisle the width of the room may be needed or one or more lateral aisles must be added.

The type of refrigeration equipment used and its location sometimes dictate the aisle layout of storage rooms. Aisles should be laid out so that air circulation is parallel to stack rows in forced-air circulation storages. In some systems, the aisle is used as a mixing plenum for the supply air; in other systems, the aisle serves as a return air duct. In either instance due regard must be given to the location of the aisle so that these functions may be properly performed. Fruit cannot be stacked directly in front of duct openings because the constant flow of air, which usually is 1 or 2 degrees below freezing at the duct opening, may freeze the fruit. Thus, the aisle layout must permit the free circulation of cold air with no damage to the stored fruit. In storages equipped with pipe coils certain clearances must be maintained between stacks and coils if freezing is to be avoided.

One factor, apart from the packinghouse operations, which affects the width of aisles, is the necessity for compliance with fire ordinances and regulations. In many areas these ordinances require a minimum aisle width of 4 feet. An aisle of this width will permit a clamp-type 2-wheel hand truck to be operated beside a belt conveyor; the conventional counter-weighted industrial trucks generally require aisles 9 feet or more wide.

Stacking Height

Stacking heights in the cold storage room are directly related to ceiling heights. Because of relatively low ceilings in many of the older plants, the stacking height is limited to 9 or 10 boxes. In more modern structures, common stacking heights range from 12 boxes to 24 boxes of fruit, or from 2 to 4 pallets high.

Stacking height may be limited by the requirements for cold air circulation. As previously pointed out, it is necessary to stack those boxes adjacent to refrigeration coils and air ducts at lower levels to prevent the fruit from freezing. The handling method used also affects the stacking heights. The usual stacking heights for both packed boxes and boxes of loose apples when handled by specified types of materials-handling equipment are shown in table 2.

From the viewpoint of storage space utilization, one of the most serious problems in older plants is that ceiling heights usually were not designed in terms of multiples of full unit loads. In a storage room in which the ceiling height permits a 9-box high stack, the 3 or 4 boxes above the original 6- or 5-high stacks will require individual handling of boxes to complete the stacks, or 2 sizes of unit loads must be made up.

Refrigeration and Air Circulation Equipment

In the older apple storage houses in the Pacific Northwest, coil-type refrigeration is commonplace. However, in recent years most installations are of the forced-air type, with the air distributed either from a central location or through ducts. The type of refrigeration equipment used affects utilization of cubic space with different types of materials-handling equipment.

Table 2.--Optimum stacking heights of apple boxes in cold storage rooms with use of different types of materials-handling equipment

Equipment	Height of unit load		Optimum stacking height	
	Packed fruit	Loose fruit	Packed fruit	Loose fruit
	Boxes	*Boxes*	*Boxes*	*Boxes*
Clamp-type 2-wheel hand truck.....	5	6	[1] 10	[1] 12
12-box industrial clamp-type truck.....	5	6	[1] 10	[1] 12
24-box industrial clamp-type lift truck	5	[2] 6	[3] 10	[3] 12
36-box industrial clamp-type lift truck	5	[2] 6	[3] 10	[3] 12
36-box forklift truck and pallets.....	5	6	15	18
48-box forklift truck and pallets.....	5	6	15	18

[1] Boxes stacked above the 5- or 6-high level are manually stacked.

[2] It is general practice to place dunnage strips between each unit load to level and steady the second tier. Such material (wood strips) is 5/8 inch to 1 inch in thickness.

[3] The industrial clamp-type lift truck can break the height of the unit load to store at off heights of 9 or 15 boxes. The clamp-type truck, ordinarily is not used to stack 15 or 18 high.

Coil Refrigeration

Coil-type refrigeration is found in many older plants. Coils usually are hung from the ceiling or from the upper part of the walls. It is necessary for stored fruit to be kept away from the coils to avoid freezing the fruit and to permit cleaning the coils. When industrial lift trucks are operated in rooms with coil-type refrigeration, adequate space must be available for moving the equipment through the room. Heavy metal guard structures should be installed around the coils. Moreover, care must be exercised in tiering the loads in order to minimize the loss of cubic space.

In a coil-equipped room, constructed for handling clamp-type 2-wheel hand trucks, a shift to forklift truck handling would require the addition of a pallet to each unit load, which would often reduce by 1 box in each stack the amount of fruit that could be stored. Two pallets would add approximately 12 inches to the height of stacks. In other words, the height of 11 boxes plus the height of 2 pallets is equivalent in height to boxes stacked 12-high without pallets. However, an industrial clamp-type lift truck, which requires no pallets, might be used without reducing stacking heights.

The effect of refrigeration coils on space utilization usually can be minimized by installing them over the aisles. However, this may interfere with the handling of large unit loads and still may require that the height of unit loads stacked near the coils be reduced.

Central Fan Systems

In a room with a central fan system, the layout of the aisles must conform to a predetermined pattern. Usually this system of refrigeration consists of a cooling unit and a system of ducts through which cold air is forced by fans. The cooling unit is not necessarily located in the storage room. The ducts may be as large as 8 by 8 feet initially and taper to about 2 by 2 feet at the terminal end. Their size, spacing, and location may reduce the stacking height in the areas beneath the ducts.

Free Delivery Unit Systems

By these systems cold air is delivered directly from the fan outlets into the storage room from one or more cooling units. Usually the equipment is located in the storage room. Occasionally a short run of duct is used between the fan and discharge opening so that the air may be discharged in the desired direction. In the older multistory plants these central air systems necessitated the use of slatted floors, which permit cold air to circulate from one floor to another. In these plants, as in those equipped with ducts, the aisles and stacks must be arranged so as to permit the proper circulation of cold air in order to maintain optimum storage conditions.

Posts and Girders

In multistory apple storage plants the upper floors and the roofs are supported by posts which usually are set on 16-foot centers (16 feet from the center of one post to the centers of neighboring posts or walls). Figure 2 shows the floor area of a bay in a typical storage room. This spacing of posts may affect storage space utilization if a change is made from single-stack to multiple-stack unit loads. Maximum utilization of space between and back of the posts rarely is possible with the larger units. One means of avoiding the loss of space is to stack boxes adjacent to the posts by hand. However, this practice increases handling costs.

Some types of equipment minimize this problem. The portable mechanical lift can be used to stack or break out single stacks of boxes 1 to 6 boxes high or a load of boxes 1, 2, or more layers high around a post or under a girder.

Another possibility of reducing the amount of space lost around and behind posts when using an industrial lift truck is to turn the unit loads behind the posts at right

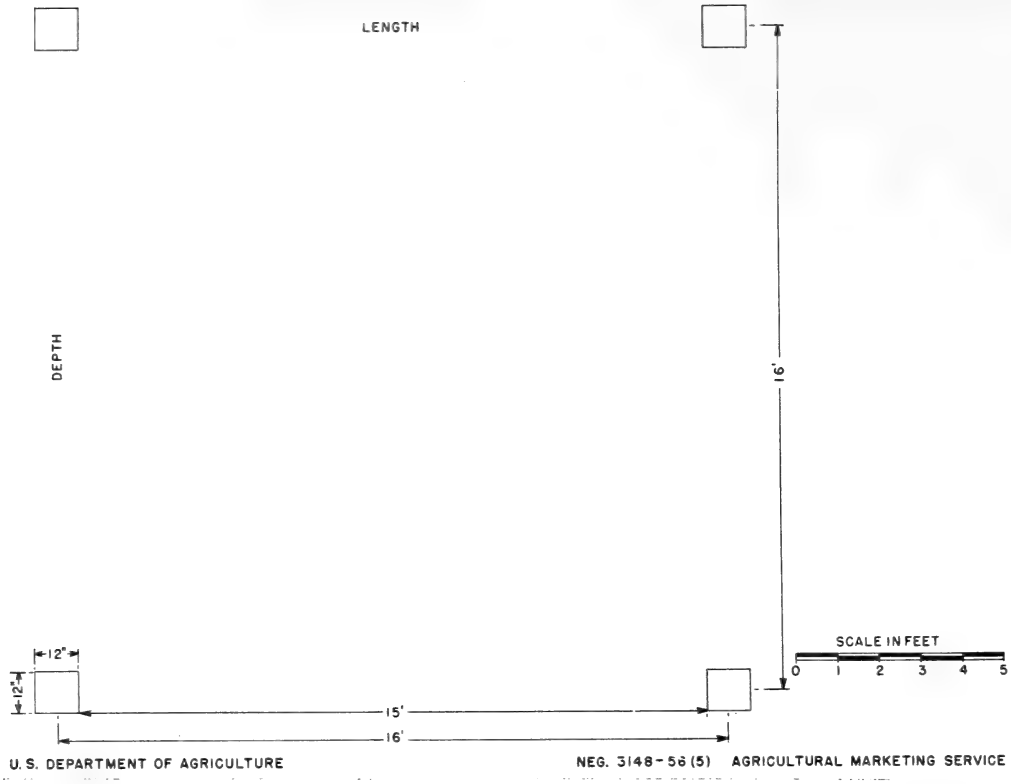

Figure 2. --Dimensions of floor area of storage bay in a typical cold storage room for apples.

angles to the loads stacked between the posts. Although this method utilizes a greater amount of the storage space, more time is required to move such loads in and out of storage. Modern single-floor plants are constructed with truss roofs so that there is little or no interference from posts in handling and storing operations.

In multistory plants girders are used to support the floors and the roof. If the stacking heights are above the level of the girders, unit loads must be broken down to fit boxes under or around them.

The presence of girders in older plants also should be considered when converting from a clamp-type 2-wheel hand truck and belt or floor chain conveyor operation to an industrial truck operation. In manual high-piling operations the crew can easily stack boxes under and beside the girders which cross the storage area. But when stacking with a mechanical lift or an industrial truck, restacking the unit load is often inconvenient and undesirable.

FLOOR CAPACITY OF A CONVENTIONAL BAY WHEN USING SPECIFIED TYPES OF EQUIPMENT

The number of boxes of apples that can be stored in a typical storage bay (fig. 2) in a conventional plant depends largely on the kind of materials-handling equipment used. As previously shown, the supporting posts usually are set on 16-foot centers with a 15-foot clearance between posts. Also, overhead obstructions, such as refrigeration coils and ducts and girders, prevent maximum use of the stacking heights of certain types of equipment.

Table 3 shows the floor-level storage capacity of a 16- by 16-foot storage bay when unpacked boxes of apples stacked 6 high are handled in unit loads of specified sizes by specified types of materials-handling equipment. Overhead obstructions are not considered in these estimates as the stacking height is only 6 boxes, or 1 unit load, high. The amount of floor space occupied by 1 unit load of boxes plus the space needed between loads for air circulation were used in computing the data in table 3. No unit loads were split for hand stacking.

Although some plants may vary the space between stacks of boxes slightly, the assumptions made are typical of industry practice. Arrangement of unit loads on the floor for specified types of materials-handling equipment are shown in figure 3. Unit loads of the size handled by clamp-type 2-wheel hand truck and 12-box industrial clamp truck utilize more of the storage space than those handled by other types of equipment. To fill a bay with single stacks handled by 2-wheel hand truck, 8 unit loads are placed lengthwise in the 15 feet of space between 2 posts, and 14 additional rows of stacks are placed parallel to this row across the depth of the bay. By stacking at a right angle, one row consisting of 8 stacks can be placed in the remaining space between and to the rear of the post. This same storage pattern can be used with the 12-box industrial clamp truck.

Table 3.--Estimated storage capacity of a standard storage bay in unpacked boxes of apples when using selected types of materials-handling equipment[1]

Equipment	Size of unit load[2]	Capacity of bay when boxes are stacked 6-high	Capacity lost when compared with hand truck placement	
	Boxes	*Boxes*	*Boxes*	*Boxes*
Clamp-type 2-wheel hand truck.....	6	[3] 768	0	0
12-box industrial clamp truck.....	12	[3] 768	0	0
24-box industrial clamp-lift truck.....	24	[4] 696	72	9.4
36-box industrial clamp-lift truck.....	36	720	48	6.2
36-box pallet and forklift truck.....	36	720	48	6.2
48-box pallet and forklift truck.....	48	576	192	25.0

[1] Standard storage bay in conventional storage plant assumed to be formed by 12- by 12-inch posts on 16-foot centers.
[2] See table 1 for dimensions of unit loads.
[3] One row of 48 boxes placed behind one post.
[4] Two rows of unit loads (192) placed at right angles beside one post.

In this bay, twenty-one 24-box unit loads, handled by industrial clamp-lift truck, plus 192 boxes in 2-row stacks, can be stored. The 192 boxes in unit loads are placed in 2 rows at right angles to the posts in the remaining space. Unit loads of 36-boxes, handled by industrial clamp-lift or forklift trucks, are arranged with 4 unit loads across the length of the bay and 5 unit loads across its depth.

More storage space is lost with the 48-box industrial forklift truck, than with any of the other types of equipment considered. Unit loads of 48 boxes, handled by forklift truck, are arranged with 4 unit loads across the length and 3 loads across the depth of the bay. (If 4 unit loads were placed across the depth of the bay, there would be no air circulation space on rear wall.)

This illustrates how many unit loads handled by various types of materials-handling equipment can be placed in a 16- by 16-foot storage bay. However, to determine the capacity for an entire storage room, the entire width of the room is the factor that determines how many unit loads can be placed in each row. Therefore, the choice of equipment type and the unit load must be explored for each storage house because each building presents a different set of determining factors, most of which have been discussed in previous sections.

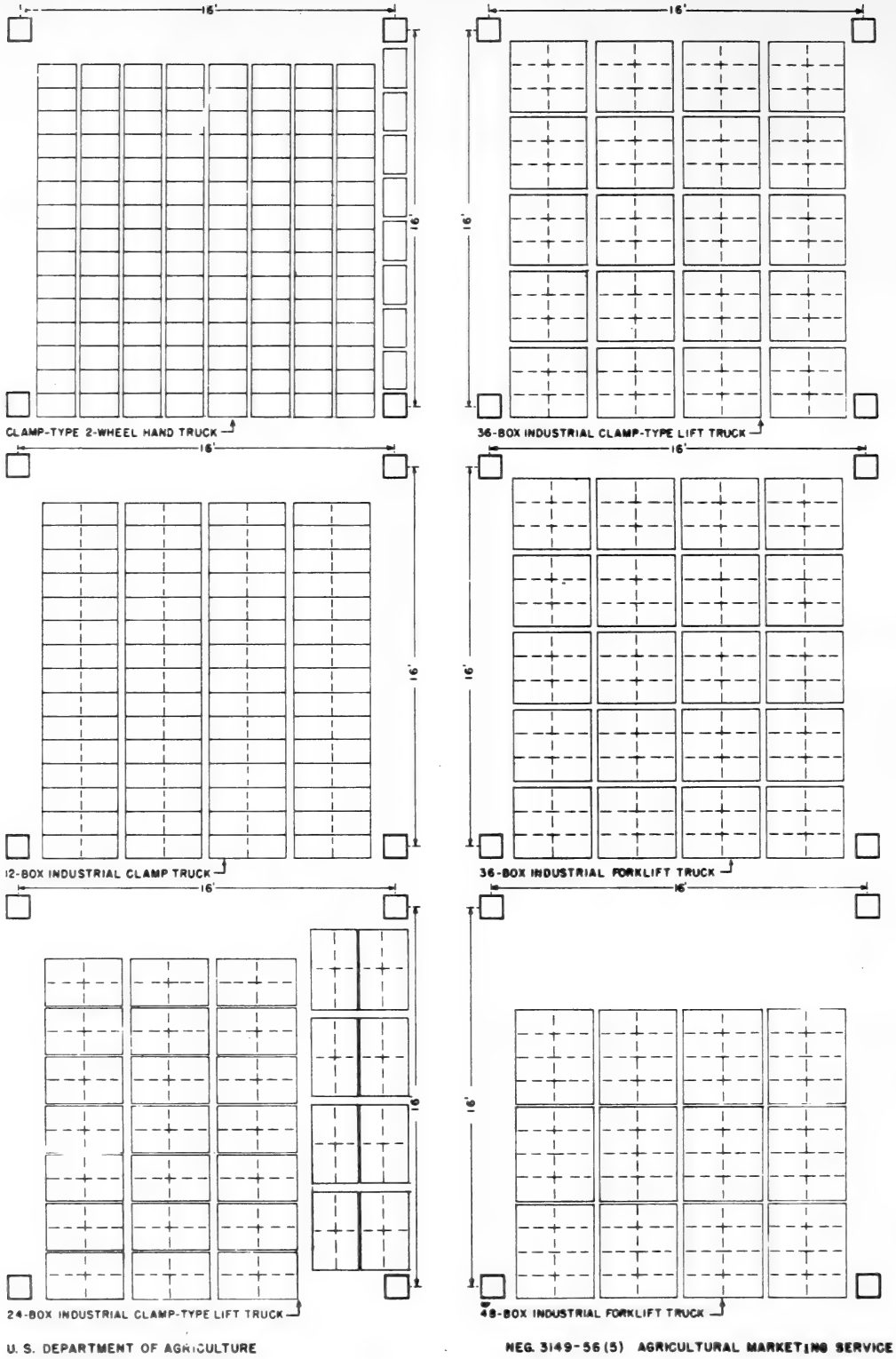

Figure 3.--Unit-load arrangements of apple boxes on floor of 16- x 16-foot storage bay when boxes are handled by specified types of materials-handling equipment.

STORAGE SPACE UTILIZED IN ROOMS OF SPECIFIED DESIGNS WHEN USING DIFFERENT TYPES OF EQUIPMENT

Because of the variable factors affecting the space utilization in rooms of different sizes and designs, it would be difficult to develop criteria which would be applicable to all situations on space gained or lost by shifting from one type of equipment to another. However, estimates can be made of the potential storage capacities of rooms of given dimensions, when the different sizes of unit loads associated with the different types of materials-handling equipment are used. Three typical storage rooms--two of conventional design and one of modern design--of various sizes were selected for making these estimates. The rooms selected were designed for specific handling methods and equipment. These rooms were converted, figuratively, to the use of other types of equipment. These conversions included a computation of space lost to aisles, posts, and refrigerating equipment. It was assumed that aisles ran lengthwise of the rooms and that boxes were placed parallel to the aisles.

The two conventional storage rooms were designed for clamp-type 2-wheel hand-truck operations, while the third was designed for industrial lift trucks. In the conventional rooms, 12- by 12-inch posts, which support the upper floors and roof, are located on 16-foot centers. The modern single-floor plant with a truss roof has no supporting posts or columns. There are 2 doorways centered on the shorter walls in each of these rooms.

Some of the aisle widths used in making this analysis are somewhat different from those recommended by equipment manufacturers and plant operators. Under actual operating conditions most plant managers will adjust aisle widths or wall air space by a few inches to maximize the storage capacity.

Table 4 shows potential net storage capacity of these 3 rooms, based on unit loads associated with specified types of materials-handling equipment, recommended aisle widths, and specified stacking heights.

It is obvious that storage space would be lost if conventionally designed plants adopted some of the more modern types of materials-handling equipment. However, this loss of space and consequent loss of revenue must be compared with savings made from reduced handling costs to determine whether the plant's net financial position has been improved. In some storage plants the total cost of shifting to other handling methods may offset the advantages that accrue in the amount of storage space gained or the increased speed with which the fruit is handled. If plant alterations are involved, it is important that the amount of space gained or lost and the cost of making the necessary alterations be compared with savings on handling costs. The labor savings that might accrue when converting from a clamp-type 2-wheel hand-truck operation to an industrial lift truck operation should be considered since it may more than offset the loss in storage capacity. When any change in materials-handling equipment is contemplated, all costs and advantages involved must be considered and compared with costs and disadvantages of using presently owned equipment.

Conventional Storage Room 50 by 80 by 13 1/2 Feet

This room is equipped with a forced-air cooling system. The duct outlets for the cooling system run the full depth of the room and extend down 18 inches from the ceiling; they are located over the center aisle, but ceiling clearance of approximately 18 inches is provided over the entire room for air circulation.

Because of the relatively low ceiling, the stacking height is limited to 12 boxes without pallets; the use of pallets reduces the stacking height to 11 boxes.

The amount of aisle space required to move the relatively large unit loads handled by industrial clamp-type and forklift trucks largely accounts for the differences in space utilization between a clamp-type 2-wheel hand-truck operation and an industrial

Table 4.--Net storage capacity in standard apple boxes of 3 cold storage rooms of specified size when using various types of materials-handling equipment, decrease in capacity, and capacity lost to aisle space

Room size and equipment type	Aisle width		Stacking height	Potential net storage capacity	Decrease in capacity[2]	Capacity lost to aisle space
	Recommended	Used[1]				
Room 50 by 80 by 13-1/2 feet[3]	*Inches*	*Inches*	*Boxes*	*Boxes*	*Boxes*	*Boxes*
Clamp-type 2-wheel hand truck	48	48	12	21,400	0	2,050
12-box industrial clamp truck	60	70	12	20,350	-1,150	3,150
24-box industrial clamp-type lift truck	108	118	12	16,950	-4,450	4,750
36-box industrial clamp-type lift truck	120	118	12	17,300	-4,100	4,750
36-box industrial forklift truck	120	118	11	16,250	-5,150	4,750
48-box industrial forklift truck	144	144	11	15,000	-6,400	6,350
Room 50 by 110 by 12-1/2 feet[4]						
Clamp-type 2-wheel hand truck	48	48	12	28,850	0	2,150
12-box industrial clamp truck	60	70	12	27,400	-1,450	3,000
24-box industrial clamp-type lift truck	108	118	12	22,450	-6,400	5,300
36-box industrial clamp-type lift truck	120	118	12	22,900	-5,950	5,300
36-box industrial forklift truck	120	118	11	21,100	-7,750	4,850
48-box industrial forklift truck	144	144	11	15,300	-13,550	6,500
Room 80 by 90 by 20 feet[5]						
Clamp-type 2-wheel hand truck (1 main and 2 feeder aisles)	48	48	12	36,000	-21,000	[6] 9,150
12-box industrial clamp truck (1 main and 2 feeder aisles)	60	70	12	36,000	-21,000	[6] 11,700
24-box industrial clamp-type lift truck	108	118	18	57,000	0	7,800
36-box industrial clamp-type lift truck	120	118	18	57,000	0	7,800
36-box industrial forklift truck	120	118	18	57,000	0	7,800
48-box industrial forklift truck	144	144	18	55,300	-1,700	10,350

[1] In some cases potential capacity could be increased by reducing aisle width or space provided for cold air circulation, a practice followed by many plant managers when pressed for space.

[2] Capacity lost when changing from type of equipment for which room was designed to other types of equipment.

[3] This room, constructed for a clamp-type 2-wheel hand truck operation, has a forced-air refrigeration system. Air ducts, with maximum cross sectional area of 4 by 4 feet, with air outlets 18 inches from the ceiling, are suspended from ceiling directly over the aisle in center of the room. The aisle runs the length of the room--80 feet. Two doorways are centered on the 50-foot walls. All supporting posts are set on 16-foot centers except 1 row of posts which are set on 15-foot centers. One-foot air spaces are provided on 80-foot walls.

[4] This room, constructed for a clamp-type 2-wheel hand-truck operation, has coil-type refrigeration system. Three banks of coils, 4 feet wide and 10 feet apart, run the length of the room--110 feet--and are suspended 18 inches from the ceiling; outside banks of coils are 9 feet from walls. Middle bank of coils centered over aisle. Two doorways are centered on 50-foot walls. Boxes are stacked 10-high under 2 banks of coils. All supporting posts are set on 16-foot centers except 1 row of posts, which are set on 13-foot centers. One-foot air space is provided on all 4 walls.

[5] This room, constructed for industrial lift trucks, has truss-supported roof (no supporting posts) and forced-air refrigeration system with air outlets above the 18-box stacking level. One-foot air space is provided on all 4 walls. Two doorways are centered on the 80-foot walls.

[6] Based on stacking height of 18 boxes.

lift-truck operation in a conventional type storage house. As shown in figure 4, one foot of air space is allowed on each of the 80-foot walls for cold air circulation for all equipment types. When clamp-type 2-wheel hand trucks are used, an aisle 48 inches wide and parallel to the 80-foot walls is used in determining the potential net storage capacity. Approximately 2,050 boxes of apples could be stored in this aisle space as compared with 4,750 boxes that could be stored in the 118-inch aisle space required for a 24-box industrial clamp-type lift and a 36-box industrial lift truck. A total of 6,350 boxes could be stored in the 144-inch aisle required for a 48-box industrial forklift truck.[3]

The inability to fully utilize the space between and back of the supporting posts and the restricted stacking height limit the use of industrial lift trucks in a storage room of this size. Only 15,000 boxes could be stored in this room if a 48-box industrial forklift truck were used, compared with 21,400 boxes in a 2-wheel hand-truck operation. If a 36-box industrial forklift truck were used, about 16,250 boxes could be stored in the room. Both industrial clamp-type lift trucks can utilize more cubic space than the 36-box industrial forklift truck. In this room the industrial clamp-type trucks can stack boxes 12 high, whereas the necessary 2 pallets required for stacking with a forklift truck reduces the stacking height by 1 box. If a 12-box industrial clamp truck were used in this room, the storage capacity would be about 20,350 boxes.

Conventional Storage Room 50 by 110 by 12 1/2 Feet

This room is equipped with a coil-type refrigeration system, consisting of 3 banks of coils with the middle bank centered over a 110-foot aisle. (Only one aisle is needed in this room.) The relatively low ceiling limits the stacking height, except under the coils, to 12 boxes without pallets. The use of pallets reduces the stacking height to 11 boxes; in the area under the refrigeration coils, stacking height is further reduced.

In this room a shift from clamp-type 2-wheel hand trucks to any other equipment (fig. 5) would result in a loss of storage capacity. Because of the extra length of the aisle (110 feet), the number of boxes lost to aisle space in this room is slightly larger than in the other conventional storage room when the same types of equipment are used. Boxes can be stacked only 10-high beneath 2 banks of coils, 11-high in the remainder of the room, and no pallet loads can be stacked at right angles behind supporting posts. Consequently, only about 15,300 boxes of apples can be stored with a 48-box industrial forklift truck. This number of boxes is about 44 percent less than can be stored by use of clamp-type 2-wheel hand trucks. When a 36-box industrial forklift truck is used, boxes can be stored 5 unit loads, or 15 boxes, deep, which is 3 boxes more than can be stored in 3 unit loads when a 48-box industrial forklift truck is used. This largely accounts for the difference in storage capacity between the 2 industrial forklift truck operations.

The difference between the storage capacity of this room when clamp-type 2-wheel hand trucks are used and the storage capacity when the 36-box industrial trucks are used is only slightly larger, percentagewise, than that for the smaller conventional storage room.

Modern Storage Room 80 by 90 by 20 Feet

This room has a forced-air cooling system, with the ducts located above the optimum stacking height of 18 boxes for an industrial lift truck. The stacking heights shown for each type of equipment in this room are based on the potential capacity of the equipment and not on ceiling height.

A cold storage room of this size is designed to accommodate industrial lift trucks. It should have a truss-supported roof with few or no supporting posts (fig. 6). The same

[3] When a 48-box industrial forklift truck is used, the space can be utilized more fully by placing 1 row of pallets, 1 unit load high, partially beneath the center bank of coils and to within 12 feet of each doorway. This arrangement places the aisle slightly off center.

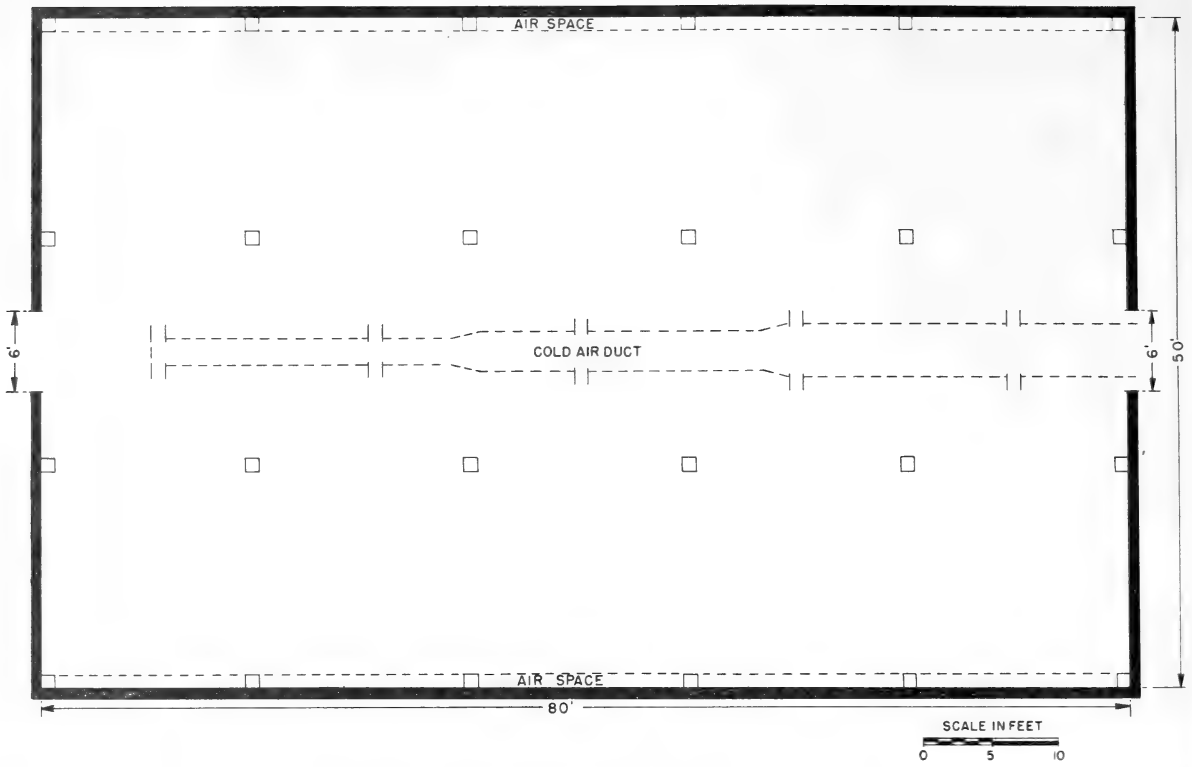

Figure 4. --Conventional apple cold storage room (50 feet wide, 80 feet long, and 13 1/2 feet high).

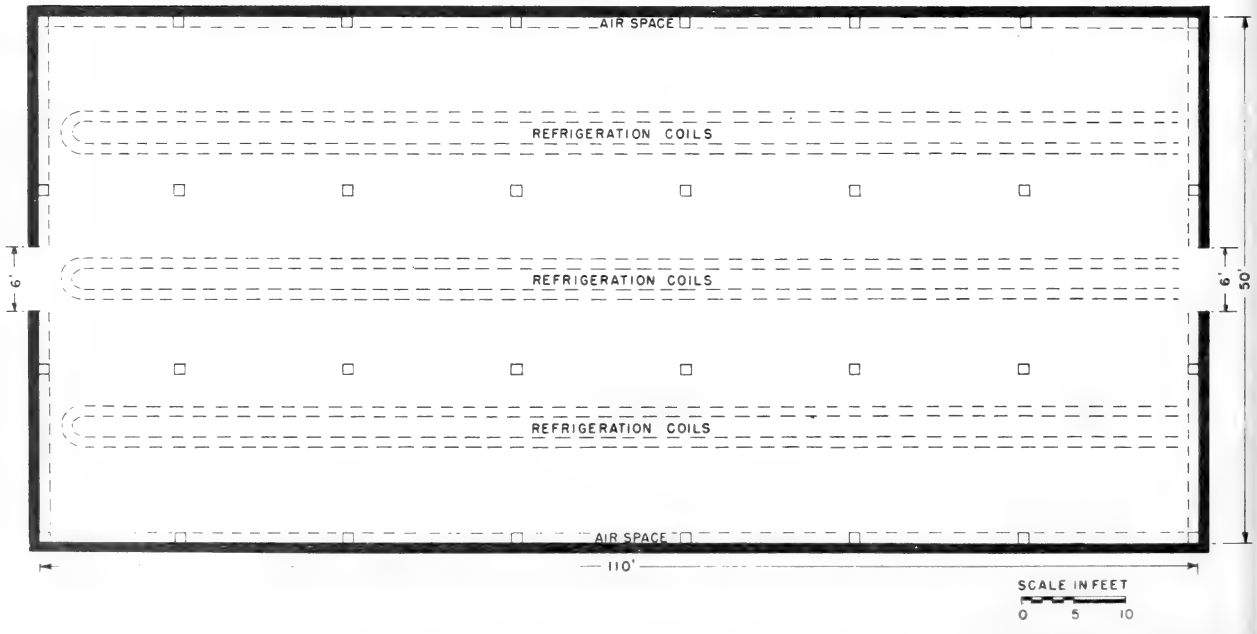

Figure 5. --Conventional apple storage room (50 feet wide, 110 feet long, and 12 1/2 feet high).

number of boxes could be stored in this room by a 36-box industrial forklift truck, a 36-box clamp-type lift truck, or a 24-box industrial clamp-type lift truck (table 4). In order to have a smooth, efficient 2-wheel hand-truck or a 12-box industrial clamp truck operation in this room, 1 main aisle and 2 feeder aisles would be needed. These aisles would displace about 9,150 boxes, if stacked 18 high, or about 1,350 boxes more than the space needed for 1 main aisle. About 10,350 boxes could be stored in the 144-inch aisle needed to maneuver an industrial forklift truck with a capacity of 4,000 pounds and carrying a 48-box pallet load. About 2,550 more boxes could be stored in the aisle needed for this equipment than in the aisle needed for other types of industrial lift trucks. Although considerable aisle space is needed by a 48-box industrial forklift truck, a significantly greater number of boxes can be stored in the remaining space by this equipment than by use of clamp-type 2-wheel hand trucks.

The inability to stack boxes efficiently to the 18 high level with clamp-type 2-wheel hand trucks accounts for most of the loss of storage capacity as compared with an industrial lift-truck operation. Note the difference in stacking heights (table 4) for the various types of materials-handling equipment for this room and the two conventional storage rooms. About 57,000 boxes of apples could be stored on pallets in this room by a 36-box industrial forklift truck. About the same volume could be stored by 24-box or 36-box industrial clamp-type lift trucks.

When fruit is handled by clamp-type 2-wheel hand trucks, the present industry practice is to limit the stacking height to 12 boxes. Because of this limitation in stacking height, about 36,000 boxes could be stored by use of this equipment, 37 percent fewer boxes than could be stored by industrial lift truck. Although wider aisles are needed for a 12-box industrial truck than for a clamp-type 2-wheel hand truck, approximately the same number of boxes could be stored in this room by this equipment. This

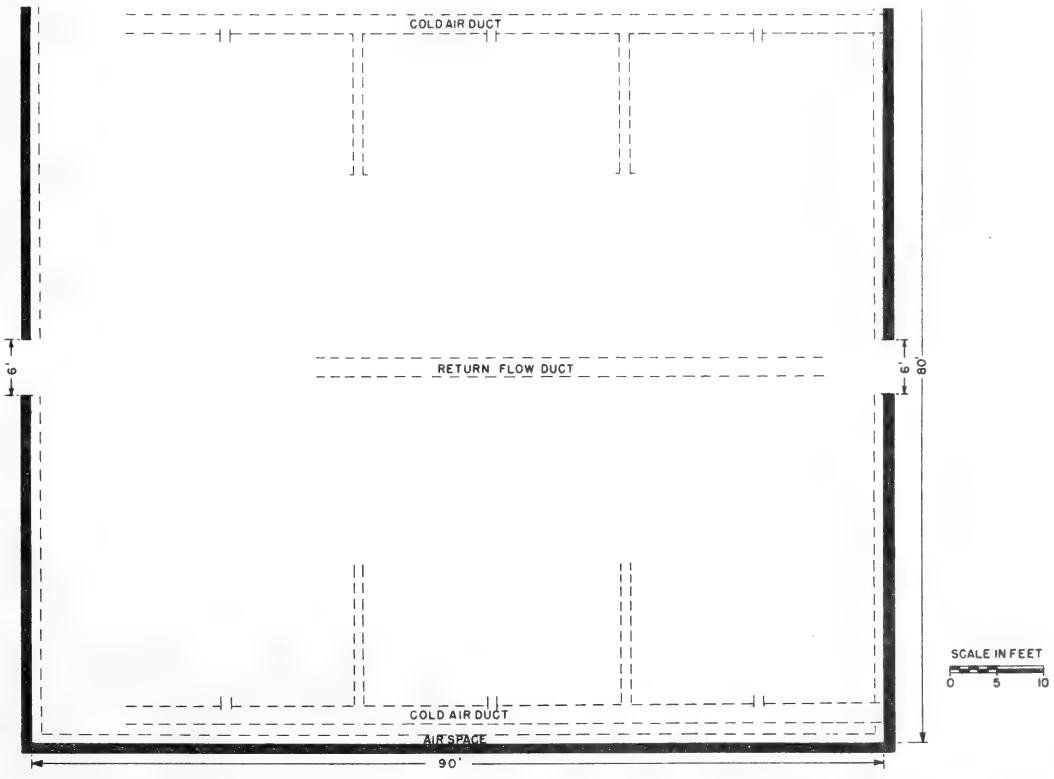

Figure 6. --Modern apple storage room (80 feet wide, 90 feet long, and 20 feet high).

is possible because of the extra space required between stacks of boxes for the clamping arms of the 2-wheel hand trucks. Air space along the walls also can be slightly reduced.

EFFECT ON STORAGE REVENUE OF CHANGING FROM ONE TYPE OF EQUIPMENT TO ANOTHER

During the 1951-52 season, commercial storage plants in the Pacific Northwest commonly charged growers rates of 20 to 25 cents a box for the storage of apples. However, these rates included services other than storage, such as moving the fruit into and out of storage. Many plant operators base their storage rates on the assumption that if the fruit is stored in their plants, they will also pack and sell the fruit for the grower. Some operators indicate that their storage charges do not cover all of the costs of services rendered. Apparently, the advantages of packing and selling the fruit are sufficient to outweigh losses that might be sustained in storage operations.

Total gross revenue received by an apple storage plant designed for a specific method of handling is directly related to the total capacity of its storage rooms and the occupancy of this space. Because individual apple storage plants vary somewhat in their design, it is difficult to generalize on the effects of storage revenue when the various types of equipment are used. Any assumptions on net revenues received from storage operations can be avoided by considering only gross revenues that would be received from rooms of typical design by changing from one type or combination of types of materials-handling equipment to another. These figures would show the amount of gross revenue gained or lost when using types of equipment different from that for which the plant was designed.

However, managers of older plants who consider a change in handling methods and equipment should weigh other considerations as well as gross revenue. Advantages from a more mechanized system of handling might include: (1) Smaller labor costs; (2) smaller crews; (3) less bruising and damage; and (4) less labor required of grower in unloading fruit. Disadvantages from such a change might include: (1) The greater capital investment required and larger equipment costs and (2) a reduction in the usable storage space. A reduction in usable storage space of course would result in a reduction in gross storage revenue.

By using the same storage rooms discussed in the preceding section, expected losses in storage revenue can be estimated for 2 typical conventional storage rooms when changing from a clamp-type 2-wheel hand truck operation to other types of materials-handling equipment. The advantage of industrial lift trucks over older types of equipment also can be shown for a modern storage room designed for that type of equipment.

Table 5 shows the potential gross storage revenues for these three rooms when various types of materials-handling equipment are used in the storage operation. In these computations for comparative purposes, an assumed storage rate of 20 cents per box per season was used. In the smaller of the conventional rooms the gross revenue for storing 21,400 boxes of apples is $4,280 when clamp-type 2-wheel hand trucks are used. This amount is about $210 more than the estimated revenue obtainable from this room if a 12-box industrial truck were used, about $890 more than if a 24-box industrial clamp-type lift truck were used, $1,030 more than with a 36-box industrial forklift truck, and $1,280 more than with a 48-box industrial forklift truck.

In the other conventional room (50 by 110 by 12 1/2 feet) the gross storage revenue of $5,480 when using 2-wheel hand trucks is reduced to $4,220 when a 36-box industrial forklift truck operation is substituted. This amount is further reduced to $3,060 when a 48-box industrial forklift truck is used. Gross storage revenue might be increased in conventional rooms that store on 36-box or 48-box pallets by utilizing aisle space, provided the refrigeration system will permit. However, aisle storage may not always be desirable because of cold air circulation requirements.

Table 5.--Comparison of potential revenue from 3 cold storage rooms of specified size and design when various types of materials-handling equipment are used

Equipment	Room 50' x 80' x 13' 6"			Room 50' x 110' x 12' 6"			Room 80' x 90' x 20'		
	Potential storage capacity[1]	Potential revenue[2]	Differential from clamp-type 2-wheel hand truck	Potential storage capacity[1]	Potential revenue[2]	Differential from clamp-type 2-wheel hand truck	Potential storage capacity[1]	Potential revenue[2]	Differential from industrial lift truck[3]
	Boxes	*Dollars*	*Dollars*	*Boxes*	*Dollars*	*Dollars*	*Boxes*	*Dollars*	*Dollars*
Clamp-type 2-wheel hand truck.....	21,400	4,280	0	28,850	5,770	0	36,000	7,200	-4,200
12-box industrial clamp truck.....	20,350	4,070	-210	27,400	5,480	-290	36,000	7,200	-4,200
24-box industrial clamp-type lift truck.	16,950	3,390	-890	22,450	4,490	-1,280	57,000	11,400	0
36-box industrial clamp-type lift truck.	17,300	3,460	-820	22,900	4,580	-1,190	57,000	11,400	0
36-box industrial forklift truck.....	16,250	3,250	-1,030	21,100	4,220	-1,550	57,000	11,400	0
48-box industrial forklift truck.....	15,000	3,000	-1,280	15,300	3,060	-2,710	55,300	11,060	-340

[1] From table 4.
[2] Based on a storage rate of 20 cents per box for the season.
[3] 36-box industrial forklift truck, 24-box and 36-box industrial clamp-type trucks.

In the modern storage room designed for industrial lift trucks, the gross storage revenue would be $11,400. However, if the clamp-type 2-wheel hand truck were used, the potential revenue for this room would drop to $7,200, a decline of $4,200 or about 37 percent. Most of this difference results from the limited stacking height of 12 boxes of manually stacked fruit. If the operation were shifted from a 36-box to a 48-box industrial forklift truck and pallet operation, the decrease in revenue would amount to only $340. The reduction in handling costs when all materials-handling operations are considered may make it desirable for operators to consider substitution of the 48-box industrial forklift truck for the 36-box industrial forklift or the 24-box or 36-box industrial clamp-type lift truck.

Obviously the choice of apple handling methods and equipment cannot be made solely on the basis of theoretical revenue considerations. There are other factors that should enter into the plant operator's decision as to the choice of type of equipment. These include speedier handling, less bruising of fruit, lower handling costs, and smaller capital investment in facilities. Often, some of the other factors are of greater importance than small losses or gains in gross storage revenue.

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