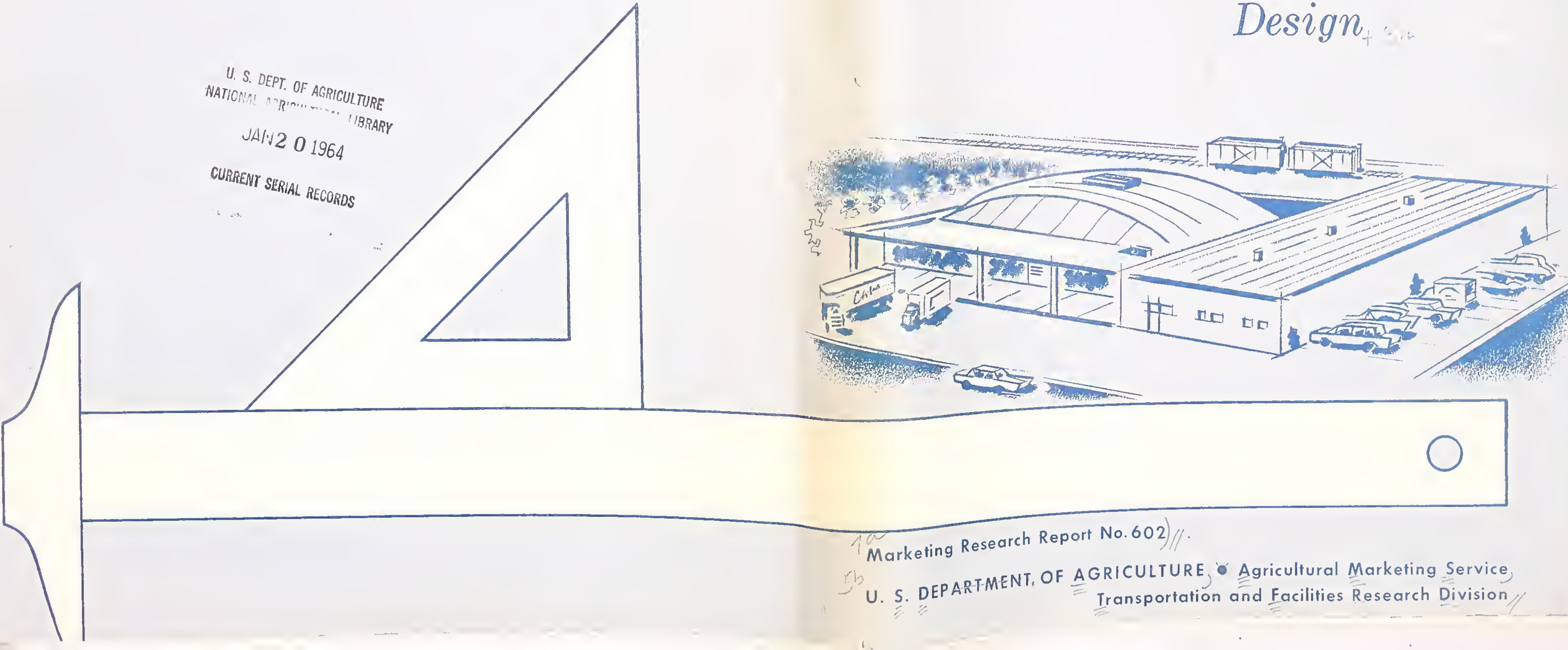
# APPLE PACKING and STORAGE HOUSES

## *Layout and Design*





Marketing Research Report No. 602
U. S. DEPARTMENT OF AGRICULTURE • Agricultural Marketing Service
Transportation and Facilities Research Division

## SUMMARY

Adoption of improved methods and equipment in apple packing and storage houses often requires that new facilities be constructed, or that old plants be remodeled. This report presents guides for the layout and design of apple packing and storage houses. These guides are developed around the use of newer and more efficient methods and equipment.

The layouts provide for a direct flow of the fruit from the storage room, through packing operations, and back to the storage room or to the shipping area, as well as optimum storage conditions. Layouts are developed for three packing rooms and three storage rooms. All are based on the use of lift trucks for handling boxes of fruit.

The first packing room layout is based on a packing line for exact sizing (dividing apples in 12 to 16 sizes) and packing fruit in standard wooden boxes. The second is based on a packing line for group sizing (dividing apples into 5 or 6 sizes) and packing fruit in trays in fiberboard boxes. The third packing room incorporates both types of packing line.

The storage-room layouts are for capacities of 25,000, 50,000, and 100,000 standard wooden boxes. Boxes of fruit are handled on 40- by 48-inch pallets in the two larger rooms, and in 36- by 40-inch unit loads, without pallets, in the smaller room. The layouts could be converted for handling and storage of apples in pallet boxes.

Designs are developed for three packing and storage houses. The first is based on layouts of the exact sizing line and the 50,000-box storage; the second, on the group sizing line and the 100,000-box storage; and the third, on the double packing line and a layout for a 200,000-box storage. The plants are designed to minimize construction costs. Estimated costs are $156,000, $220,000, and $395,000 for the three plants, based on building costs for the Yakima, Wash. area.

## PREFACE

This report applies previous research on improved methods, equipment, and facilities to apple packing and storage house layout and design. This study is part of a broad program of continuing research to increase the efficiency of physical handling of farm commodities during marketing, to hold down costs.

The research on which this report is based was conducted by the Fruit Industries Research Foundation, Inc. (now known as Food Industries Research and Engineering), under a research contract with the United States Department of Agriculture.

Frank Alberti, professional engineer, associated with The Fund Insurance Companies, Seattle, Wash., cooperated in the preparation of the section on "Modern Design, Materials, and Building Techniques Can Reduce Fire Losses."

Use of brand names in this report does not constitute endorsement of the product named or imply discrimination against other products.

Complete plans and specifications for the designs presented in this report are available for review or purchase. Copies may be reviewed during office hours at the following locations:

Transportation and Facilities Research Division Field Office
Post Office Annex Building, P.O. Box 99
Wenatchee, Wash.
Attn: Glenn O. Patchen, Mechanical Engineer

Maine State Department of Agriculture
State House Building
Augusta, Maine
Attn: George H. Chick, Deputy Commissioner

Appalachian Apple Service, Inc.
Martinsburg, W. Va.
Attn: Carroll R. Miller, Secretary-Manager

Agricultural Experiment Station
Michigan State University
East Lansing, Mich.
Attn: Dr. Arthur E. Mitchell, Professor of Horticulture

Transportation and Facilities Research Division
Agricultural Marketing Service
U.S. Department of Agriculture
Federal Center Building
Hyattsville, Md. 20781

Missouri State Horticultural Society
Whitten Hall, University of Missouri
Columbia, Mo.
Attn: Dr. W. R. Martin, Jr., Secretary

Sets of the plans and specifications, which include eight blueprints, may be purchased from:

Cooper-Trent Blueprint and Microfilm Corporation
2701 Wilson Boulevard
Arlington, Va. Attn: Walter Boyden

Prices, which include postage to any point in the continental United States are: 50,000-box—$4.50 per set; 100,000-box—$4.50 per set; 200,000-box—$7.00 per set.

Related reports previously issued that are of general interest to the apple industry are:

Cooling Apples in Pallet Boxes. U.S. Dept. Agr. Mktg. Res. Rpt. No. 532. August 1962.

An Automatic Pallet-Box Filler for Apples. U.S. Dept. Agr. Mktg. Res. Rpt. No. 550. November 1962.

Air Door for Cold Storage Houses. U.S. Dept. Agr. AMS-458. December 1961.

Packing Apples in the Northeast. U.S. Dept. Agr. Mktg. Res. Rpt. No. 543. October 1962.

Heat Leakage Through Floors, Walls, and Ceilings of Apple Storages. U.S. Dept. Agr. Mktg. Res. Rpt. No. 315. October 1959.

Cooling Apples and Pears in Storage Rooms. U.S. Dept. Agr. Mktg. Res. Rpt. No. 474. September 1961.

Apple Handling and Packing in the Appalachian Area. U.S. Dept. Agr. Mktg. Res. Rpt. No. 476. June 1961.

An Experimental Packing Line for McIntosh Apples. An Interim Report. In cooperation with N.Y. State Dept. Agr., and Markets, Division of Markets, and Maine Agr. Expt. Sta., Dept. of Agr. Econ. U.S. Dept. Agr. AMS-330. August 1959.

The Effect of Apple Handling Methods on Storage Space Utilization. U.S. Dept. Agr. Mktg. Res. Rpt. No. 130. July 1956.

Storage and Cooling Capacity in Apple Storages in the Wenatchee-Okanogan, Washington District. U.S. Dept. Agr. AMS-196. July 1957.

Controlled-Atmosphere Storage of Starking Delicious Apples in the Pacific Northwest. U.S. Dept. Agr. AMS-178. March 1957.

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Washington, D.C. January 1964



## CONTENTS

# Apple Packing and Storage Houses ● LAYOUT AND DESIGN

by JOSEPH F. HERRICK, Jr., *marketing research analyst*, and G. F. SAINSBURY, *agricultural engineer*,[1] Transportation and Facilities Research Division, Agricultural Marketing Service, and EARL W. CARLSEN and D LOYD HUNTER Fruit Industries Research Foundation,[2] Yakima, Wash.

## BACKGROUND OF STUDY

Extensive research by the U.S. Department of Agriculture in the Pacific Northwest apple producing areas has resulted in improved methods and equipment for handling, packing, and storing apples. These improvements reduce both labor requirements and fruit loss from bruises, stem punctures, decay, and mechanical injuries. Although these improvements have been adopted in many apple packing and storage houses throughout the country, operators of older plants find they must extensively remodel their plants, or build new ones, if they wish to use the new methods and equipment.

In addition to plants that are built as replacements, construction of new apple packing and storage houses throughout the United States is increasing. Economic trends in the industry indicate that more new plants will be built in the next few years. Much of this new construction is not being designed for the improved equipment and methods. Because of the need for guides and standards in planning and constructing apple packing and storage houses, this report describes efficient layouts and designs that would minimize the cost of construction.

### Operation of Apple Packing and Storage Houses

The general method of operation of apple packing and storage houses in the Pacific Northwest was used as a basis for development of the layouts and designs in this report.

[1] Resigned from the Agricultural Marketing Service.

[2] Now known as Food Industries Research and Engineering.

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In that area, all of the newer plants receive fruit either by forklift or clamp-lift trucks. As fruit is received from the orchard, it is most frequently moved directly into refrigerated storage rooms for cooling before it is packed. It is good practice to remove the field heat from fruit as soon as possible after it is picked, or much of its storage life may be lost.

Depending on a firm's marketing practices or production schedule, fruit may be packed and shipped as orders are received, or all the fruit may be packed at the same time and returned to storage for later shipment. Fruit that is packed for immediate shipment is loaded on refrigerated rail cars or highway trucks.

In packing, fruit is dumped from field boxes at the head of the packing line, washed, sorted into grades, sized, and packed. The boxes of packed fruit are labeled and sorted by lot, grade, and size. The two or three grades depend upon the degree of coloring and the amount of bruises, stem punctures, blemishes, and other visible defects.

Two methods are used in sizing fruit. In the first, "exact" sizing, fruit may be separated into 16 or more sizes. Exact sizes are by count of the apples required to fill the standard wooden box (12 by 20 by 11½ inches); those most frequently used are: 48, 56, 64, 72, 80, 88, 100, 113, 125, 138, 150, 163, 175, 198, 216, and 232. The purpose of exact sizing is to assure uniformity in the pack and, though it is not often recognized, to avoid or minimize bruising.

Recently, packers have used "group" sizing; in this method, the fruit is separated into 5 or 6 sizes. With the advent of consumer packaging, all of the smaller salable sizes (163 and below; also called the "5-tier") are usually bagged as one size. A few of the smaller sizes are still packed individually, mostly for export. In group sizing, with the smaller sizes bagged, the remaining fruit is packed out as sizes 150, 125, 100, 80, and 64.

Two types of sizing equipment are used; the first type sizes the fruit according to approximate weight, and the second, according to approximate dimension. The weight sizer may be used for either exact or group sizing. The newer dimension sizer, with higher capacity than the weight-type, is used for group sizing.

Apples that are sized exactly usually are individually wrapped in oiled paper and packed in standard wooden boxes (standard wrap-and-pack). A firm using this method of sizing and packing generally packs all the fruit at once and returns it to storage. This type of pack holds well in storage.

Apples that are group-sized are usually placed on cardboard trays in layers in fiberboard boxes: semiautomatic machines may be used to fill the trays. Apples packed this way usually are shipped as soon as they are packed.

### Importance of Proper Layout and Design

In recent years, costly mistakes have been made in the design and construction of commercial apple packing and storage houses. For example, the storage room in one new plant was constructed with the main aisle 1 foot too narrow for forklift truck operation. Because of this mistake, space for one row of pallets was lost. In another instance, a storage room had about 10 percent less storage capacity than a room of equal size, but different dimensions.

Many packing rooms lack adequate space for storing supplies near the packing line. This causes extra handling. Other common mistakes, that cost plant operators money or reduce fruit quality, are improper spacing of fruit in storage for good air circulation, and lack of an adequate air circulation pattern.

An operator who plans to build or add to his present facilities often follows what has been done in the past in his area, without considering new methods of packing, handling, and construction which are more economical and efficient. In many cases, owners do not give the necessary thought to building size and height required for the methods of receiving, handling, and storing to be used. It is not unusual to find an owner wishing his building were just 2 feet longer or 1 foot higher.

Careful planning of the layout and design of a plant may be the wisest investment a plant manager can make. In any event, the approach to any design and layout problem should not be influenced by the exterior shell of the building. The handling methods, operating procedures, refrigeration systems, and other features should be definitely decided upon before the completion of the plans and drawings for the building are undertaken. The equipment selected, its arrangement or layout, and the flow of work through a plant determine the relative efficiency at which the plant operates. Proper layout and work flow keep the number of workers required to a minimum, make it easier to supervise the workers, and facilitate the movement of fruit into, through, and out of the packing and storage house.

Layout and work flow are the two most important factors affecting design. Efficient design can reduce construction costs and eliminate the necessity for subsequent expensive alterations, by making provision in advance for expansion.

## Scope and Purpose of the Study

The layouts and designs presented in this report are intended to serve as guides for the planning and construction of apple packing and storage houses of various sizes throughout the country.

Layouts are developed for: Three packing rooms, using different methods of sizing and packing apples, or having a different packing capacity; and three storage houses, with capacities of 25,000, 50,000, and 100,000 standard wooden boxes. The first packing room layout is for a single packing line for exact sizing, the second is for a single line for group sizing, and the third is for a double line—one for exact sizing and the other for group sizing. The equipment in each packing line was selected to provide the most efficient and economical overall operation.

Designs, construction details, and cost estimates are developed for three complete apple packing and storage houses. These houses are designed around the following layouts:

- The exact sizing line and the 50,000-box storage.
- The group sizing line and the 100,000-box storage.
- The double line and an additional layout for a 200,000-box storage.

All plants are single-story buildings, designed for lift truck operations.

It is assumed that the standard wooden box is used for handling and storing fruit, and that both fiberboard and standard wooden boxes are used as shipping containers. Boxes are handled on 40- by 48-inch pallets, except in the 25,000-box storage, where a 36- by 40-inch unit load without pallets is used.

Complete plans and specifications for these plants are not included with this report, but are available for review or purchase, as stated in the Preface.

The building codes, economic requirements, industry conditions, and wind and snow loads in the area of Yakima, Washington, were used as a basis in developing the designs. Most of the construction designs can be used as basic guides in all apple-producing areas, but the data should be carefully applied to meet local conditions.

Operators considering constructing new plants, modifying or rebuilding their existing facilities, or changing their handling and packing equipment, can weigh the data in this report and select the elements that apply best to their operations.

New developments in apple packing and storage are taking place, and others may occur, that should be considered before remodeling or construction plans are made. Pallet boxes, for example, are being rapidly adopted for handling and storage. There is no standard pallet box in general use, however, and the standard wooden box is still used in many plants. The layouts and designs presented here may be converted to the use of pallet boxes. See the Bibliography, page 27, for reports dealing with handling and storage of apples in pallet boxes.

Operators should obtain qualified engineering advice when planning remodeling or new construction. Such advice may be available through State Agricultural Experiment Stations, State Departments of Agriculture, or private engineering firms, that are experienced with the problems that arise in handling, storing, and packing fruit.

## FACTORS AFFECTING PLANT LAYOUT

Marketing and storage practices have a most important influence on plant layout. If an operator decides to pack apples out as they are received from the orchard, relatively less storage space and more packing line capacity—meaning more or different types of equipment—would be needed. Or, a smaller packing line capacity and larger storage facilities would be required if the plant followed the policy of moving all fruit into storage for holding and later packing at a slower pace, as market requirements dictate. Or, again, they may prefer to pack their apples out in selected types of packs which efficiently utilize certain types of equipment. Thus, the choice of equipment and layout are often prescribed by the decisions of management about storing and packing the fruit.

There are dynamic changes occurring in marketing which affect plant layout. For instance, the development of self-service merchandising has brought about a need for new types of packages that can deliver fruit with fewer bruises to the consumer. The tray-pack shipping container and consumer packages of many types, which fill this need, are in increased demand. The packing room layout must be versatile, so that management can easily switch from one type of package to another. Additional area for supplies is required, space requirements for segregating may be altered, and other features of the plant layout are influenced by the newer merchandising trends.

Group sizing is a relatively new development in the marketing of apples. It is preferred by supermarkets or large-volume retail stores, who find it simpler to handle fewer sizes of apples. These stores report that they are better able to meet the demands of the consumer with fewer sizes. Group sizing permits use of less complicated sizing equipment, and makes it more practical to use return-flow belts for packing, instead of rotating tubs.

In a similar way, plant layout is affected by the site on which the building is to be placed, including topography of the land and the amount of space available. The building may have to be located near rail sidings or roads that limit one or more of its dimensions. Also, even if old buildings are abandoned and new ones built, there nearly always is some equipment from the old plant that can be effectively used in the new one.

All these conditions and requirements will influence the plant layout.

## PACKING ROOM LAYOUTS

Layouts are developed for three separate packing rooms. The first is for a single packing line doing exact sizing, the second is for a single line doing group sizing, and the third is for a double line, one doing exact sizing and the other, group sizing. All layouts include space for general offices, a shop, lunch and rest rooms, and storage of supplies.

The equipment and method of operation of each line is selected to provide the most efficient overall operation at the lowest cost, based on the type of pack desired. All lines provide for some flexibility in the type of pack used.

Basic features, principles, and assumptions are:

1. All layouts are designed for handling both loose and packed boxes of fruit by forklift trucks and pallets (fig. 1).
2. All layouts provide for possible future expansion of the packing line and room.
3. Most of the loose fruit is received and moved directly to refrigerated storage rooms and later to the packing line.
4. The stacking patterns, aisles, equipment, work stations, and doors are arranged to provide the most direct flow of fruit from refrigerated storage rooms through the packing room and back to storage with a minimum of out-of-line and return hauls.
5. Space is provided between work areas, where necessary, for supplies, such as at the dumping station and at the segregating area. This permits continuous work, with little influence on the rate at which different workers are able to perform their respective jobs.
6. Work areas are separated so that there is little possibility of one worker interfering with another. Workers from one area will seldom find it necessary to go through other work areas.
7. The packing lines are arranged to provide a straight-line flow, to: Facilitate production; avoid changing direction of travel of the fruit on the conveyors; and minimize the distance fruit drops as it moves from one piece of equipment to another.

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FIGURE 1.—Placing a 48-box pallet load of loose fruit in storage.

8. Space for rest rooms is based on the total number of employees, to satisfy building code requirements.

9. The commonly accepted amount of office space is provided for the office and management personnel, and the foreman or other supervisory personnel.

## A Packing Room Layout for Exact Sizing

This layout is for a single packing line for exact sizing and manual packing of apples from rotating tubs (fig. 2).

The layout is primarily for firms that sell hand-wrapped fruit packed in standard wooden boxes. Such firms usually pack in advance of sales and hold the packed fruit in cold storage, instead of catering to the day-to-day demands of the market. Tray packs may also be packed from the rotating tubs, however, and the layout provides for both packing methods. Consumer-size apples are accumulated on a return-flow belt, and automatically filled into bags or boxes.

The packing line can be used with either a large or a small storage. Average capacity of the line, operated by 39 workers, is 420 boxes of loose apples per hour. Maximum capacity is 600 boxes per hour.

The line is designed for sorting apples into two grades, but it may easily be switched to three.

### Equipment Required

The items listed are well-known in the apple industry. Certain terms, which may be unfamiliar to the general reader, are described in a following section, "Description of Operations." The principal items of equipment in the layout of the packing line to do exact sizing are:

Stack-breaker with 10 feet of floor chain conveyor for moving stacks of boxes into it.

An automatic drum-type dumper.

A 25-foot gravity conveyor and gravity curved section, for moving empty boxes from the dumping station to the empty-box area.

A 3-foot section of 48-inch-wide belt conveyor, serving as a dumping apron.

A 2-foot leaf eliminator. This is a short section of roller conveyor that leaves can fall through.

A 3-foot chain, or wire screen, eliminator to remove "juicer" apples. They fall to a power belt conveyor, which extends, at a right angle, 3 feet to an automatic box-filler.

A 5-foot length of gravity conveyor and an automatic box-filler for filling juicer apples into boxes.

A washer with wash, fresh water rinse, and drying sections.

A 10-foot float-roll sorting table.

A 55-foot belt conveyor for moving cull fruit from the sorting table.

A cull lowering device for filling cull apples into large pallet boxes or tote bins.

Conveyors of various lengths above the sorting table for conveying apples to each section of the weight sizer.

A 3-foot chain, or wire screen, eliminator for taking out bagging size apples of the major grade with a belt conveyor, extends 3 feet to a return-flow belt accumulating station for bagging fruit.

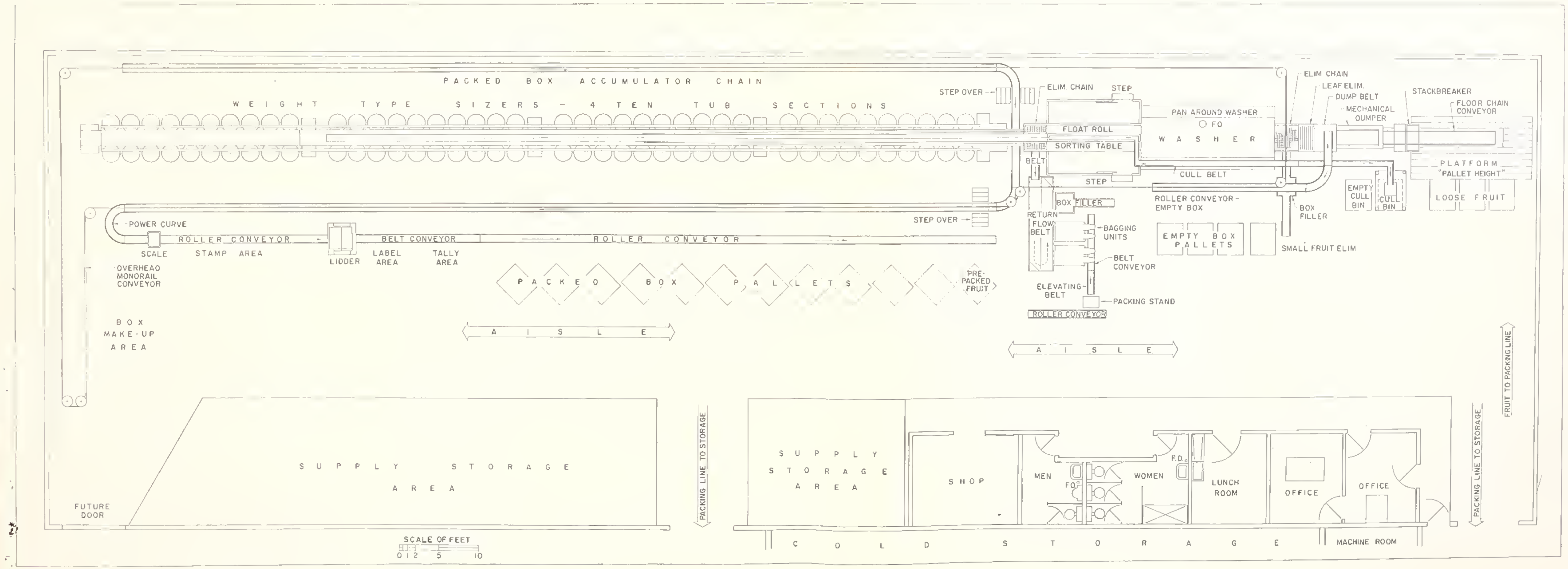


FIGURE 2.—Layout of a single-line packing room for exact sizing.

A 12-foot return-flow belt table for bagging apples.

An automatic box filler, for filling bagging size apples into fiberboard or wooden boxes.

Two bagging machines, with a 10-foot belt conveyor for moving bagged apples from the bagging machines to a packing stand or station.

A 10-foot roller conveyor, for moving containers of bagged apples to the segregating area.

Four double sections of weight sizers, each having 10 tub sections on both sides, with singulators, feed-on belts, and drives.

A 232-foot packed box accumulator conveyor, with powered chain, two 90° power curves, and one 180° power curve.

One scale for check-weighing packed boxes.

A 90-foot roller conveyor, for accumulating boxes in front of the lidder and at the segregating area.

One power lidding machine.

A 15½-foot belt conveyor, for moving boxes from the lidder to the segregating conveyor.

A powered overhead box-carrying conveyor (392 feet) installed around the packing line, from the empty-box handling area past the fiberboard box makeup area.

One post stitcher for assembling fiberboard shipping containers. (This item is optional.)

### Description of Layout

The packing room layout for the exact-sizing packing line is shown in figure 2. This single-line layout is designed for high-capacity operation; the sizer is used only for the larger fruit. The smaller consumer-packaging-type apples are taken out of the main run of fruit by a screen eliminator after passing over the sorting table and before going into the sizer. Capacity is further increased by the addition of an extra sizer section, making four sections instead of the usual three.

The packing line is at one side of the room, leaving space for segregating and an aisle for materials handling operations, so that they do not interfere with packing. By using the doors in the front and back of the packing room, the forklift truck can serve any necessary point in the room. There is ample aisle space for the lift trucks, and an adequate area for storage of supplies, empty boxes, culls, and loose fruit.

The office space is relatively small, because little sales work is done at the packing plant. The offices are largely for bookkeeping and personnel work.

### Description of Operations

The essential operations in this exact-sizing packing line perhaps will be more understandable if the reader refers to the three-dimensional layout in figure 3. Many phases or parts of these operations described in this section are common to other types of packing lines included in this report; therefore, this description will serve as background for later discussion of other packing lines.

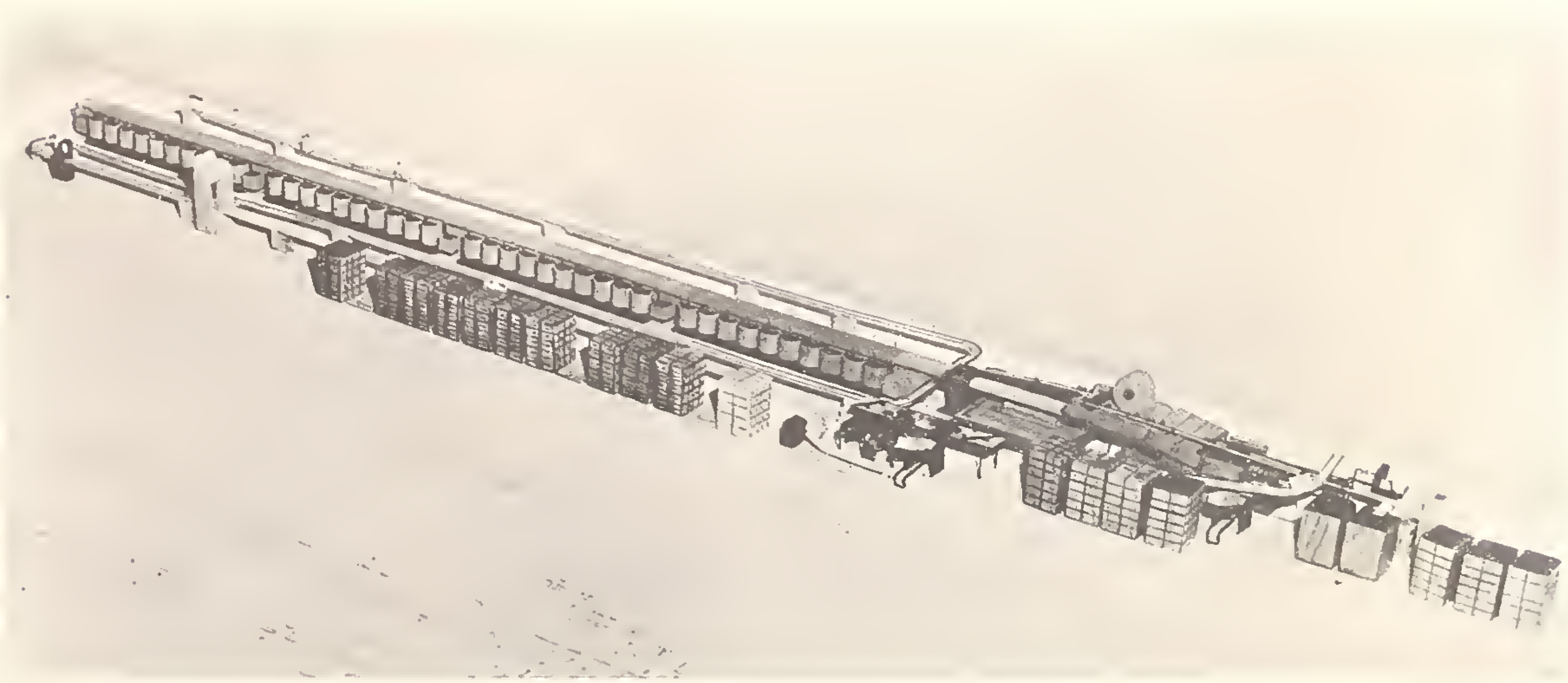

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FIGURE 3.—Model of a packing line designed for exact sizing.

SUPPLYING LINE WITH LOOSE FRUIT.—Boxes of loose fruit are brought from the receiving area, or storage, in 48-box pallet loads (40 by 48 inches) by forklift truck. The loads are set on the floor against a platform which is the same height as the thickness of the pallet. One worker, with a two-wheel clamp handtruck, picks up six-high stacks of boxes from the pallets, and places them on a short length of floor chain conveyor which moves the stacks into a machine known as a "stack-breaker." The stack-breaker lifts all but the bottom box in a stack from the conveyor. While the top boxes are raised, the bottom box moves away on the floor chain conveyor, and the upper part of the stack then is set down. This continues until all of the boxes in a stack have been "destacked." The boxes move from the stack-breaker on a conveyor one at a time to the dumper.

DUMPING.—The automatic drum-type dumper picks up a box of unpacked fruit and holds the box against a rotating drum that has a series of V-belts embedded in its surface. As the drum rotates, the box is pulled around with the drum until it is inverted. As the box reaches the top of the drum its contents, the fruit, rests on the V-belts. Two V-belts near the ends of the box pick the box up, off the fruit, while the rest of the V-belts move the fruit ahead to a short section of belt conveyor, or "dumping apron." The empty boxes are deposited on a gravity roller conveyor, which moves them to an accumulating point.

EMPTY BOX HANDLING.—When the empty boxes reach the accumulation point, a worker places them on the overhead monorail box conveyor, or nests three boxes into the space of two and stacks them onto pallets.

When clean, new, standard boxes are used, the worker places a portion of them on the overhead monorail box conveyor supplying the packers and the remainder onto pallets. Field boxes and lugs, or old boxes, always are placed on pallets. If the packing line is turning out tray-pack cartons only, all boxes are placed on pallets; old and new boxes are usually separated. Pallet loads of empty boxes are moved by forklift truck (fig. 4) to the loading platform for return to the orchard, or are placed in storage rooms, or piled outdoors until the next season.

LEAF ELIMINATING.—The fruit moves off the dumping apron onto a short section of slatted conveyor which has sufficient space between the flights to permit leaves, small twigs, and other debris to drop through. The fruit is carried by the flights to the next piece of equipment. Accumulated leaves are removed every day or so.

ELIMINATING SMALL JUICER APPLES.—An eliminator removes small juicer apples—sizes that are not accepted by consumers. Most of this fruit is sound and wholesome; it is usually sold to a processor for making juice. The eliminator is a small section of chain or wire-mesh conveyor. Small apples drop through the screen onto a conveyor belt which moves them at right angles to the packing line to a place where they are filled into boxes by an automatic box-filler. A worker stacks the filled boxes on pallets, so that they can be moved by forklift truck to cold storage, or another location.

WASHING.—The rest of the fruit rolls into a washer, where it is carried by an endless conveyor of rollers, suspended by chains at either side. The fruit first goes through a washing solution, which usually contains a detergent, and, at times, a mold preventive or inhibitor. Some plants also use an oil in the wash water to produce a shine and help in drying. After washing, the fruit moves through a fresh water rinse, and then through a dryer, where excess surface water is removed from the fruit before it moves onto the sorting table. A series of rotating brushes may be used at this point to shine the fruit.

SORTING.—Sorting can be done in a heated enclosure or room built around the sorting table to help keep the workers warm. Because sorters do not move about as much as the other workers in the plant, they need a higher temperature in which to work. This enclosure is optional for management; building code requirements can be met by heating the entire building to the temperature specified for sorting.

As the fruit moves forward on the sorting table, workers separate the apples into various grades (fig. 5). Usually, one grade predominates in a given lot of fruit being packed at any one time, and is called the major grade; all other grades are termed minor. The minor grades of fruit are lifted by the workers and placed on a conveyor belt where it moves directly to a section of the sizer. The major grade of fruit remains on the sorting table and is conveyed forward, automatically running off onto belts which carry the fruit to the sections of the sizer that are being used for the major grade.

HANDLING CULL APPLES.—Cull apples are picked out of the lot by the sorters and placed on a conveyor belt over the sorting table. They move to the head of the sorting table, out at a right angle to the packing line, and back along the washer where they accumulate. Here a feed device lowers the culls into large pallet boxes. As the pallet box is filled, the feed device retracts to the top of the box. A worker, using a forklift truck, removes the filled

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FIGURE 4.—Pallet load of 72 empty boxes (a third box is nested inside of each two boxes) being transported by a forklift truck.

box, and replaces it with an empty one, as needed. This is usually done during a nonoperating period.

Another method of handling cull apples is to place them in chutes on the side of the table. The culls drop onto a belt conveyor under the sorting table, and are carried to the cull bin by a special section of belt conveyor that raises them to the top of the bin and drops them in. Although cull chutes are more efficient than the other method, and are becoming increasingly popular, they bruise more fruit. The decision to use chutes might be affected by the anticipated volume of culls and on how the cull fruit is to be used.

HANDLING BAGGING APPLES.—As the major grade of apples leaves the sorting table, it rolls across another wire screen or mesh eliminator which permits selected sizes of apples to drop through onto a conveyor belt. These bagging-size apples move onto a return-flow table which keeps an accumulated supply in position for either automatic box filling or bagging.

When bagging-size apples are not being bagged, they can be automatically accumulated in boxes by an automatic box filler and returned to cold storage for later packing or for sale as a loose pack. A broader range of sizes can be handled by regulating or changing the size of the eliminator screen.

When bagging operations are carried on simultaneously with sizing, the fruit moves from the sizer eliminator, to the return-flow table, and then to the bagging machines. The workers there bag the apples, close the bags, and place them on a short length of conveyor. The conveyor raises the bags to a stand, where another worker puts them into a fiberboard master shipping container. The master containers are glued or stapled shut, and moved on a short length of gravity roller conveyor to the segregator, who stacks them into pallet loads in the segregating area. When the flow of bagging apples is small, the bagging machine operators may place the bagged fruit directly into the master containers; labor cost for one worker is saved.

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FIGURE 5.—Float-roll sorting table used to separate apples into grades.

SIZING.—Individual fruits are fed into each half-section of the weight sizer by a small belt leading to a singulator timing device, which prevents more than one piece of fruit from falling into a carrier cup on the sizer.

In the sizer, each apple is conveyed on a carrier cup over a track that is breached by steel blades attached to spring balance scales. When the weight of an apple overbalances the scale, the carrier cup tips the apple into a rotary-tub packing station. There is a separate tub packing station for each sizing scale.

PACKING.—Packing is done at individual stations. A packer places an empty standard box on a packing stand, and moves the stand into position next to one of the rotating tubs along the sizer. The packer puts the appropriate liner in the box; selection depends upon the grade of fruit. Apples are removed from the rotating tubs one at a time, wrapped, and packed in the box. When the box is full, the worker rolls the stand over to the packed-box conveyor at the side of the aisle and puts the box on the conveyor.

The packing operation is similar for tray packs. An empty box is placed on the packing stand, the worker places a tray in the bottom and then places the apples one at a time into the tray, places another tray in the box, and repeats until all four or five trays are filled. The fruits may or may not be wrapped as they are placed into the trays. When all layers of trays have been filled, the worker rolls the stand to the conveyor and puts the box onto the conveyor.

In both cases, before releasing the box, the worker will mark her designated packer number on one or both ends of the box.

SUPPLYING CONTAINERS TO PACKERS.—Empty boxes are moved to packers on an overhead monorail conveyor that circulates completely around the packing line, over the packing station, and past a fiberboard box makeup station. At the box makeup station, fiberboard boxes are placed on the conveyor, or, if the plant uses field lugs, wooden boxes are made up here and put on the conveyor. More commonly, when fruit is packed in standard boxes, loose fruit is moved to the packing line in new packing boxes. These boxes will be placed on the overhead monorail conveyor by the worker and go to the packing stations.

CONVEYING PACKED BOXES.—The packers place packed boxes of fruit on the powered conveyor; the boxes move along one side of the packing line under the sizing equipment near the sorting table, and back along the other side of the line. This permits all packed boxes to be taken to the lidding area on one conveyor. In addition, the packed boxes on the conveyor are all in the proper position when they get to the box lidder, regardless of which side of the packing line they come from. Should the number of boxes become too great or the lidder be held up for a time, the conveyor is designed to let the chain slip under the boxes, allowing them to accumulate (fig. 6).

Powered curved sections of the conveyor move packed boxes around turns and have proved to be a desirable addition to the handling equipment (fig. 7).

Quite often it is necessary for workers to cross over the packed box conveyors, so stepovers, illustrated in figure 7, are provided in the layout.

CHECK-WEIGHING.—Set in the conveyor line is a scale for check-weighing packed boxes or containers of fruit. The check-weighing is required quite frequently when switching from one lot of fruit to another, or when changing varieties. Normally, check-weighing is done only periodically to be sure that the minimum weights required by law are met.

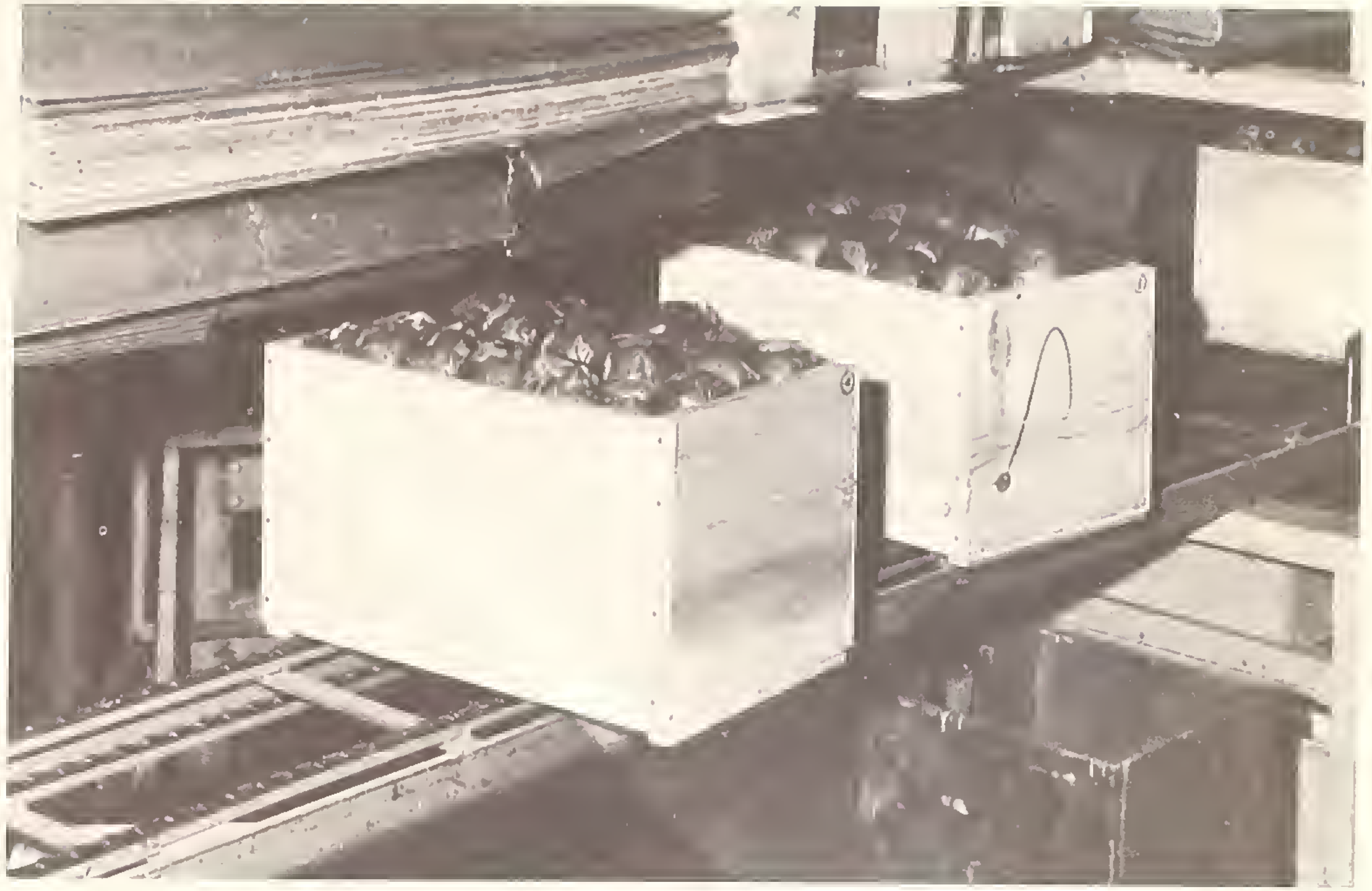

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FIGURE 6.—Conveyor for moving packed boxes of fruit to the lidding or closing machine, showing how boxes rest on the powered chain.

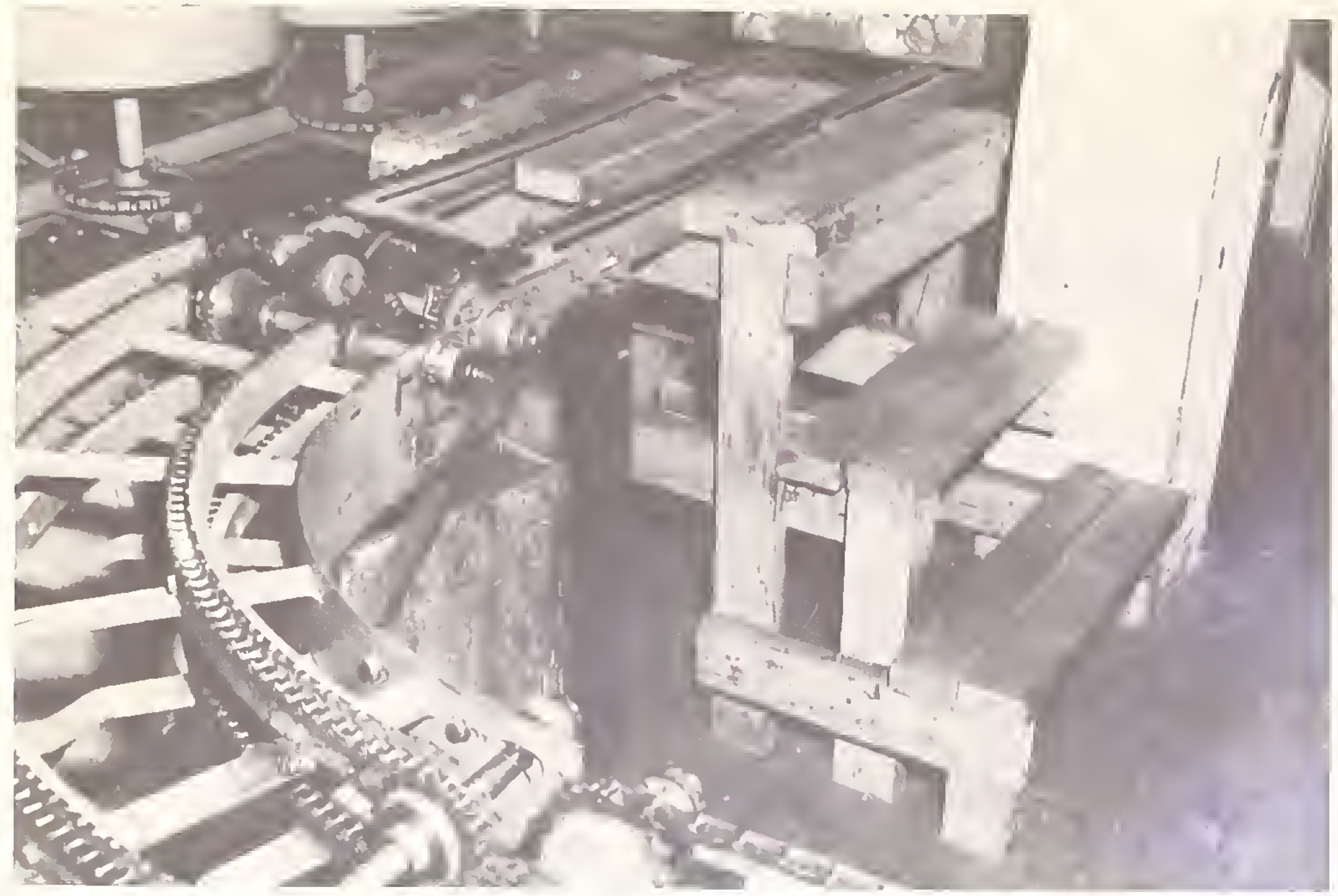

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FIGURE 7.—Powered curved section of conveyor. Note stepover which allows workers to cross over the packed-box conveyor.

STAMPING.—A section of gravity roller allows boxes to stop temporarily before going on to the lidding machine. A worker stamps the proper grade, variety, and size on the container. Stamping is nearly always done before lidding the container, so that the worker can see which size of fruit is in the box.

LIDDING.—Wooden boxes are lidded by machine; the conveyor moves boxes directly into it. The roller conveyor just ahead of the lidder not only serves as a stamping area, but accumulates boxes before they go into the lidder. This accumulating space is necessary to even the workload, and avoid interruption if the lidder should momentarily jam. To lid a box, a worker places a lid in the machine and as the box moves into the machine, the worker presses a foot pedal. The lid comes down on the box and is nailed to it. On most packs the worker places a pad on top of the fruit in the box to protect the fruit from the pressure of the lid.

LABELING AND TALLYING.—Labels are usually placed on boxes after they have been lidded; however, labeling can be performed before lidding. The worker is at a stand with a glue applicating machine, through which the labels are rolled to receive a coating of glue. The label is pressed against the end of the box and smoothed into place with a sponge. Another worker tallies the grade and size of the fruit and the number of the packer who packed the box. When the packing line runs at small capacity, both operations can be done by one worker, but at average capacity one worker would be required for each job.

SEGREGATING.—The conveyor at the discharge end of the lidder raises the boxes and gives them momentum so that they will move forward on a gravity conveyor. Here they accumulate and are lifted by the segregator, a worker who stacks boxes on pallets, according to grade and size of the fruit. The roller conveyor helps even the workload, because several boxes arrive at one time. As each pallet load is completed, the lift-truck operator moves the load to cold storage or to a loading area.

### Number of Workers Required

The number of workers needed to operate the packing line depends mainly on the rate at which loose fruit is supplied to the line. The maximum capacity of this line is 600 boxes per hour. Assuming, however, that the line is operated at the rate used in an average plant—420 boxes per hour—39 workers would be required (table 6, appendix). This number includes the supervisor, 18 packers, 8 sorters, and 12 other workers. If the fruit is of larger sizes, two fewer packers could be used, because large fruit takes less time to pack. If the major grade of apples are the smaller sizes, 18 packers would have difficulty keeping up with the rest of the line.

One lift truck operator is required to supply the line, handle culls and empty boxes, and transfer packed fruit from the segregating area. If long transporting distances are necessary for performing the work, this worker might often have more work than he can handle. At those times, he would require help from one of the other forklift truck operators in the plant. On the other hand, this worker may have time to help receive or load out when the line is running slow and transport distances are short.

One worker is needed to hand-truck fruit from the pallets onto the floor chain conveyor that feeds the dumper. He would work productively for about three-fourths of the time. Similarly, another worker, who places empty boxes on the monorail conveyor or pallets, and tends the small fruit eliminator, would work at less than full capacity. A practical arrangement is for one, or both, of these workers to change jobs periodically with the segregator, who must work at capacity on a tiring job.

With an average packout of fruit over the exact sizing line, it is estimated that eight sorters could handle the volume. When the lots are of high quality, sorters would not be working to full capacity. When the lots are of poor quality, the workers would sometimes have to work harder than usual.

Three workers would be used for bagging. Two workers operate the bagging machine, filling the bags and closing them; the third worker would pack the filled and closed bags into shipping containers. In a below-normal rate of operation, the two workers bagging fruit might also place the bags in the containers; the third worker would not be needed.

One worker each would be needed for the jobs of stamping, lidding, labeling, and tallying boxes. The workers who label and tally would not need to work at full capacity. When fruit is running to the smaller sizes, the rate of boxes leaving the pack-

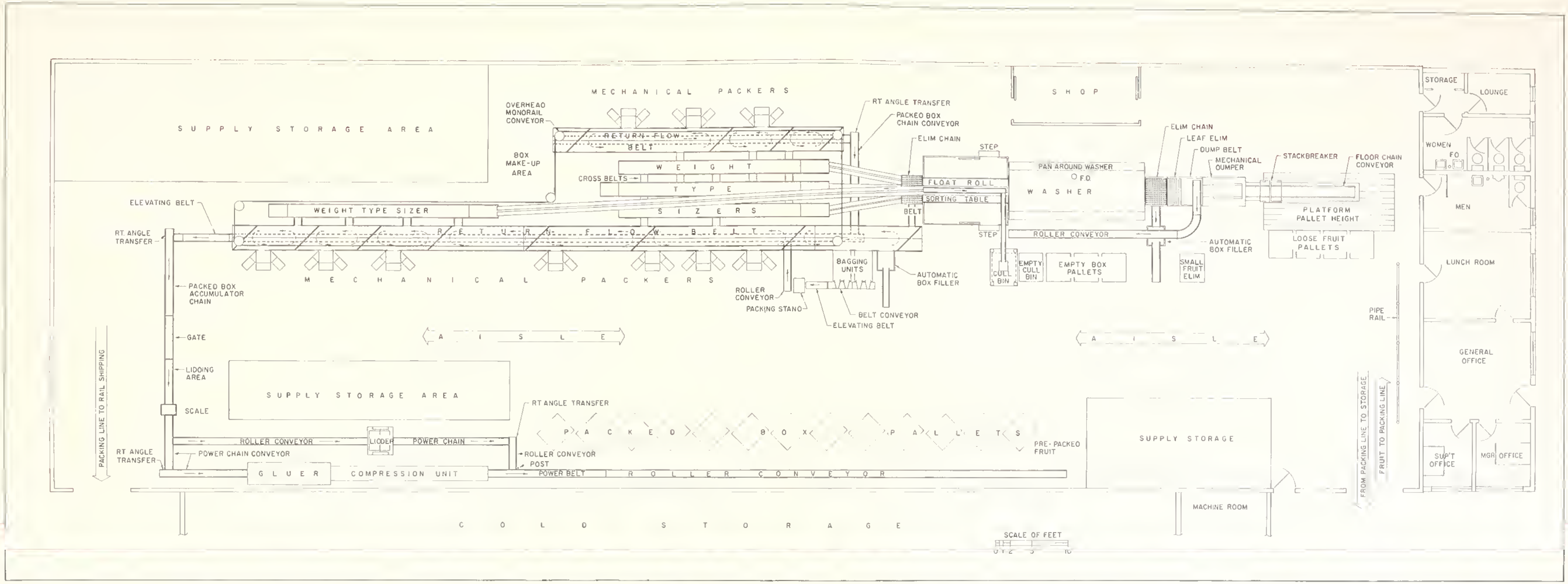


FIGURE 8.—Layout of a single-line packing room for group sizing.

ing line is relatively reduced; then, all of these workers might be working below capacity.

Segregating is done by one worker, but it might be necessary for the segregator to work above normal effort, at times, in order to handle the full volume coming off the packing line. Under these circumstances it would be desirable to have this worker periodically change assignments as described above.

One general worker is needed to furnish supplies to the packing line, and handle other general duties. When the work is sufficiently organized, this worker then might not operate at full capacity.

## A Packing Room Layout for Group Sizing

This layout is for group sizing and low-cost mechanical packing of apples from return-flow belt tables (fig. 8).

The layout is designed primarily for operators who pack on order and move the fruit directly onto carriers, rather than back into storage. It is assumed that most fruit is packed in trays in fiberboard boxes by semiautomatic packing machines. Consumer-size apples are automatically filled into bags or boxes.

This line may also be used to turn out the standard wrap-and-pack manually, or other types of packages as the market demands. Automatic box fillers could be used to fill loose fruit into cartons or boxes for sale or return to storage. Bagging machines could also be used along the packing table.

Average capacity of the line, using the semiautomatic packing machines and a total of 27 workers, is over 420 boxes of loose fruit dumped per hour. Maximum capacity is 600 boxes per hour.

This line is designed for sorting apples into two grades only, and would require additional equipment for packing three grades.

### Equipment Required

In this layout the weight sizer is used for group sizing, with the units placed side by side. The dimension sizer may also be used for group sizing, but the weight sizer was selected for this layout to show how presently owned equipment can be used in a newer type of packing operation. Many operators now have weight sizers. The dimension sizer is shown in the layout for the double packing line.

Other principal items of equipment are the same as those in the exact sizing line as far as the eliminator at the end of the sorting table. There is one difference in this part of the line: Culls are conveyed a shorter distance. From the eliminator for bagging-size apples on, the packing line differs greatly from that previously described. The items of equipment are:

Stack-breaker, with a 10-foot floor-chain conveyor for moving stacks of boxes into the stack-breaker.

An automatic drum-type dumper.

A 25-foot gravity conveyor and gravity curved section, for moving empty boxes from the dumping station to the empty box area.

A 3-foot section of 48-inch wide belt conveyor on which dumped fruit is released; it serves as a dumping apron.

A 2-foot leaf eliminator like that in the exact sizing line.

A 3-foot chain or wire-screen eliminator for eliminating juicer apples with a power belt conveyor extending 3 feet to an automatic box-filler.

An automatic box-filler for filling juicer apples into boxes and a 5-foot gravity conveyor.

A washer with wash, fresh rinse, and drying sections.

A 12-foot float-roll sorting table.

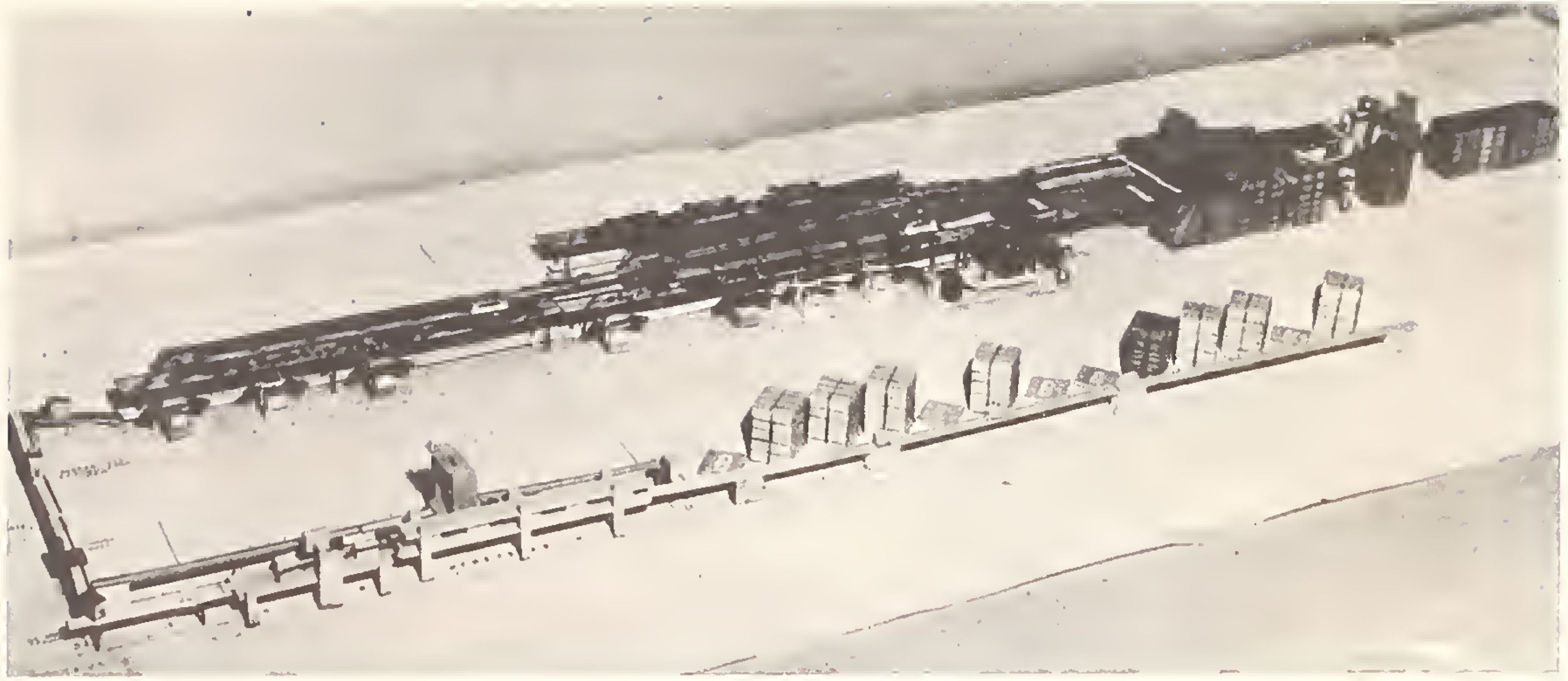

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FIGURE 9.—Model of a packing line for group sizing.

A 24-foot belt conveyor for moving cull apples from the sorting table.

A cull lowering device for filling cull apples into large pallet boxes or tote bins.

Narrow belt conveyors of various lengths above the sorting table and beyond the eliminator, for conveying apples to each section of the sizer.

A 3-foot chain, or wire-screen, eliminator for removing bagging size apples of the major grade, and a power belt conveyor that extends 3 feet to a return-flow belt packing table.

Four double-sections of weight sizers.

Five 10-foot cross belts running under three double sections of sizing equipment.

Two return-flow-belt packing tables, with two 20-inch wide belts. One table is 40 feet long; the other, 96 feet.

Ten semiautomatic packing machines with tray racks and conveyor connections to the main packing tables.

One automatic box-filler, with the necessary lengths of gravity conveyor, for holding supplies of boxes.

Two bagging machines, with a 10-foot belt conveyor for moving bagged apples from the bagging machine to the packing stand or station, and a 6-foot gravity conveyor to convey the boxes to the main conveyor.

A 220-foot power chain conveyor with drives, motors, and right-angle transfers for conveying packed boxes to the case sealer and the lidding areas. A 97-foot gravity roller conveyor and a 16-foot power belt conveyor for accumulating boxes before lidding.

One scale for weighing boxes of fruit.

One power lidder.

One case sealer with a compression unit.

A 200-foot overhead conveyor for conveying empty boxes to the packing stations.

Two optional items of equipment might also be included. Fourteen gang adjustors for tying together the spring adjustments on sizing scales; all positions can be adjusted simultaneously from one position. Two or more mechanical box transfers for lowering the packages of larger apples of the two different grades that will be packed by hand onto the main conveyor.

### Description of Layout

The packing room layout for a group-sizing packing line is shown in figure 8. This line can operate at high capacity, without workers in one area interfering with those in another. The layout features are essentially the same as those in the exact sizing line. The packing line proper is essentially in a straight line.

In the group sizing layout, the segregating area is moved to one side of the room, and an aisle for industrial lift trucks runs between the packing line and the segregating area. This makes handling supplies convenient, and minimizes the transportation distance from the segregating area to the outside door. It is desirable in a mechanical packing operation to provide space for storing fiberboard box supplies behind the workers. The layout arrangement provides this space.

The packing line is designed for packing two grades. The major grade is packed on return-flow conveyor tables at either side of the sizing machine. About 40 feet of one of the return-flow belt conveyor tables would be used to pack the minor grade.

In this packing line arrangement, as with the previous one, only a small amount of office space is needed. In fact, less office space may be required because a smaller crew is used when mechanical packing is done.

### Description of Operations

The essential operations of this packing line may be visualized by referring to figure 9. Many operations are the same as those of the exact-sizing packing line: Supplying the line with loose fruit; dumping; empty box handling; leaf eliminating; eliminating juicer apples; washing; and sorting. Operations which are not the same are discussed below.

HANDLING CULL APPLES.—The method of handling cull apples with the group sizing line is the same as for the exact sizing line, except that culls are conveyed a shorter distance to the pallet box. The return-flow bagging table in the exact sizing line is no longer needed, and there is room for the cull bin nearer the sorting table.

HANDLING BAGGING APPLES.—Bagging apples are conveyed from the eliminator at the end of the sorting table onto the end of the return-flow belt packing table. A box-filler, or bagging units, handles the fruit. It is similar to that described for the exact sizing line, with one variation—after the bagged apples are placed in the master container, they roll by gravity conveyor onto the main packed-box conveyor under the sorting tables. The boxes of bagged apples move through the case sealer to the segregating area, where they can be conveniently handled with all other packed containers.

SIZING.—While sizing in this packing room layout is done by exact-weight machines, the sections of weight sizers are arranged side by side, and are used for group sizing (fig. 10), except for a sizer for the minor grade. Only a part of the weighing posi-

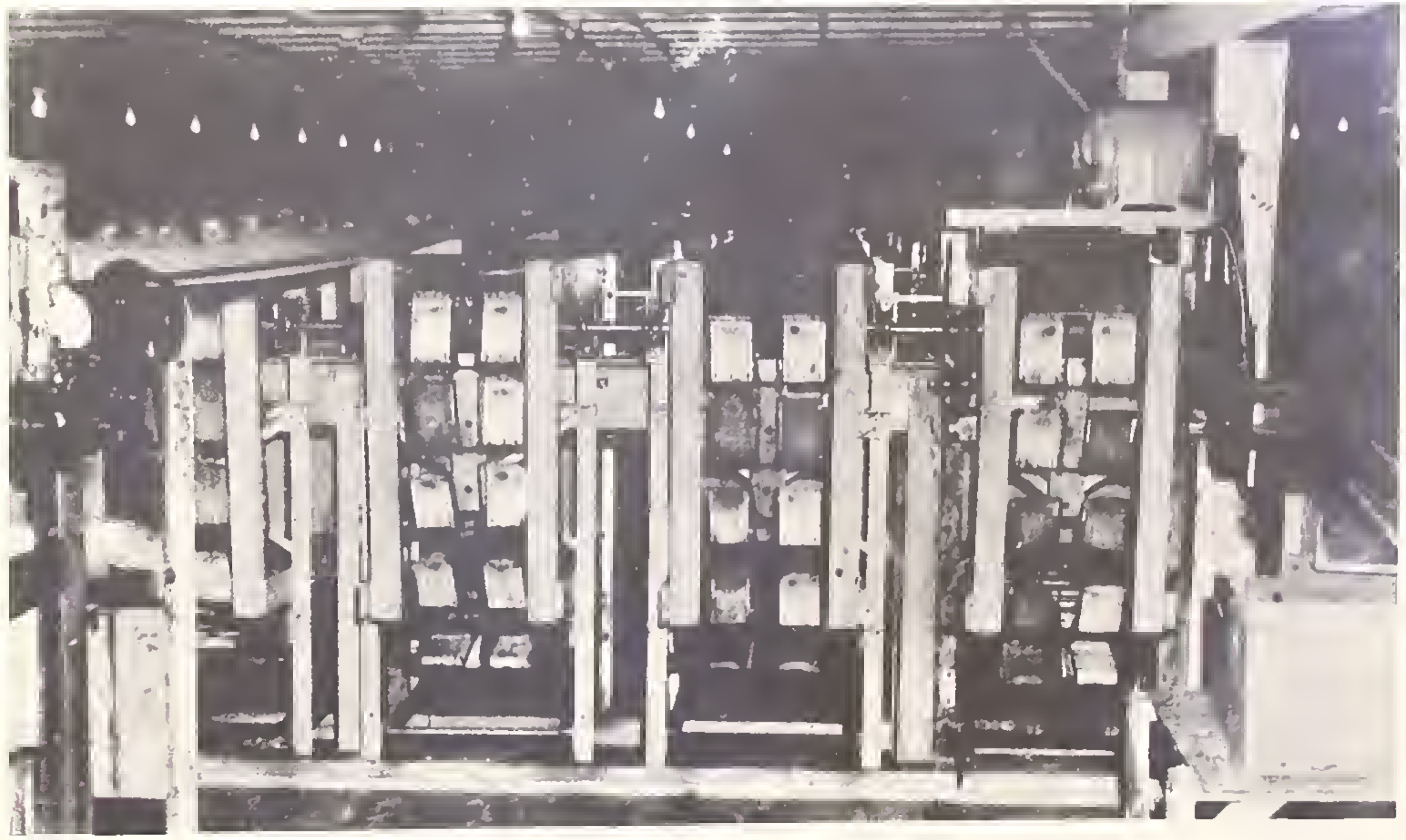

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FIGURE 10.—Sections of weight-type sizers arranged side by side for mechanical group-size packing.

tions on each section of the sizer is used. Belts, at right angles to the sizer, convey the apples of each size group to return-flow-belt packing tables on both sides of the sizer. Alternate belts move the fruit to the right and the left of the sizer. If the volume of fruit of a particular size going to one position should become too great, the amount of space devoted to that size group on the return-flow-belt packing table can be increased by changing the position of the shunt. The layout is designed so that a peak size and a nonpeak size will usually adjoin each other on the packing table. Since this research was completed, improved machinery has been developed. Converters of older facilities may need the equipment described; constructors of new plants should determine the equipment best suited to their operation.

Packing.—This operation is semiautomatic (mechanical). Figure 11 shows one packing machine with a rack on either side for a supply of trays. These machines are so located that if there is a shift in the peak of size groups, an appropriate shift can be made in the machines by moving a shunt on the return-flow-belt table.

In using the semiautomatic packing machine, the operator removes a fiberboard box from the overhead monorail conveyor, or, more often, makes it up from a stack of collapsed cartons behind her. She folds the carton and places it into position in the machine, puts a tray in the rack provided for it, fills the tray and straightens the fruit, then releases the tray into the box. The box contains 4 or 5 trays. She ejects the box by pressing a foot-operated pedal (fig. 12). The filled box then rolls onto the main conveyor, underneath the return-flow belt conveyor packing table, and moves on to the lidding and case sealing areas.

A manual wrap-and-pack operation can be carried on at this packing table by using packing stands with the operators packing directly from the return-flow belt table (fig. 13). The boxes could be placed on the main conveyor under the return-flow belts by roller box transfer (fig. 14), which gently lowers boxes from packing-stand height to the low conveyor.

Conveying Packed Boxes.—In this layout, all packed boxes are conveyed under the return-flow belt packing tables by a chain conveyor (fig. 15), which takes the boxes or cartons directly to the lidding and case sealing area.

Stamping, Lidding, and Tallying.—This work varies with the type of carton or container. If full telescope boxes are used, a worker folds the tops up and places them on filled boxes, ready for the case sealer. If regular slotted cartons (RSC) are used, the lidding operation is eliminated because the top is part of the filled box.

If telescope fiberboard containers are used, stamping and tallying could very well be combined with lidding by prestamping stacks of tops for various sizes, then folding and placing the proper top of each container of apples. Precounting the tops would record what was packed. If packers are paid by the hour, it would not be necessary to record each packer's work, and the rest of the task of tallying could be eliminated.

Another alternative for stamping and tallying would be to place automatic stamping devices and counters on the mechanical box fillers, so that the containers would automatically be stamped and counted (fig. 16). Stamping could be combined with packing, by putting an automatic roller stamper at each packing station.

Still another method of stamping, used with mechanical packing of RSC cartons, is to prestamp the stacks of flats.

Tallying also could be done by one other method: Counting the number of pallet loads of each size and grade of fruit that is packed and stacked at the segregating area during the tally period.

Labeling.—When mechanical packing is done, it is the general practice to use preprinted containers. The printing includes the brand name, so labeling is not necessary.

Segregating.—Segregating packed fruit at the group size packing line is essentially the same as at the exact size packing line except that fewer separations are needed with the smaller number of size categories. However, if both wood boxes and

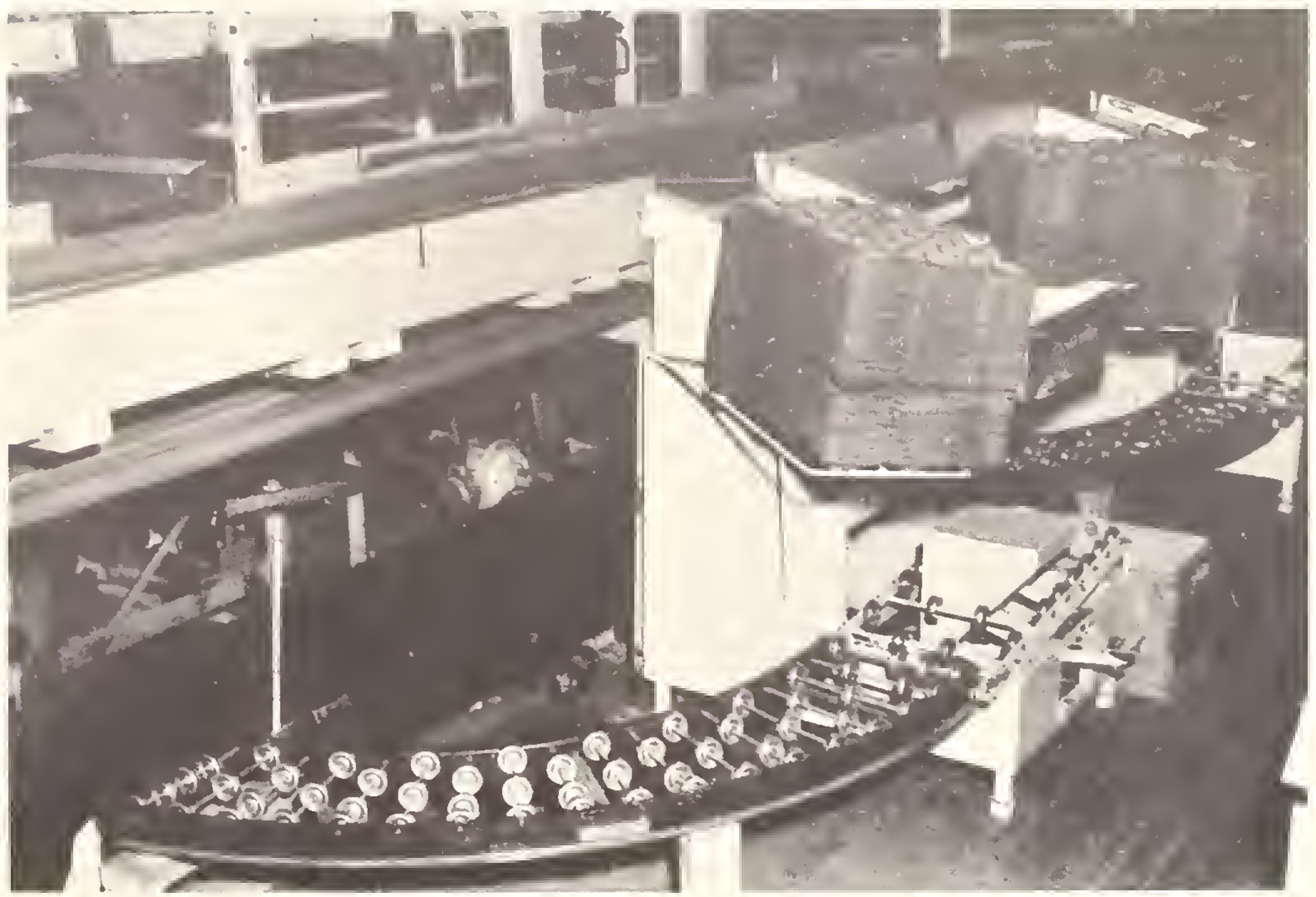

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Figure 11.—A semiautomatic (mechanical) tray packing station.

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Figure 12.—The filled box is ejected by depressing the pedal, which permits the packed box to roll onto the conveyor.

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FIGURE 13.—Worker packing fruit in the standard box (wrap and pack) from a return-flow belt conveyor.

fiberboard containers are packed at the same time, there may be a lot of necessary separations, unless the two types of containers are used for different grades.

### Number of Workers Required

The main feature of the group sizing packing line is the use of mechanical packing equipment. This reduces the number of workers required in the plant, and simplifies some operating problems. It is estimated that 27 workers, including the supervisor, are needed in the packing room to perform packing and associated operations (table 6, appendix). Of these workers, only eight are packers. Even though the packing crew is small, it is able to handle fruit at a rate of more than 420 loose boxes an hour. The maximum capacity of the line is estimated to be 600 loose boxes per hour, like the exact sizing line, because both lines use the same amount of sizing equipment. Fast and well trained workers using semiautomatic packing equipment have been known to pack at twice the average of 40 boxes per hour.

The number of other workers in the plant is the same as for the exact sizing line. Bagging also requires three workers, unless the volume of bagging fruit is low enought to permit these workers to place bags in the master containers. Then, the bagging crew could be reduced by one worker.

One worker is needed to stamp containers. If the fiberboard flats are prestamped, part of the time of this worker could be used to assist in other operations. Fiberboard containers are closed automatically by a case sealer. No worker is required, other than for occasional maintenance. If full telescope boxes are used, the time of one worker will be needed to place the outer telescope lid over the box. This worker could also stamp.

One worker is needed for tallying the boxes; this can be combined with other operations, by tallying boxes after they have been placed on the pallets, or by attaching counters to the mechanical packing machines.

Because fiberboard containers usually are printed with the label on the ends, no labeler is required.

The work of segregating and providing supplies for the packing line is essentially the same as for the exact sizing line, and requires two workers.

## Two-Line Packing Room Layout—Exact and Group Sizing

This layout is developed around two packing lines—one for exact sizing and manual packing, and the other for group sizing and mechanical packing.

The two-line layout provides both flexibility in type of pack and packing capacity for a large volume of fruit. The layout is designed primarily for operators of large plants who store loose fruit and pack out a large total volume during the marketing season, and for operators of medium-size plants who do not store loose fruit, but pack as rapidly as fruit is received.

The exact sizing line is specifically designed to turn out the standard wrap-and-pack, but may also be used for manual packing of tray packs. The group sizing line is specifically designed for semiautomatic packing of the tray pack, but it can readily be adapted to manual packing of the standard wrap-and-pack or other types of pack, if this is what the market demands. Both lines use bagging machines for consumer-size apples.



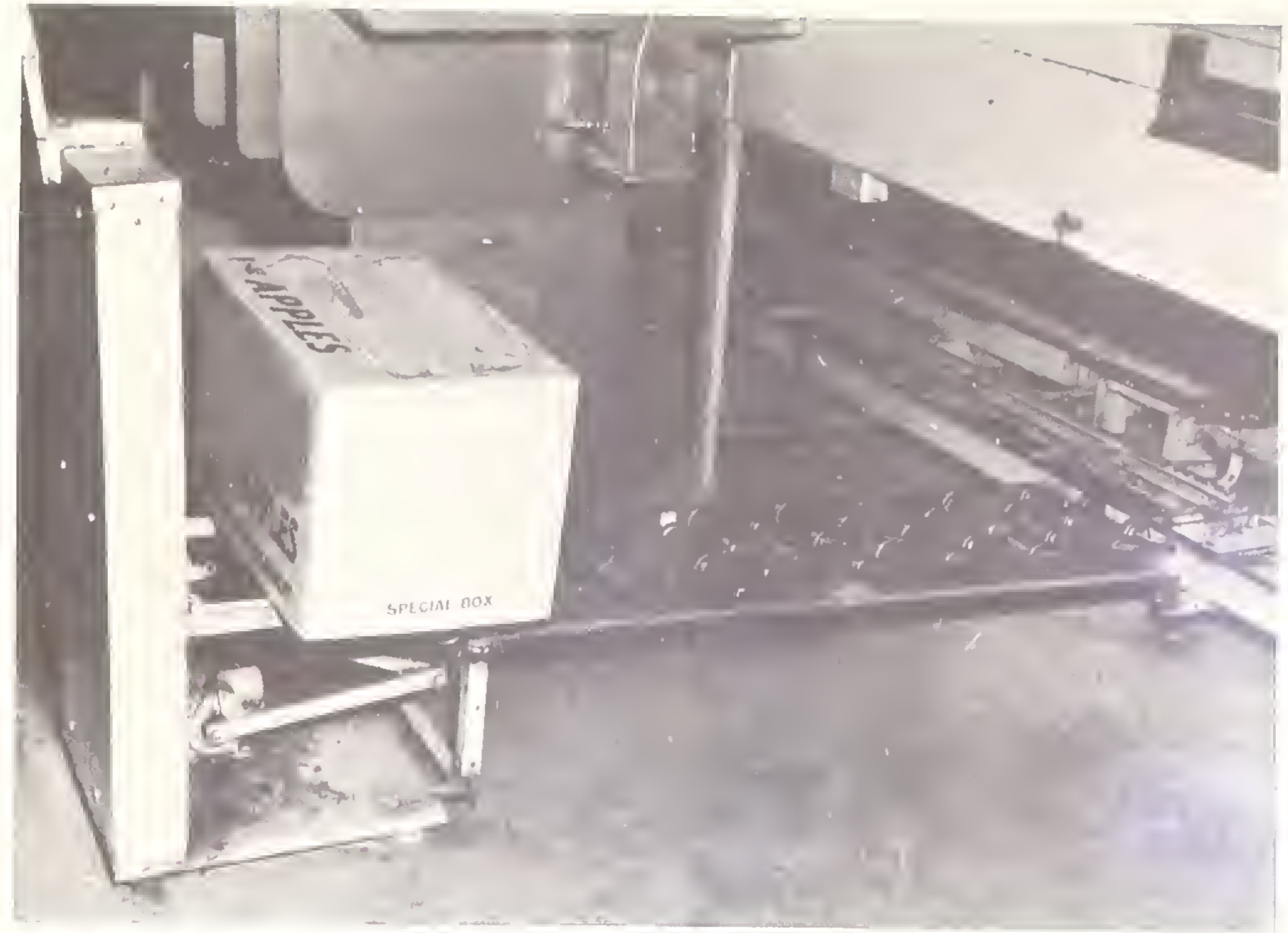


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FIGURE 14.—A roller transfer used to lower and move boxes from packing stand to conveyor under packing table.

Total capacity of the lines, when the exact sizing line is turning out the standard wrap-and-pack and the group sizing line, the tray pack, is 920 boxes of loose fruit per hour. Total labor requirements for this capacity are 68 or 69 workers. Maximum capacity of the lines is 1,300 boxes per hour.

The dimension sizer, which is of greater capacity than commonly used weight sizers, is used in the group sizing line in this layout for the major grade of fruit, which accounts for the increased capacity of the combined lines.

Both packing lines are designed for sorting apples into two grades. The exact sizing line may easily be converted to sort three grades by installing a belt-conveyor for the third grade over the sorting table, to deliver this fruit to one or more sections of the sizer.

### Equipment Required

The equipment used for the exact sizing line in this layout is the same as that described earlier, except that the overhead monorail conveyor is about 50 feet shorter. Its overall length is approximately 285 feet.

The main difference in equipment between the group sizing line in this layout and the single line layout is in the use of the dimension sizer. The equipment up to the discharge end of the sorting table is the same. The dumper and dumper-feed chains, however, are at right angles to the packing line in this layout.

The eliminator for bagging apples is not required at the end of the sorting table, because the dimension sizer also serves as the eliminator.

Items of equipment that are the same as for the single line layout are:

- Ten semiautomatic apple packing machines, with connecting conveyors and transfers;
- One automatic box filler for bagging size apples;
- Two bagging machines, with approximately 10 feet of chain and belt conveyor to carry the bagged apples to a packing stand; and
- One case sealer with compression unit and scale for weighing packed containers.

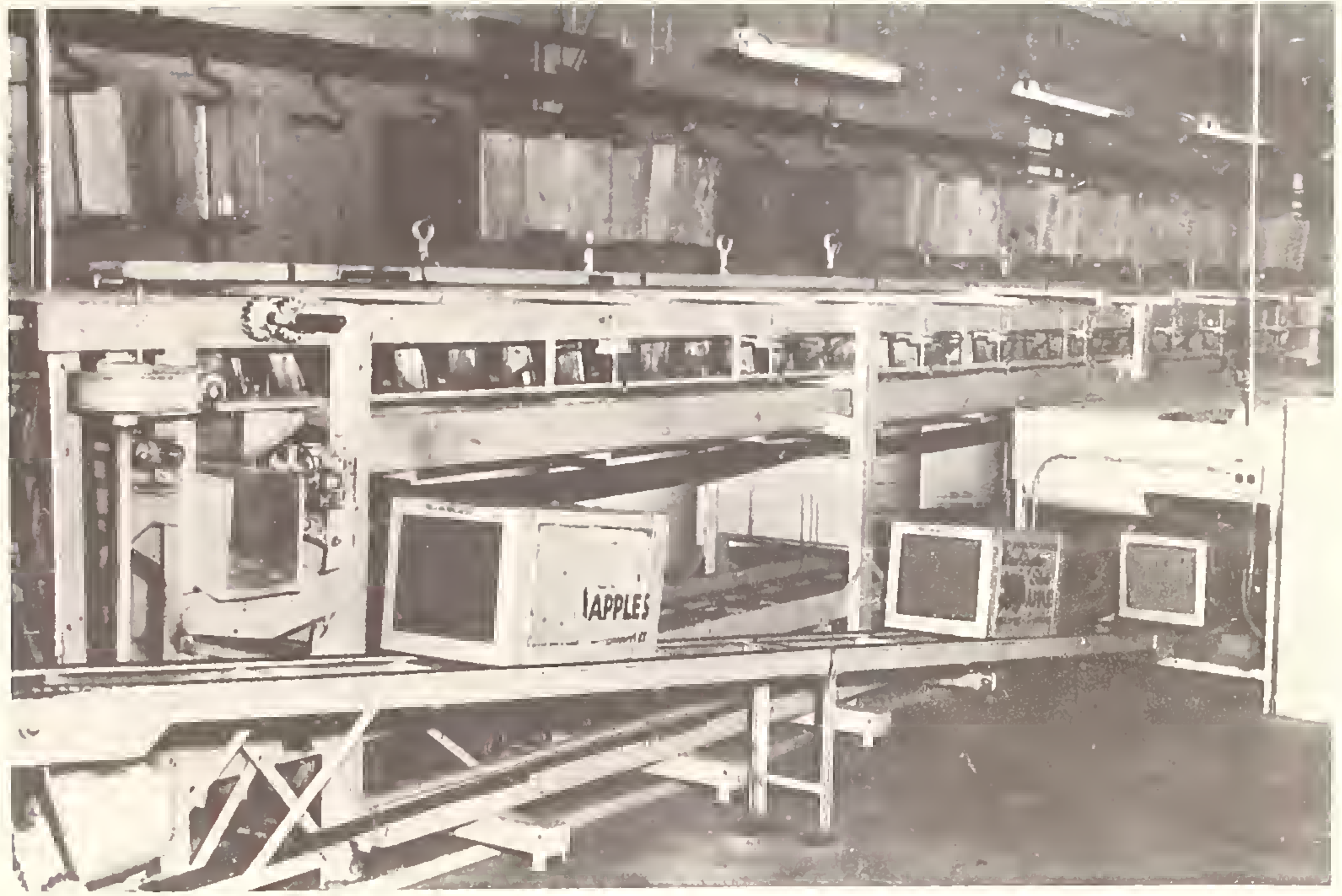

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FIGURE 15.—Packed cartons of apples being elevated to working level by chain conveyor from under the return-flow belt packing table. From here the cartons move to the case sealing area.

Additional items of equipment are:

Two return-flow-belt packing tables, consisting of two 20-inch-wide belts, one table 80 feet long and another 60 feet long.

One 187-foot chain conveyor, running underneath the return-flow-belt packing tables, and connecting with other conveyors to move fruit to the segregating area. Part of the same conveyor system also consists of 8 feet of belt conveyor, for raising boxes from the low conveyor to the regular conveyor level, and 60 feet of roller conveyor for accumulating apples at the segregating area.

A 52-foot distributing belt, used to distribute apples from the sizer to the return-flow-belt packing table for bagging apples.

One 14-foot dimension sizer, 4 feet wide, with take-away belts for five group sizes (fig. 17).

One section of weight sizer for sizing the second grade of fruit, with approximately 50 feet of double-wing feed belt to convey the apples from the sorting table to the sizer.

### Description of Layout

Figures 18 and 19 show the details of the layout. A main aisle for industrial lift trucks is between the two packing lines. This aisle serves both segregating areas, to conserve space. The mechanical packing line is the shorter of the two and is arranged with the dumping area at a right angle to the packing line, to shorten it further. This permits the lift trucks to have access to the ends of both lines without crossing any work areas.

In this layout, the work space and the doors are so arranged that the main supply area is best located near the ends of both lines; here it does not interfere with work areas or aisles. Additional space is provided around the mechanical packing line for supplies; this space is necessary because the fiberboard containers used with this line are rather bulky. Supplies are conveniently at hand and yet do not interfere with production.

Office and rest room facilities are somewhat larger than those in the previous layouts, to accommodate a larger crew and greater volume of business.

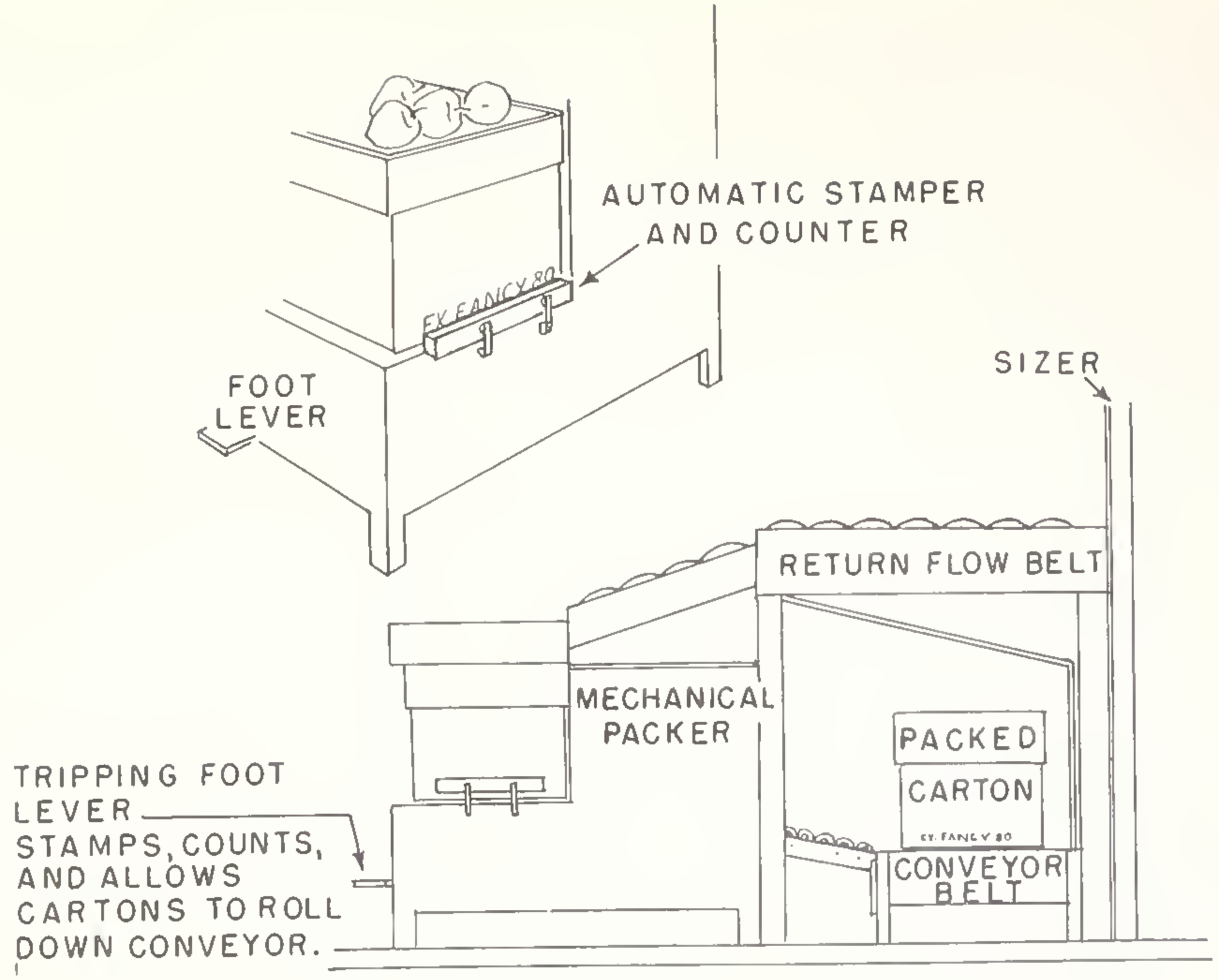


FIGURE 16.—An automatic stamper and counter used with a mechanical packing machine.

### Description of Operations

With this two-line packing room layout, the operations are identical with those for the exact sizing line and group sizing line; each of the two lines is a complete packing unit in itself (fig. 18). There is, however, a possible variation in operations for bagging-size fruit.

Perhaps the best operation would be to bag fruit from both lines at the bagging table of one line. Bagging sizes from the other line would be accumulated in loose boxes and transported by lift truck to this table. Combining the operations might make it possible to reduce the bagging crew by one or two workers. Whether this method is used depends on the rate with which the bagging sizes accumulate from a particular lot of apples, and whether or not the bagging sizes can be pooled into one lot.

### Number of Workers Required

The average output of the two lines would be 920 boxes, with 420 boxes packed in the exact sizing line and 500 on the group sizing line. The maximum output would be 1,300 boxes—600 with the exact, and 700 with the group sizing line. Approximately 68 workers are required to achieve these outputs (Appendix, table 6). These workers would be assigned as follows: 37 to the exact line, 28 to the group sizing line, and 3 would divide their time between the two lines.

Moving pallet loads of loose fruit, culls, empty boxes, and bagged fruit would require two workers, using lift trucks. Hand-trucking stacks of boxes from the pallets to the start of the lines would require two workers. Stacking empty boxes and placing boxes on the overhead monorail conveyor would also require two workers.

There is a difference in the number of sorters required, compared with the two single lines discussed previously. Each of these lines required eight sorters. The group sizing line in this layout is operated with a dimension sizer which can handle a greater volume. To supply fruit for this greater volume, it is necessary to have two additional sorters, making a total of 18 sorters for the two lines.

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FIGURE 17.—A high-volume 12-foot dimension sizer with 4 take-away belts.

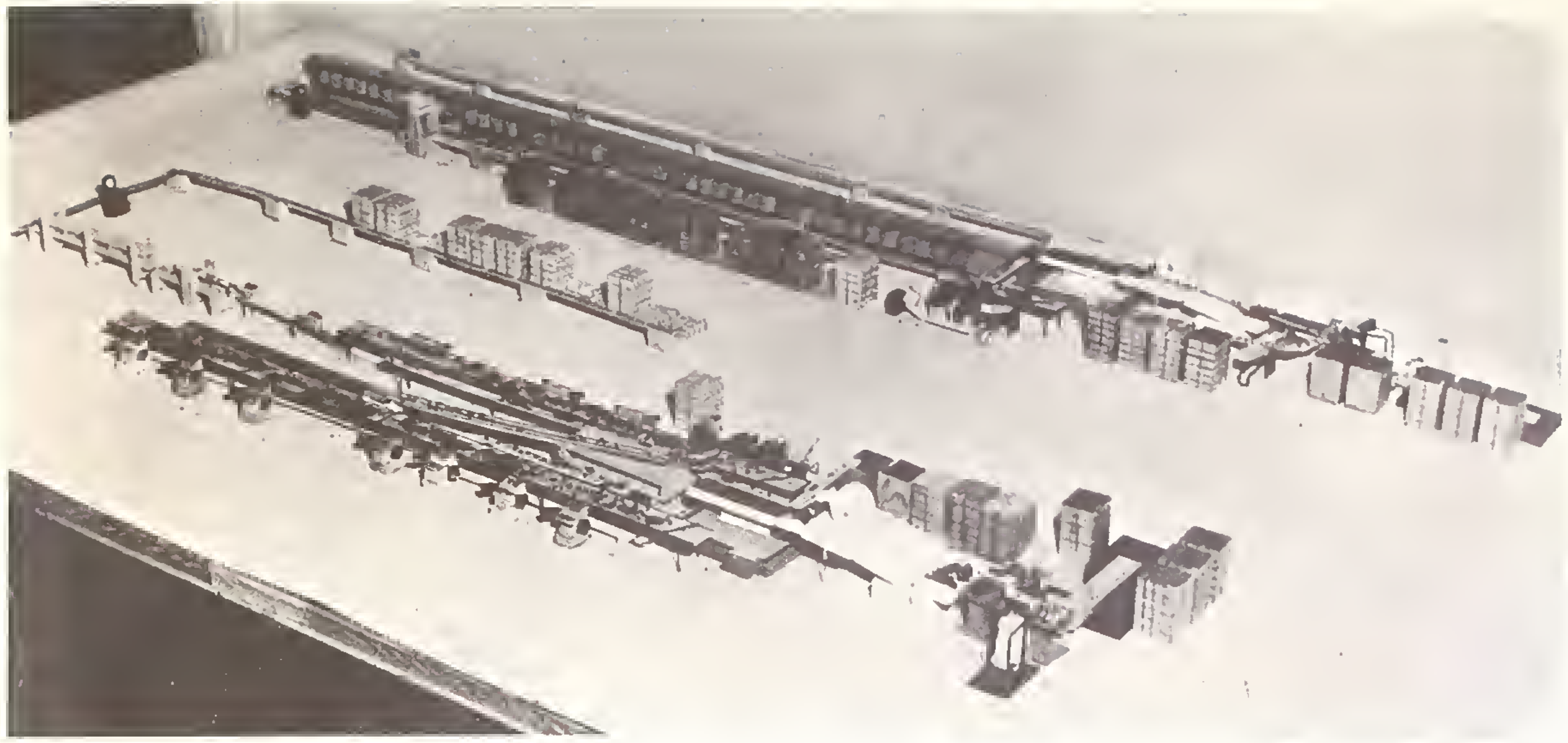

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FIGURE 18.—Model of equipment for a two-line packing room—one line for exact sizing and the other for group sizing.

Because of the increased volume moving over the group sizing line, one additional packer is needed. This means 9 workers on mechanical packing and 18 on wrap-packing.

With some methods of operation, the number of workers bagging fruit would be the same as on the two lines separately—six workers. During slow periods, the workers could place the bags directly in the master containers, rather than using an additional worker. Then four workers are needed. Accumulating the loose fruit in boxes on the one line, and bagging it on the other line can also reduce the number of bagging workers from six to four.

Stamping containers, lidding and closing packed containers, tallying, labeling, and segregating are the same as for the two separate lines. Eight workers are required, unless some of the variations in tallying and stamping boxes discussed under the single line for group sizing are used.

Combining the two lines in one room allows one supervisor and one man supplying the packing lines to serve both lines. An additional worker is required for maintenanee to relieve the supervisor of some of this work. (In the single-line layouts, the supervisor might do some maintenance work, and may be helped by the worker handling supplies.)

## STORAGE ROOM LAYOUTS

Layouts are developed for three cold-storage rooms of the following standard-box capacity: 25,000, 50,000, and 100,000.

All storages are of one-story design to facilitate lift truck handling of fruit. The layouts are planned to provide proper air circulation for the stored fruit and to minimize space requirements and construction costs.

The storages are designed for completely automatic refrigeration systems. Outside areas for receiving and shipping fruit are paved. Parts of these areas are covered to provide both protection from the weather for handling operations and storage for empty boxes or other supplies.

The two larger storages are designed around 48- by 40-inch pallet loads of 48 unpacked boxes of apples, and the small storage, around 36- by 40-inch loads of 36 unpacked boxes of apples without pallets.

### Storage Pattern

In the two larger storages, pallet loads are stacked three-high; each pallet load is six boxes high. The unit loads in the smaller storage are six boxes high, and are stacked two loads high.

Each storage has only one main aisle. Cross aisles take up valuable storage space and are unnecessary when lift trucks are used.

The pallets or unit loads are stored in single rows, facing the center aisle, with a 6-inch space between each row. An 8-inch space is left along the side walls and a 9-inch space at the back wall. These spaces are provided to permit proper air circulation, facilitate handling operations, and prevent damage to the walls and insulation.

### Air Circulation

Refrigeration units are installed over the center aisle (fig. 20). Air circulates from the center of the rooms outward to the walls, down through and between the rows of fruit, and back up through the center of the room.

### Storage-Room Dimensions

The dimensions of the rooms are designed to keep the rows of stored fruit as short as possible for convenience of checking fruit quality and removing specified lots, and to use roof trusses of a standard length to keep costs low. Short pallet rows are

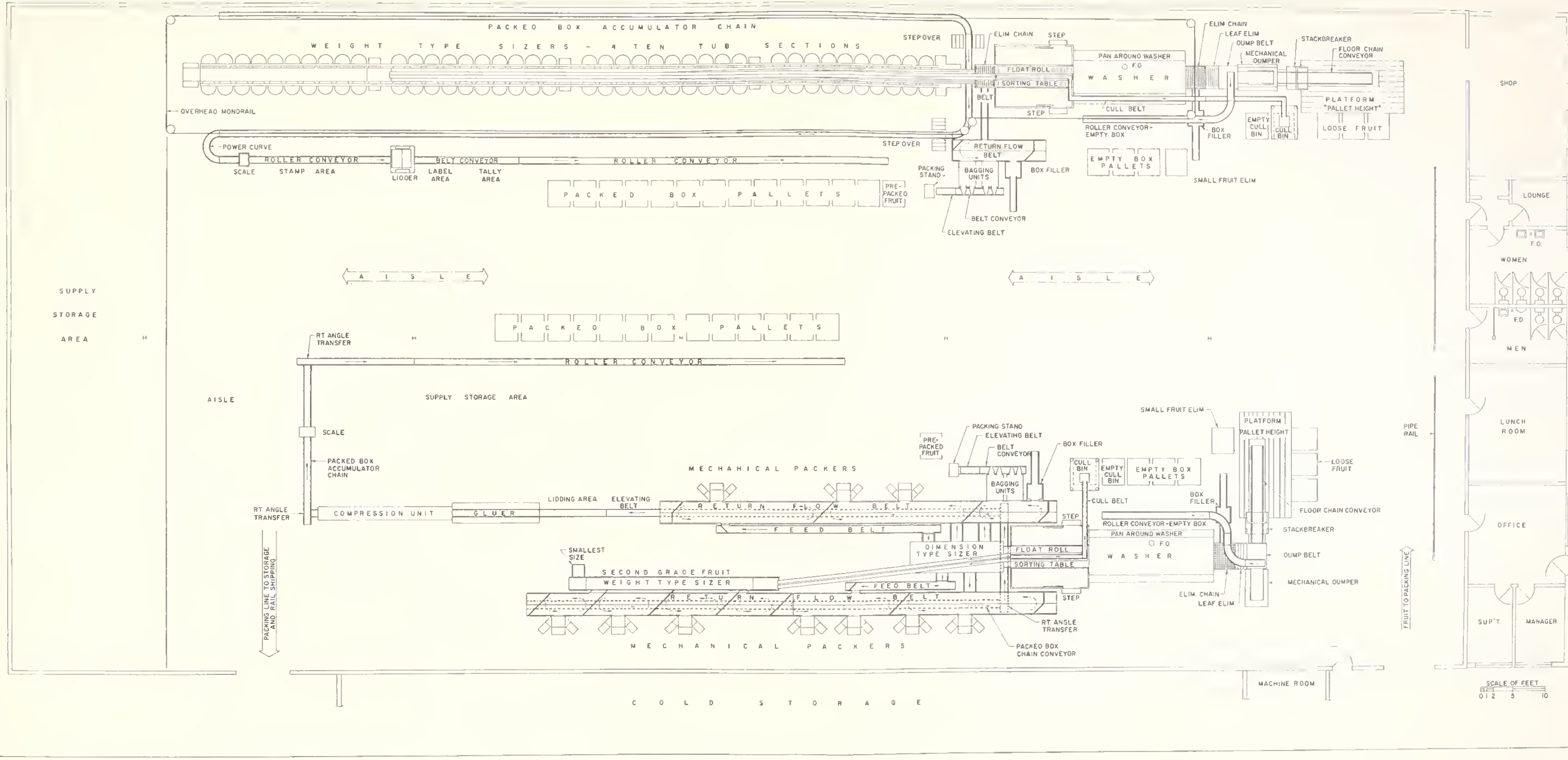


FIGURE 19.—Layout of a high-volume two-line packing room for exact and group sizing.

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FIGURE 20.—Refrigeration units in the truss area of the storage room. Lights mounted on the trusses down the center aisle are directed to shine parallel to the rows of pallets.

preferable for storing fruit from a number of growers or for many small lots of apples of different variety and grade.

In the two larger storages, the clear height under the trusses is 21 feet, to allow ample space for circulation and to position and remove the top load.

Normally, pallets holding packed fruit will be stacked 5 boxes high, so that a clear height of 20 feet under the trusses would be adequate. These storages are designed to accommodate 6-box-high pallet loads, to provide ample space during peak production years. The extra space is worth a great deal compared to the small cost of extra construction.

The main aisle is a minimum of 12 feet wide. Doorways at each end of the aisle are a minimum of 8 feet wide and 10 feet high, to accommodate industrial lift trucks.[3]

## Lighting

Lighting of the storage rooms provides sufficient illumination for handling operations without increasing refrigeration requirements.

The lights are installed over the center of the main aisle and are directed outward to the back walls so that they illuminate the length of the storage row (fig. 20). This type of installation is less expensive than placing lights all over the room. The switches are arranged so that lights need be turned on only in the section of the storage being used.

Lighting is also provided for the outside receiving and shipping areas. These areas may be used at night, and some lights may also be left on all night for security.

## Receiving and Shipping Areas

Truck loading areas or aprons are of ample size, to enable several highway trucks to unload at one time, with space between them to permit forklift trucks to operate on either side. A minimum of 15 feet is allowed between trucks.

Unloading areas are paved and properly sloped for adequate drainage. Paved areas should be smooth and permit fast forklift truck operation. During the winter, unpaved unloading areas would soon be a mass of mire, and interfere with unloading operations.

If possible, it is recommended that the fruit unloading area be put on the east side of the building, away from the prevailing wind. This will provide some shelter against strong winds.

The covered areas have been designed 19 feet, 3 inches high, to permit stacking pallet loads 3 high. A minimum of posts and columns is used to allow freedom of fruit handling with a minimum of interference.

Another feature, common to all of these storage-room layouts, is that they are planned for quick receiving and shipping. The receiving period is usually the busiest time of the year, so the layouts are made as efficient as possible by locating the covered receiving areas near the cold-storage rooms.

## Future Expansion

One of the more important considerations in designing a storage, and one that is frequently overlooked, is providing for future expansion. It is difficult to generalize plans for expansion because so much depends upon the proximity of roads and railroads, and topography of the particular site. In the layouts discussed here, provisions for expansion have been made on the assumption that the topography is rather uniform. The direction of expansion is determined almost entirely on the basis of the efficiency of fruit handling in relation to the location of the packing line and the rail siding.

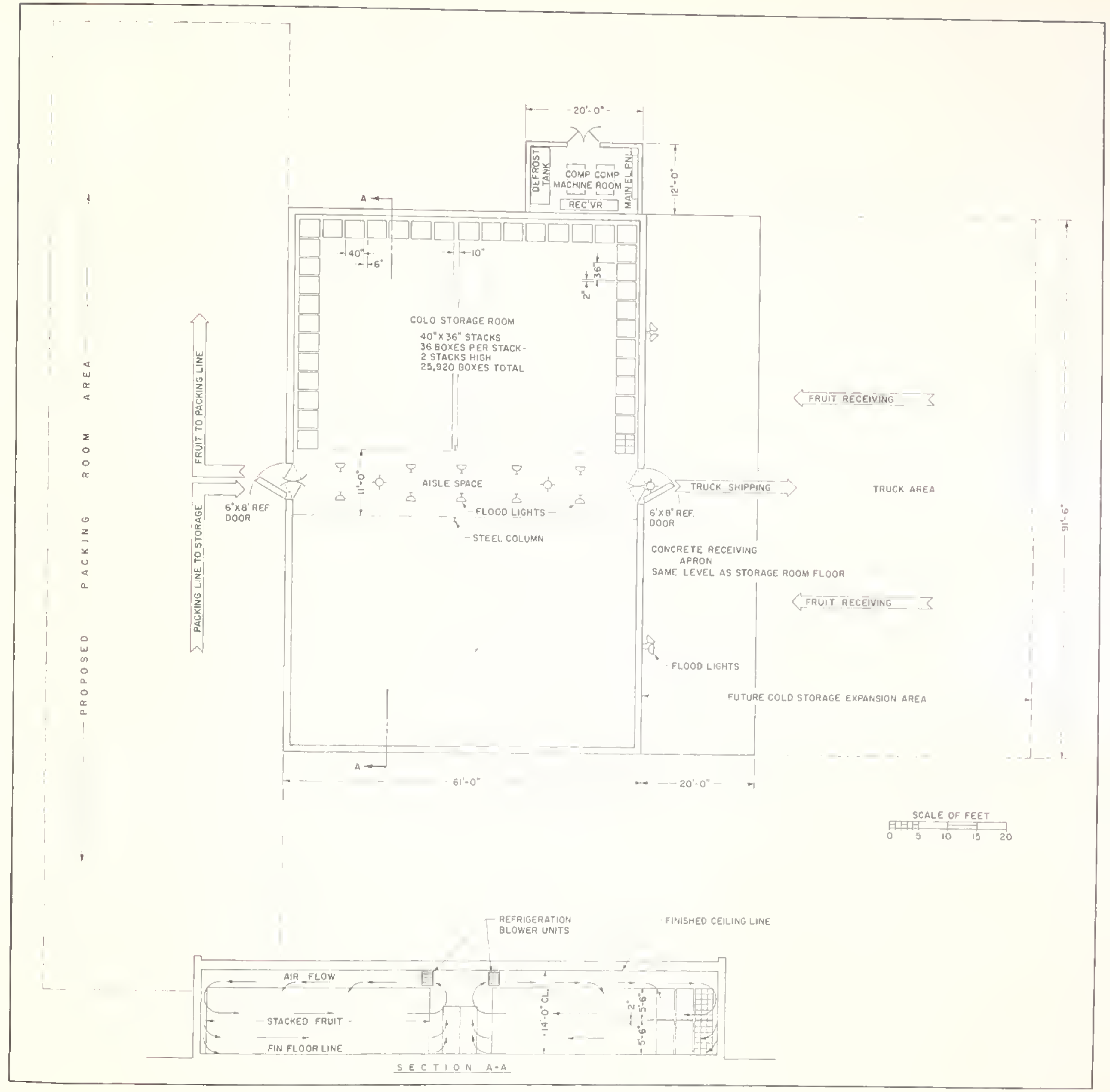


FIGURE 21.—Layout of a 25,000-box-capacity refrigerated storage room.

[3] Doorways of cold-storage rooms are usually equipped with batten or bumper doors, as described on page 20. Air doors, which are becoming increasingly popular, might be substituted for the batten doors.

## A 25,000-Box Storage

### General Characteristics

The cold-storage room designed for the 25,000-box plant is shown in figure 21. It actually holds 25,920 loose boxes of fruit. This type of storage is suitable for the small ranch or farm operated by a grower with his family, and several full-time employees. Extra help is hired during the packing season. Although this type of storage seldom would be expanded, provision is made in the layout for an expansion to double its capacity.

The usual practice, in storages of this type in the Pacific Northwest, is that all the fruit is moved directly into storage; packing is done after the harvest season.

It is assumed that all fruit is loaded onto highway trucks for shipment to market. These plants are usually not located near or on railroad sidings. Occasionally packed fruit is hauled to a railroad siding where it is loaded, but more frequently loading is directly onto a highway truck. All shipping is usually completed, and the storage emptied, before spring orchard activities start.

A completely automatic refrigeration system is recommended. The calculated refrigeration load is 16.5 tons. This is based on a daily average fruit and outside temperature of 65° F., a roof temperature of 75° F., a daily average inside temperature of 32° F., a loading period of 12 to 13 days, and an average receiving rate of 2,000 field boxes per day.

### Description of Operation

Handling operations of a 25,000-box storage are based on the use of a 36-box-capacity clamp truck. This is a lift truck that can be conveniently used for receiving fruit from orchard trailers. These trailers will probably be used, because the plant is located in or near the orchard. The clamp-truck operator can build unit loads, 3 boxes high—the way they are received—to 6 boxes high, for storage.

Two methods of unloading and moving to storage are possible. The lift-truck operator may build the loads 6-high on the orchard trailer, lift them off the trailer and place the loads on the apron so that the trailer can return to the orchard. After the trailer has gone, the lift-truck operator moves the unit loads into storage, placing dunnage, or stabilizing strips, usually 1-inch by 4-inch material, between the unit loads to stabilize the upper load.

The alternative practice is for the lift-truck operator to build the unit load 6-high on the trailer, lift the load and move it directly into cold-storage without setting it down on the apron. This method requires less lift-truck operating time, but ties up the trailers a little longer.

As fruit is moved into cold storage, it is placed in rows at right angles to the aisle with a space for air circulation between each row of unit loads.

When fruit is removed from cold storage and taken to the packing line, the lift-truck operator transports loads of apples from the storage room. He stacks several loads in the dumping area, where packing room workers dump the fruit onto the packing line. As frequently as is necessary, the lift-truck operator picks up a unit load of packed, segregated fruit and places it in storage or takes it to the loading area. At other times, he will remove empty boxes, or boxes of culls or juicer apples.

## 50,000- and 100,000-Box Storage Rooms

### General Characteristics

The important layout features of the 50,000- and 100,000-box cold-storage rooms are so similar that they are presented together. Both are designed for operation by a large grower or a central packer.

When full, the 50,000-box room accommodates 51,840 unpacked boxes stacked in 48-box unit loads on pallets, 3 pallet loads to the stack. The 100,000-box room accommodates 100,800 boxes. It is assumed that both plants pack some of their fruit as it is received, but most of it is moved into cold storage for packing later. Both pack fruit late into the season.

The two rooms are laid out to receive fruit at one end of the building and to load out to railroad cars at the other, reducing congestion in the handling operations. The layouts of these two storage rooms are shown in figures 22 and 23.

### Description of Operation

During the receiving season, most fruit that is packed is loaded out directly; only part of it goes back to cold storage. Later in the season, after the receiving period is over, the loose fruit is moved out of storage to the packing room, packed, segregated, and returned to cold storage. Only part of the packing line output is loaded out directly from the packing room. Most frequently, loads of packed fruit are blocked out in the storage room or in the covered area on the outside, and from there moved onto railroad cars or highway transport trucks.

The pallet loads of fruit are stored in rows at right angles to the aisle. The unit loads on the aisle in each row can be marked to indicate the lot or the grower to whom the fruit belongs. Occasionally, fruit in one of the rows might be of two different lots, or belong to two different growers. This could entail extra handling of the unit loads in moving them from cold storage or getting them ready for shipment. The cost for the extra handling is quite small, however, since it requires only a small amount of time with a forklift truck.

The forklift truck operations are carried on relatively efficiently, combining hauling of loose fruit from storage with transporting the empty boxes, culls, juicer fruit, and packed fruit out of the packing room. Seldom will the forklift truck be moving about empty.

# PACKING AND STORAGE HOUSE DESIGNS

Once an efficient layout has been developed, a building can be designed to fit the operating pattern. Using 5 of the layouts already discussed, and a layout developed for a 200,000-box storage, three apple packing and storage houses were designed. The first incorporates the exact sizing line and the 50,000-box storage; the second incorporates the group sizing line and the 100,000-box storage; and the third incorporates the double packing line and a 200,000-box storage. Each of the designs includes plans for future expansion of the storage. Flow diagrams for the three plants are shown in figures 24, 25, and 26.

Detailed plans and specifications were developed for each plant and supplement this section of the report. The plans and specifications are available for inspection or purchase as listed in the Preface.

### General Discussion of Construction

There are many possible construction materials for apple packing and storage houses. Some plants are constructed completely of wood, bricks, or blocks; others have steel frames and roofs. Some plants are built of reinforced concrete. Still other plants include a combination of these types of construction.

The cost of a building varies greatly, depending upon the materials selected. For example, an office in a plant could have the outside walls faced with brick and the inside walls fully plastered, or concrete block walls painted on the inside. Other examples of how building costs could vary include: The use of copper flashing and gutters instead of galvanized iron; and radiant heating installed in the floor of the packing room, instead of portable heaters.

Other factors that are not directly controllable may affect costs. For instance, it may be necessary to use a great deal of fill on the building site; or the soil may be such that extra large footings are required. Examples such as these and others can add 20 to 50 percent to the construction cost of a packing and storage house.

Generally, plant managers can obtain several cost estimates which will permit alternative choices of quality, materials, and other items included in the facility, which in turn influence costs. These choices can be made as plans progress, if an architect or engineer has been selected to work with the owner in developing the plans.

Another factor that should be considered is providing for future expansion. Often, because of budget limitations, only a portion of the complete unit can be built. The future building program should be planned from the beginning, to avoid unnecessary costs when additions are made.

Complete and detailed plans and specifications, which are part of the contract documents, allow for competitive bidding among contractors, and provide precise and concise understanding between contractor and owner. These documents give the plant manager detailed information of what he is to receive for money spent, and also show the contractor what is desired by the owner. Plans and specifications help hold additions and plan changes during construction to a minimum. Whenever final construction costs far exceed initial estimates, these two factors are usually the causes. For the contractor, plans showing detail and dimensions eliminate guessing, errors, and loss of time, and minimize risks, all of which must be reflected in the contractor's bid.

Local conditions also influence cost. For example, concrete blocks or gravel fill in one area may be considerably cheaper than in a neighboring community. Because gravel is generally available in the Yakima area, reinforced concrete construction is desirable there.

Local ordinances sometimes permit variation in the structures. For example, within city limits of Yakima, ordinances require steel columns to be encased in concrete, and all steel members in the building completely covered. The same building could be built in an outlying area, with nearly the same structural strength, but at a substantially lower cost.

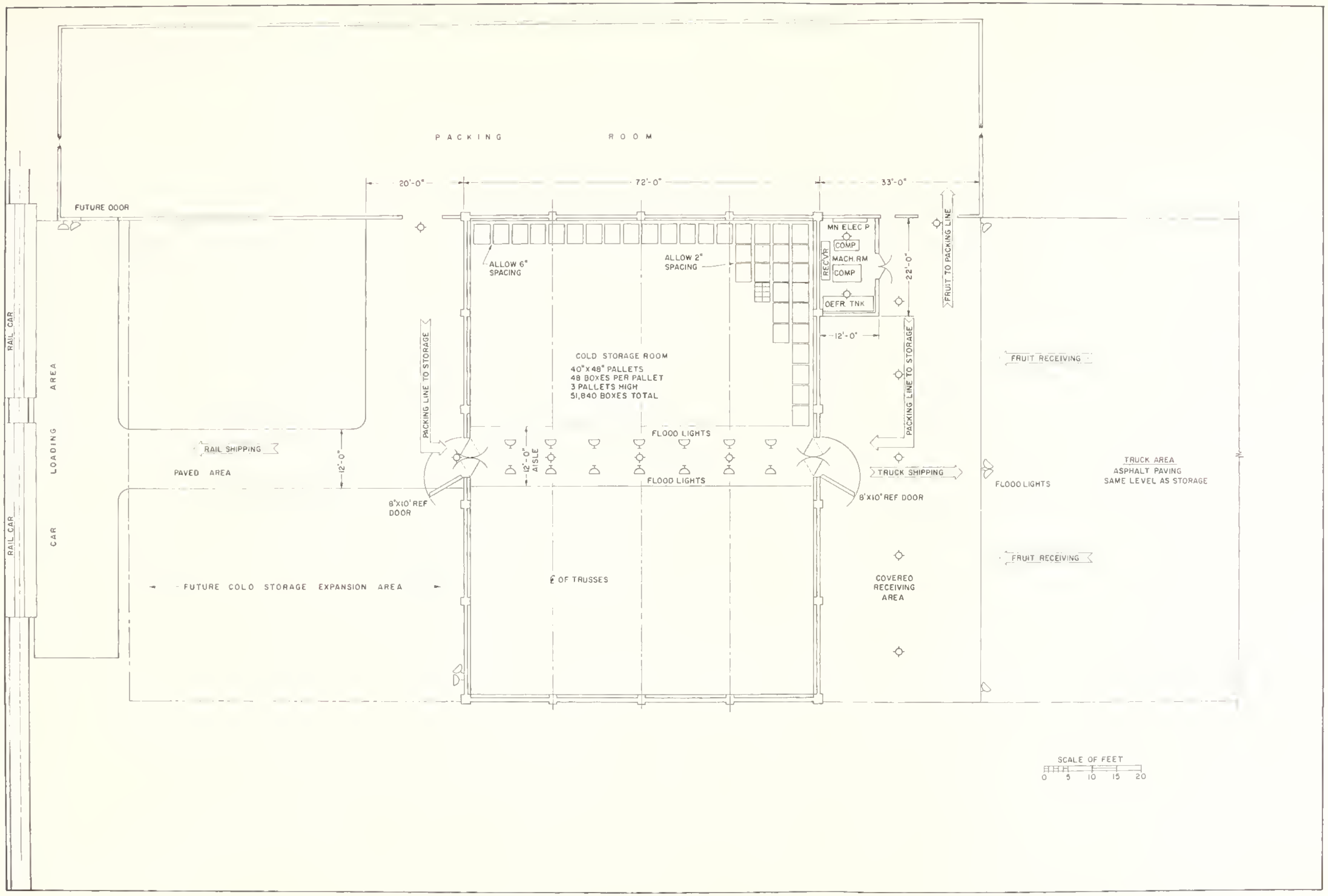


FIGURE 22.—Layout of a 50,000-box-capacity refrigerated storage room.

## Features of Designs for Three Plants

All three plants are on ground level and are designed for lift truck operations. The shapes of the buildings, the materials from which they are constructed, and the other features have been decided upon after careful consideration of costs of construction, insurance, and maintenance and operating problems.

SITE SELECTION.—Sites for the three packing and storage houses should be selected with the following points in mind:

- Access to a rail siding;
- Access to a highway;
- Availability of such utilities as electricity, fuel, telephone lines, water, and sewer;
- Adequate area to allow for parking, loading and unloading, and future expansion; and
- A site as level as possible to minimize the cost of excavations, retaining walls, and steep driveways.

FOUNDATION.—A concrete ringwall extends around the perimeter of the building; it has footing pads for concrete pilasters, which support the roof. All foundation walls and footings are reinforced with steel, to insure proper tie and bond, and to prevent undue shrinkage or settling. Foundation bases are a minimum of 3 feet below the finished grade around the building, to prevent heaving or settling from frost.

This type of construction is rodent- and termite-proof, and is not subject to rot or to deterioration from the weather. The floor is a 5½-inch reinforced-concrete slab, thick enough to withstand heavy trucking and stacking loads.[4] Under all concrete floors, except in the covered area, a 6-inch gravel fill is provided, to prevent moisture and dampness from entering the floor slab by capillary action. The gravel also tends to distribute the loads over small soft spots that may occur after excavation and backfilling. Wire mesh acts as reinforcing steel in all concrete floors, to prevent cracking and failure of concrete over soft spots or voids.

In an attempt to save money, asphalt has been used for floors in buildings instead of concrete, but it has not proved satisfactory. Asphalt tends to compress or "run" under heavy use. The small tires on forklift trucks that continually carry heavy

[4] Thickness determined from Portland Cement Association publication "Concrete Floors on Ground for Industrial and Other Heavy Uses." 6 pp., illus. 1951.

loads over the same route intensify the problem, and the result is constant maintenance. Asphalt's rough surface is hard to clean and maintain.

Wood floors have also been used, but do not withstand the heavy traffic of forklift trucks. The cost of wood to take the same loading as on grade concrete is unreasonably high.

Walls of the Plants Are of Precast Concrete.—Mobile cranes can raise sections of walls, which are precast at the site, into position. This eliminates double-form wall construction and greatly reduces the cost of concrete walls. Wall sections are poured at ground level, where steel and concrete placement is simplified, and the slabs may be easily troweled and finished, to eliminate voids, gravel pockets, and the like, which so often occur in walls formed in place (figs. 27 and 28).

The walls are essentially nonload bearing, except that they must be adequately reinforced to withstand hoisting into place and wind loads. They must also be braced in position until the permanent concrete pilasters are poured.

There are many methods of tilting or raising the wall sections. Some contractors prefer to pour an entire wall section, usually 20 by 20 feet, and raise the entire slab. Others have developed a technique where lighter hoisting equipment is used. In this method the panels are made 5 or 6 by 20 feet and placed one on top of the other until the desired height is reached.

Pilasters.—The pilasters and footings are designed to permit future expansion and to carry the increased loads of this expansion. In addition, they are designed to carry the entire weight of the roof and snow and wind loads.

Forms for making concrete pilasters are usually made of wood. Concrete is poured into them after the wall sections are set in place. These pilasters fill the voids between the wall sections and also tie them together into a solid reinforced wall. The pilasters are reinforced to tie them down to the footing. This makes a strong wall, capable of withstanding high winds and mild earthquakes.

Roofs.—Different types of roofs are specified for the packing and storage rooms.

The storage-room roof consists of bowstring wood trusses, wood joists, and roof decking, with adequate bracing, bridging, and blocking. The roof area is then covered with a bonded, 20-year, built-up felt paper and tar roof.

Because wood is more widely available in the northwest, wood was chosen for the roof trusses instead of steel. Insurance rates for wood are considerably less expensive than for steel. Roof maintenance and repair are comparable.

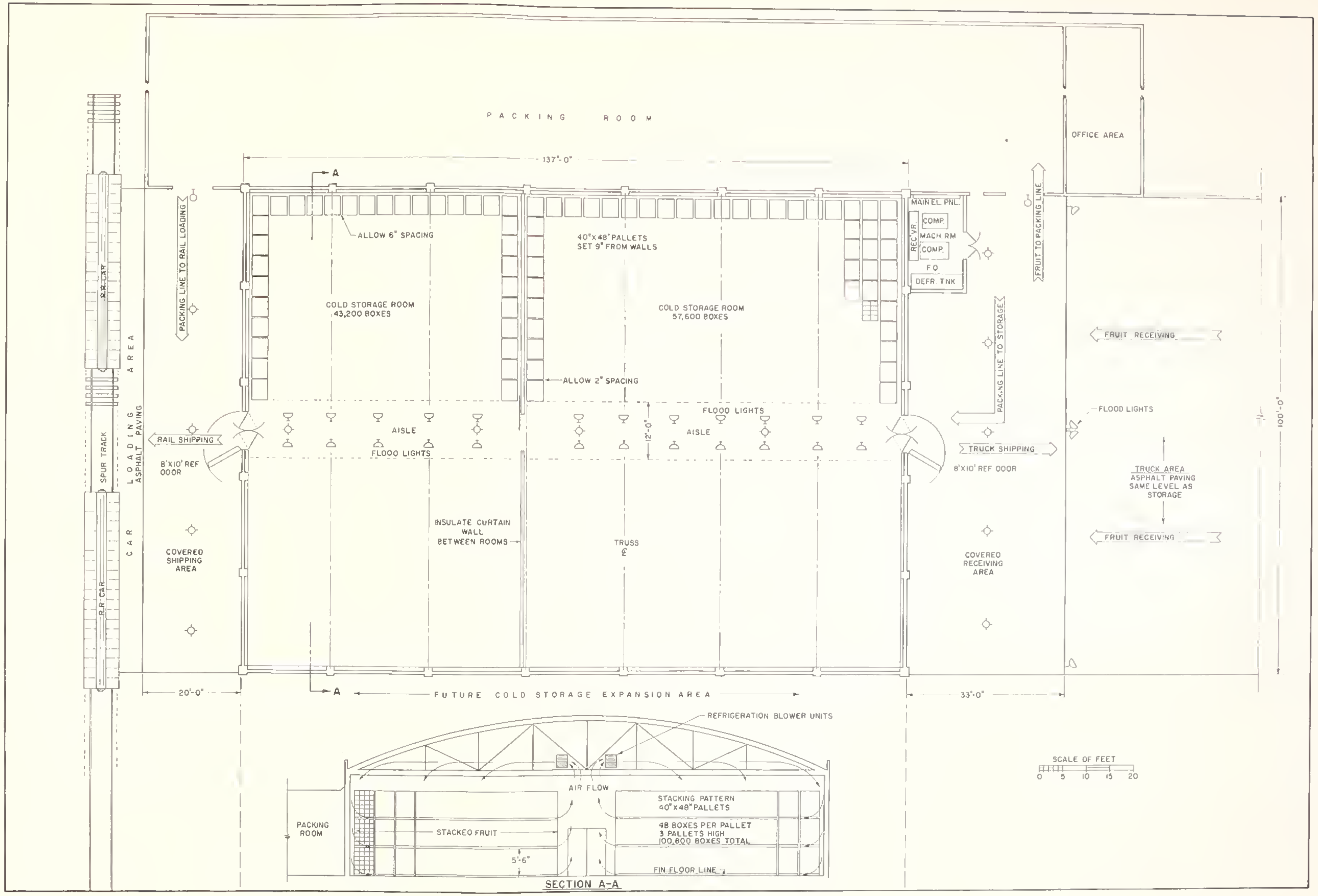


Figure 23.—Layout of a 100,000-box-capacity refrigerated storage room.

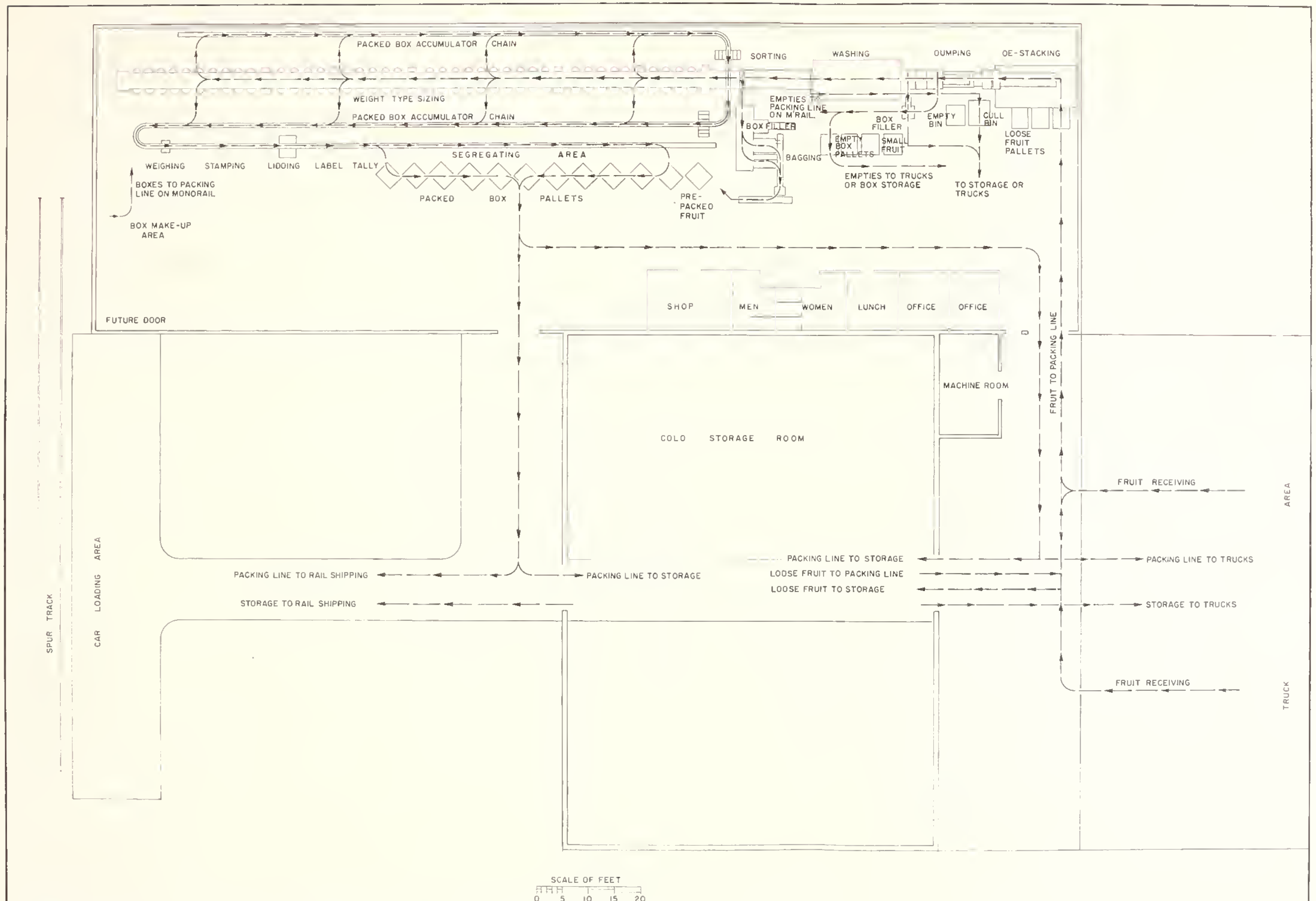


Figure 24.—Fruit flow diagram for apple packing and storage house of 50,000-box capacity.

The space between trusses is spanned by 2- by 12-inch joists. The spacing of the joists is governed by the span and the loading. For a total load of approximately 60 pounds per square foot, the joists are spaced 12 inches on centers.[5] The joists are covered with shiplap, which is laid diagonally to give extra support and bracing.

Two different systems were evaluated for spanning the distance between the trusses. One system was using the 2- by 12-inch joists, which was selected, and the second system made use of 10- by 12-inch purlins on 8-foot centers. The purlin system was 15 to 20 percent more expensive, mainly because of the end bays in the room; the 2- by 12-inch joists were merely "jackknifed" down to the wall. Purlins required extra furring, sheathing, and insulation.

Cold-storage and packing-room roofs are designed for a live load of 30 p.s.f. (pounds per square foot) plus 15 p.s.f. wind load, a total live load of 45 p.s.f. for the Yakima area. Live loads should be determined for local conditions.

Open-web steel roof joists were selected for the packing-room roof. Steel joists were selected instead of wood trusses, because steel lends itself to longer spans and takes less room than wood trusses. In this case, for the span required, the overall height of the packing room was lowered by using steel, which still allowed the same head room inside and resulted in lower wall construction and better heating conditions.

Another advantage to these steel joists in the packing room is the case with which electrical conduit and water piping may be installed. The open joists permit placing the piping laterally or longitudinally without cutting and patching or twisting around wood members. Costs for wood and steel were very nearly the same, but steel saved about 2 percent.

The solid tongue-and-groove roof decking specified not only provides a strong roof deck, but also gives a finished appearance to the ceiling inside the room. This saves the cost of plywood or other wood joist covering.

The roofing specified is bonded, 20-year-guaranteed roof.[6] It consists of built-up layers of tar and felt paper and has an excellent service record. While it requires some maintenance, it is the most economical and is as widely accepted as any type of roof application.

Refrigeration doors.—Insulated refrigeration doors are provided. Doors are of sufficient height

[5] Determined from "West Coast Lumberman's Associated Structural Data and Design Tables for Douglas Fir." 312 pp., illus. Rev. 1961.

[6] Some roofing companies do not bond bowstring truss roofs.

to clear the mast of the forklift truck as it passes through the opening.

Bumper doors that swing in or out (or air doors)[7] are usually installed inside all refrigeration doors because the large refrigeration door is left open during many operations. These swinging doors are self-closing and can easily be opened by bumping them with the forklift truck. This permits easy access in and out of the room and also prevents undue loss of refrigeration. Several types of bumper doors are available.

Parapet Walls.—Parapet walls stop fire from spreading from one section of the building to another; they separate different portions of the building. In the area studied, they are required to extend a minimum of 2 feet above the roof. Separating the cold storage room from the other parts of the building (covered areas and packing room), lowers insurance rates. A discussion of insurance is in the appendix.

Covered Areas.—Covered area roofs are constructed with open web steel frame joists. This provides a maximum of headroom with a minimum of depth for the span required. In this case, much lower fire insurance rates are obtained by using steel instead of wood construction. The floors of the covered areas are concrete, for lift truck operations.

Office and Machine Rooms.—Concrete block was chosen instead of wood or tilt-up precast concrete construction for the office and machine room walls because:

- The cost of concrete-block walls is about the same as for wood;
- Concrete-block walls require less maintenance than wood;
- The large size of the tilt-up panels and the need for several openings for windows and doors made concrete block construction more practical; and
- Because of the small area of these rooms, and the concrete parapet wall of the packing room, a wooden roof on the two rooms is allowable without insurance penalty.

Lunchrooms and Restrooms.—As is general practice in fruit packinghouses, a lunchroom for employees is provided. Restrooms are provided for both men and women.

[7] An air door recently developed is reported in U.S. Dept. Agr. AMS-458, Air Door for Cold Storage Houses, 1961. Air doors eliminate many of the hazards and drawbacks of other doors by giving the operator of the forklift truck an unobstructed view of both sides of the doorway.

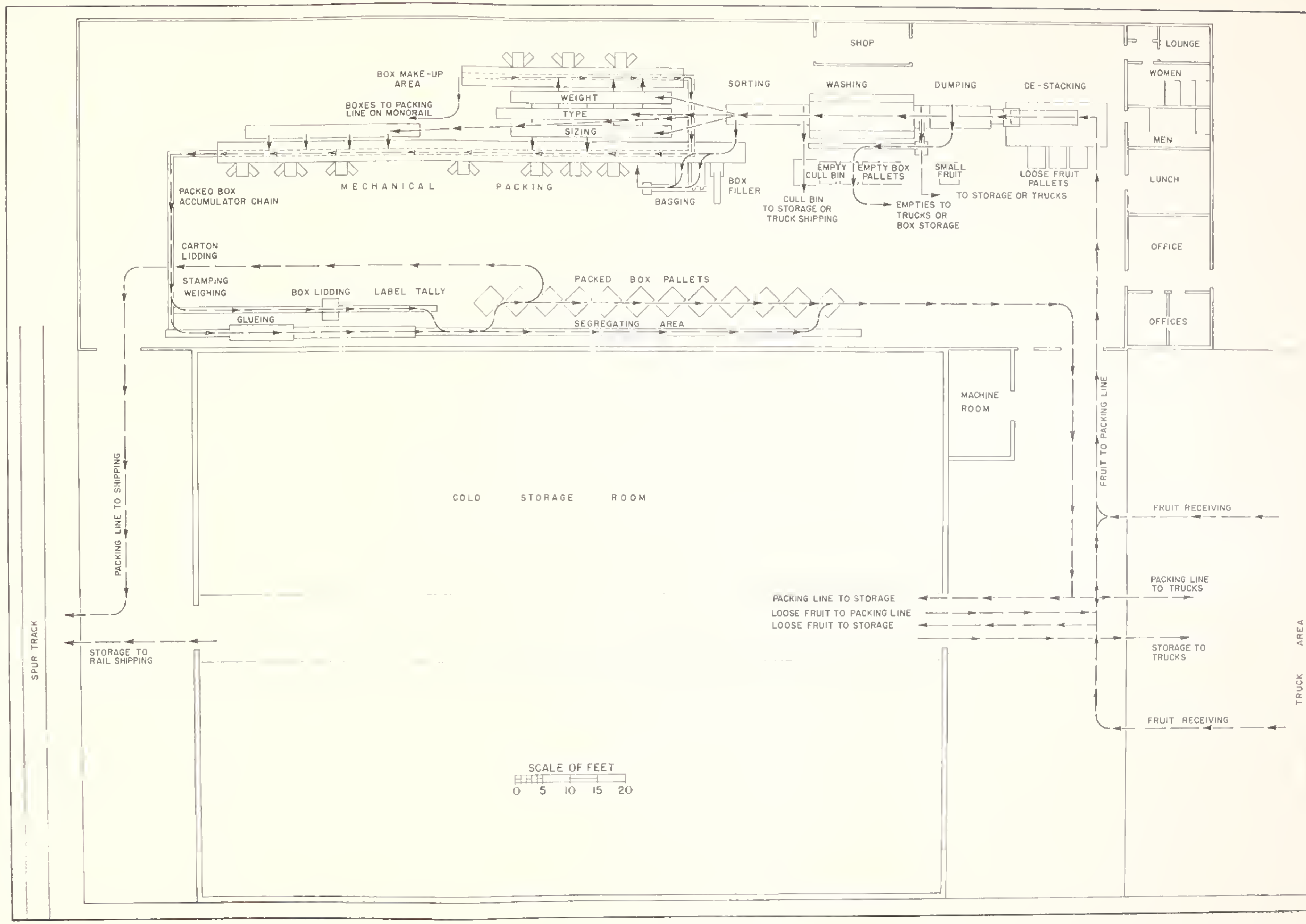


Figure 25.—Fruit flow diagram for apple packing and storage house of 100,000-box capacity.

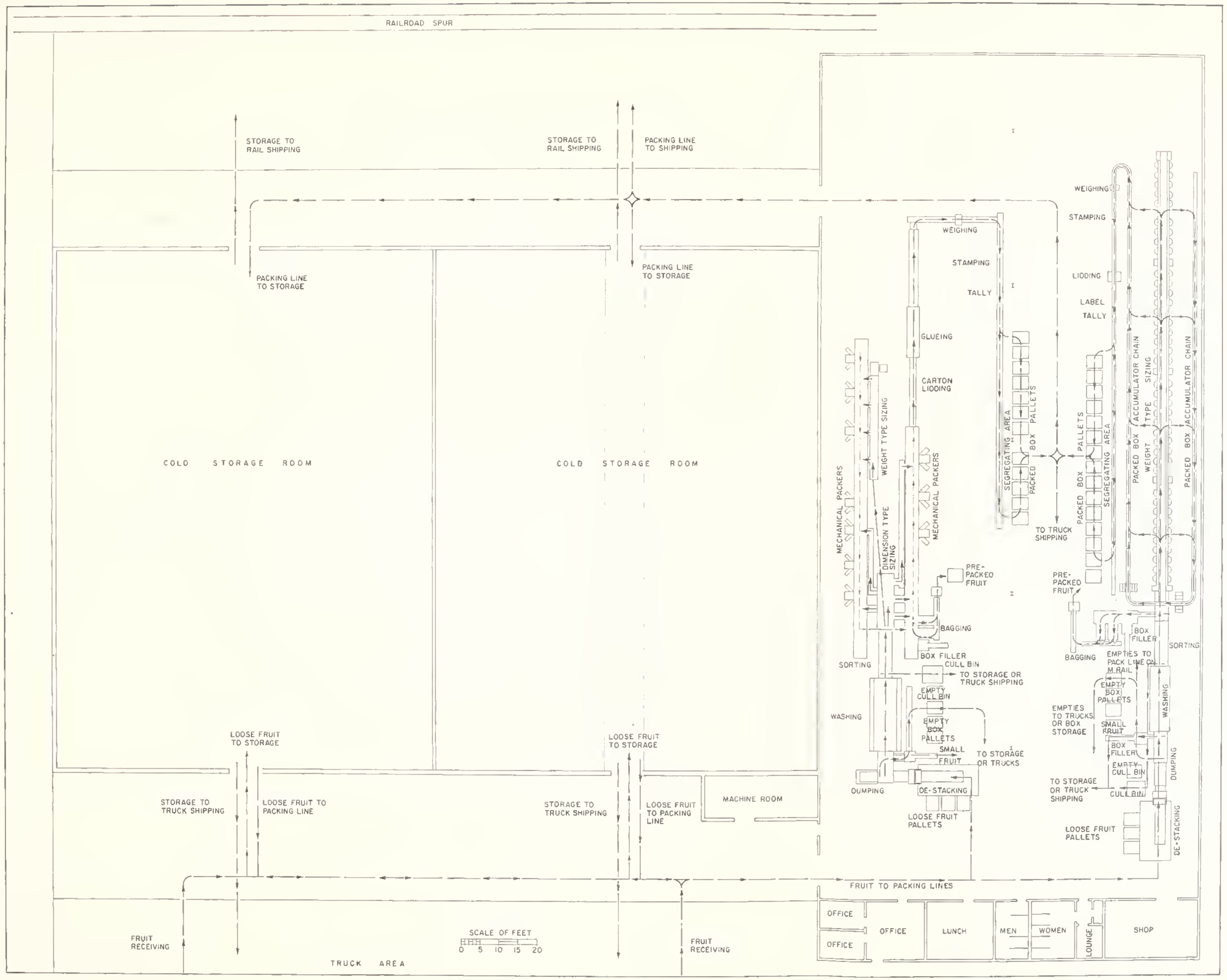


FIGURE 26.—Fruit flow diagram for apple packing and storage house of 200,000-box capacity.

PLUMBING.—The plumbing fixtures and sewage disposal system specified are those commonly used and are to be installed in accordance with local ordinances and acceptable standards of the trade. A septic tank and sewage disposal field is provided because city or community sewage disposal was not assumed to be available at the site.

City water service was assumed to be available at the property line, so a 2-inch pipe connection is provided to service the refrigeration units and other equipment and fixtures.

EMPLOYEE PARKING.—Off-highway parking is planned for employees. This keeps parked cars of employees away from the fruit handling operations and permits an easy flow of truck traffic to and from the storage and packinghouse.

The parking area is graveled because it will not have to bear heavy traffic loads and forklift truck operations. Gravel parking lots have been satisfactory where used only for passenger cars. Asphalt or concrete surfaces are better; however, management generally does not feel justified in spending the extra amount for this seasonal use.

ELECTRICAL EQUIPMENT.—The main control panels in the engine rooms are designed to provide for increased power requirements to take care of additional small fractional horsepower motors for the packing line equipment, and future expansion of the refrigeration system. Subservice panels are located at several points in the packing rooms for easy access to lighting and motor control. The electrical system complies with all local and State codes, as well as the National Electric Code. All wiring is in conduit.

In the cold-storage room, lights are installed over the center aisle. In this location there is little chance for damage or breakage by being struck with the extended masts of industrial forklift trucks. Floodlights are located to illuminate certain areas of the cold storage, which permits selective lighting of the areas as needed. This saves electricity and refrigeration. The estimated electric load for the three sizes of plants is in the appendix. A summary of these loads is in table 1.

INTERCOMMUNICATION SYSTEM.—Where operations are as diversified and scattered as in an apple packing and storage house, an intercommunication system is needed. The system specified is one which has proved successful in new plants in the Pacific northwest. Essentially, it is a system of telephones and unit broadcasters, strategically located around the packing and handling area. Calls are announced over the broadcaster; private conversations can be carried on over telephones.

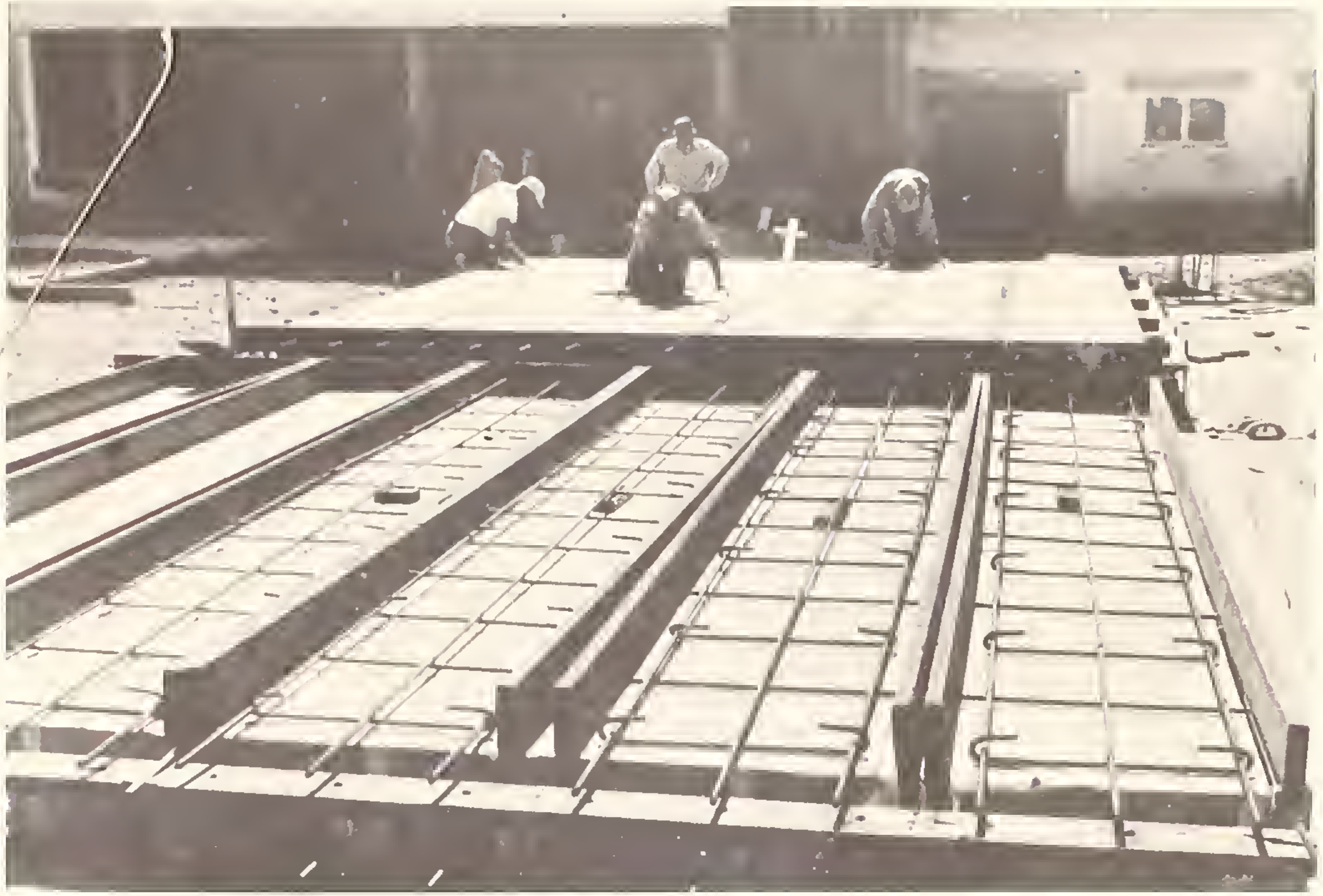

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FIGURE 27.—Form for wall section in foreground, showing reinforcing steel in place.

INSULATION.—Insulation for the cold-storage rooms was selected to meet minimum refrigeration requirements. Installation methods that best fit into the structural pattern of the building are specified. Insulation requirements are discussed in the appendix.

TABLE 1.—*Estimated electrical load for three storage and packinghouses* [1]

| Power demand item | Storage capacity | | |
|---|---|---|---|
| | 50,000 boxes | 100,000 boxes | 200,000 boxes |
| | *Amperes* | *Amperes* | *Amperes* |
| Refrigeration | 123 | 241 | 458 |
| Packing operations | 65 | 65 | 127 |
| Lighting | 71 | 79 | 134 |
| Total | 259 | 385 | 719 |
| Amperage to be provided at the main circuit breaker | 400 | 400 | 800 |

[1] For additional detail, see appendix.

REFRIGERATION.—The refrigerating equipment for each plant was selected to handle the loads shown in table 2. A list of equipment is in the specifications for each plant. Load calculations for the 100,000-box storage are in the appendix.

Because palletized handling is assumed for all storages, receiving should be very rapid during the peak of the harvest season. Therefore, the calculations have been made for a short loading period. A general discussion of refrigeration requirements and the types of equipment selected for the plants is given here.

INTERIM STORAGE FOR PEARS.—Although these plants are designed primarily as apple storages, some operators may also want to use them for Bartlett pears during the pear season. The receiving capacity of each plant, when handling Bartlett pears, was determined by a calculation similar to that made in the section, "Determining Performance of Refrigeration Systems When Receiving Bartlett Pears," in the appendix, p. 36.

Bartlett pears are received in mid-August, during the hottest part of the season, and impose a

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FIGURE 28.—A poured wall section being troweled.

TABLE 2.—*Factors considered in determining refrigeration loads for 3 refrigerated storage plants*

| Factor | Unit | Storage capacity | | |
|---|---|---|---|---|
| | | 50,000 boxes | 100,000 boxes | 200,000 boxes |
| Average of daily outside temperature and initial fruit temperature. | °F | 65 | 65 | 65 |
| Average daily roof temperature. | °F | 75 | 75 | 75 |
| Average daily inside temperature. | °F | 32 | 32 | 32 |
| Loading period | Number of days. | 14–15 | 14–15 | 14–15 |
| Average daily receiving rate of apples. | Field boxes. | 3,500 | 7,000 | 14,000 |
| Total refrigeration load. | Tons of refrigeration. | 27 | 52 | 101 |

heavier load on the refrigeration equipment than apples. In all cases, it was found that the allowable pear receiving rate was about 50 percent of the apple receiving rate. This means that, in a normal 15-day receiving period, about half of the space in the storage could be filled with Bartlett pears. It is not generally advisable to fill more than half of the storage space with pears because in normal crop years, the last of the Bartletts do not move out of storage until the end of October or the first part of November. If too much storage space is occupied by pears, it may not be available for apples when needed. Unless the storage must be planned for an unusually large tonnage of pears, the arrangement presented here, primarily designed for apples, will probably be satisfactory for pear storage.

AMMONIA AS A REFRIGERANT.—Ammonia was selected for these installations for several reasons. Under fluctuating loads, such as occur in apple storages, ammonia equipment presents fewer problems than other equipment in properly feeding the evaporators, maintaining proper oil levels in the various compressor crankcases is much simpler. With the large number of evaporators planned, the full-flooded feeding of the refrigerant to the evaporators that is customary with ammonia is much superior to other feeding methods. Personnel familiar with the operation, maintenance, and repair of ammonia equipment of the size involved are apparently more generally available in the area. There may be circumstances where these advantages will be overshadowed by other considerations (one will be discussed under heating), but for most storages of the sizes planned here, use of ammonia equipment seems sound practice.

SELECTION OF EVAPORATORS.—A number of overhead cooling, or refrigeration, units with propeller fans are hung in the truss spaces above the aisles. One pair of units, back to back, draws air from the aisles, blows it to the side walls, down the walls, and back to the aisles through the fruit. There is considerable aspiration of room air into the cold air stream from the units before the air starts its passage through the fruit stacks. In this way, the total quantity of air in motion is very large and the change in temperature in passing through the fruit is quite small. Resistance through the unit is low, and there is no duct resistance. It is therefore possible to economically circulate much larger quantities of air through the room than with large cooling units distributing air through ducts. The horsepower per c.f.m. (cubic feet per minute) of air circulated with this system is about one-half that needed with the large unit and duct combination. It is possible to obtain very large evaporator surfaces, because the design of these cooling units is standardized. The units are mass-produced at relatively low cost.

The proposed units have from 250 to 300 square feet of fin and tube surface per T.R. (ton of refrigeration). The quantity of air ciculated through the units is about 1,500 c.f.m. per T.R.

A similar arrangement of cooling units has been installed in a number of apple storages in recent years, and has provided very satisfactory service.

In the two larger storages, the cooling units are arranged in more than one zone for flexibility of control and ease of defrosting. In the smaller storage, the units are fed, controlled, and defrosted in a single zone. Each zone is provided with liquid ammonia and suction headers connected to a suitable suction trap, so that gravity-fed full-flooded operation of all evaporating surface is assured under all the various load conditions that may be encountered. In each zone, a single float controller maintains the desired liquid level in the trap, headers, and evaporators. A proper oil trap and drain connection at the bottom of the liquid drop leg of the suction trap has been specified to guard against oil clogging the evaporators.

The proposed suction traps are of ample size to guard against liquid slopover after shutdown during the low-capacity season, when this problem is critical. The specification also calls for the suction piping and valves on the outlet of the trap, arranged so that any liquid condensing in the suction line during the defrost period will drain back into the suction trap. This is important in these systems.

Where high-speed multicylinder compressors are used, a vertical suction trap should be used in the machine room to eliminate occasional liquid slopover from the evaporators. The trap contains a subcooling coil through which warm liquid passes in going from the receiver to the evaporators. Heat from this source is adequate to evaporate mild intermittent slopovers that may normally be encountered with the system.

SELECTION OF CONDENSERS.—Evaporative condensers have been selected for these storages because a good reliable supply of condensing water is not available from wells without going to a depth of more than 300 feet at many places in the area studied. There are some locations where an adequate supply of water is available from comparatively shallow wells. However, these wells often fluctuate substantially in level from one season of the year to another, and require fairly expensive deep-well pumps to cope with the change in water level. Capacity has been specified for design conditions of 65° F. wet-bulb air to the condenser, and 90° F. condensing temperature.

Because the maximum refrigeration capacity of the system is rarely used for more than 6 weeks during a season, two-speed fan motors have been specified for the evaporative condensers on the two larger storages. During periods of full capacity, fans are operated at full speed. As soon as the load drops to about 75 percent, the fans can be operated at low speed and use only about one-third of full power. Because low-speed operation is used for the greater part of the year, the power saving will be substantial.

Operation of either evaporative condensers or cooling towers in the winter months requires special consideration. A warm-water defrost system permits a very favorable arrangement to meet cold weather conditions. The water that is sprayed over the coils of the evaporative condenser drains from the bottom of the condenser tank to the defrost tank in the machine room. When outside temperatures are near or below freezing, the condenser fan does not operate. Because the load at this time of year is about 25 percent of full capacity, the condenser will have sufficient capacity with the water only being circulated over the coils. Experience has shown that with the temperature outside below 32° F., the condensing temperatures obtained by operating only the water circulation pump without the fan are very similar to those obtained by running the fan only and leaving the coil dry. Because the pump needs less power, its use is preferred. This system can operate without danger of freezing during the off-cycle, because the piping is arranged so that all water drains back into the defrost tank in the machine room when shutdown occurs. This system allows heating of the defrost water without any water heater in the discharge line from the compressors.

SELECTION OF COMPRESSORS.—Multiple compressors have been specified for all layouts. The smaller compressors in each of the smaller proposed plants has between 25 and 33 percent of the total capacity. This means that the larger machine will have about twice the capacity of the smaller machine, so the two machines will have three capacity steps between minimum and full load—a very flexible arrangement. In the largest storage, even greater flexibility is provided by using three compressors; the smallest has a capacity of about 15 percent of full load.

SELECTION OF CONTROLS.—The control system includes appropriate devices to: Protect the equipment against certain malfunctions; maintain the room temperatures at certain preset temperatures; select the proper increments of compressor capacity as required by the load; automatically operate the evaporative condenser fans; and automatically defrost the cooling units in the various zones.

The safety controls include: High- and low-pressure safety switches to protect the system against excessive pressures or against operation on a vacuum; jacket water line thermostats to assure that compressors will not operate when jacket cooling water is unavailable; jacket water-line magnetic valves to admit water to jackets only when compressor is in operation; and oil-pressure safety switches on all pressure-lubricated compressors.

Recording temperature controllers are recommended in each room, so that the plant operator can see any deviation from normal temperature that may occur during the periods he is not actively attending to the plant. Because these are automatic systems, one mechanic probably will be responsible for the refrigeration plant operation and maintenance, as well as assisting in maintenance of packing line and handling equipment. During the receiving season, these duties leave little time for observing how the refrigeration system is actually operating; a recording controller aids in this task.

The controller for each room opens the magnetic liquid line and magnetic suction line valves and starts the lead compressor when the temperature rises above the control point and refrigeration is required, and closes the valves and stops the lead compressor when refrigeration is no longer required. An additional switch, upon a slight rise in room temperature, starts a second compressor. As the temperature falls, this compressor stops; the lead compressor runs until the lower control point is reached. In storages having more than one room, the controllers in either room can start both the lead and second compressor as required. A manual selector switch in the compressor room allows the plant attendant to use either machine as the lead compressor. In the large storage, that has three compressors, either the largest or the smallest compressor may be used as the lead machine. When the small machine leads, only one of the two larger machines is used as a follower. When the large machine leads, the two smaller compressors follow as one machine.

Relays are specified for proper isolation of circuits and to operate the various evaporative condenser fans and pumps whenever a compressor is in operation. Cooling unit fans operate continuously except during the defrost periods.

DEFROSTING THE EVAPORATORS.—Defrosting for each zone is controlled by a timeclock. During the early part of the season, defrosting four times a day is normal, but after the storage has been filled, defrosting once a day is sufficient. To compensate for operating time lost during defrosting the proposed plant capacity has been selected to handle the design load by operating 22 hours of the day.

When the clock starts defrosting a particular zone, the fans stop, and the magnetic valves on both suction and liquid lines close. The defrost pump for the particular zone circulates water from the defrost tank in the compressor room to the water distributing devices in the cooling units. The warm water passes down over the cooling surface, melts the frost on the fins and tubes, and drops into the collecting pan which forms the bottom of each unit. After a 10-minute defrosting period, the clock stops the defrost pump; there is a 2-minute period for water to drip off the coil before the timing mechanism places the zone in operation again. All defrost water and drain lines are sloped to drain back to the defrost tank, so that there will be no water left in the lines, either in the cold-storage room or in the exposed lines outside the building.

The water piping allows city water to pass through the compressor jackets to the defrost tank, and make up for losses from the evaporative condenser. This water provides a constant overflow to dilute the build-up of salts in the water caused by evaporation.

Four defrosting zones in the large storage minimize the problem of distributing the defrost water among the several units, and also allow for the possibility that some storages might have four rooms, rather than two. In this case, partitions between the two zones in each room, a temperature controller for each zone, and modifications to the control wiring would be needed.

All defrost and ammonia piping is above the aisles in the cold-storage room; lateral pipes are on the outside of the building, to avoid interference with stacking in the storage rooms.

PIPE COVERING.—Low-pressure ammonia piping and suction traps inside the cold-storage rooms are covered with light-duty pipe covering to protect them from frosting during the operating period, and dripping water on the floor during the defrost period. Ammonia suction lines outside the storage room are to be covered with standard pipe covering to minimize heat pickup from unrefrigerated spaces, and also to cut down on the superheat in the suction gas coming to the compressors.

The defrost water and drain lines are not insulated. Investigation shows that the amount of heat required to warm the pipe to the defrost-water temperature at each defrost cycle is greater than the heat loss to the surrounding atmosphere during each cycle. Insulation would not minimize the heat required to warm the pipe to the defrost water temperature, but would probably increase the heat requirement by increasing the mass of cold material. This is the greatest source of heat loss in cold weather.

ESTIMATED REFRIGERATION COSTS.—Refrigeration installation costs were estimated from typical bid prices of newly installed systems in the area, and their capacity, and determining the cost per ton of refrigeration. This factor was then applied to tonnages specified for these storages to determine their cost. Costs vary as size of the plant varies; refrigeration for the largest plants would cost approximately $600/T.R., and for the smaller plants, $700/T.R. The estimated installed cost of refrigerating machinery, controls, piping, and defrost system for the various plants is shown in table 3.

TABLE 3.—*Estimated installed cost of refrigerating machinery, controls, piping, and defrost systems for three refrigerated storage plants for apples and pears*

| Item | Storage capacity | | |
|---|---|---|---|
| | 50,000 boxes | 100,000 boxes | 200,000 boxes |
| | *Dollars* | *Dollars* | *Dollars* |
| Cost/T.R. | 667 | 633 | 600 |
| Cost of equipment installed | 18,000 | 33,000 | 60,600 |

## Heating

Suitable heating must be provided for the office, lunchroom, restrooms, shop, and packing room. With the increased trend toward packing to order, it is normal for packing operations to continue through the coldest winter weather.

Typical load calculations for the heating of the packing room during outside temperatures of −5° F. are given in the appendix. Although there are three ventilating fans in the packing room, only one 5,000-c.f.m. fan will be operated during the cold weather, to carry away fumes of the fungicide used in the apple washer. The heat-load calculations are based on heating the packing room to 60° F., because most of the occupants are performing physical labor. Some additional heat will be needed in the sorting area, because sorting does not demand as much physical exertion.

In the section, "Economic Analyses of Wall and Ceiling Insulation" (appendix), an estimate is made of the total operating time for the packing room, and the estimated normal number of degree-days for the packing room heating derived from that estimate. These same figures will be used in considering some of the economic aspects involved in selecting heating equipment.

Typical calculations for the office heating load are in the appendix, in "Heating, Load Calculations, Office." The heating for this space is the normal 70° F. inside temperature. Table 4 gives heating loads for packing room and office for each of the three plants.

TABLE 4.—*Assumed winter heating loads for packing rooms and offices of three plants*

| Item | Storage capacity | | |
|---|---|---|---|
| | 50,000 boxes | 100,000 boxes | 200,000 boxes |
| | *B.t.u./hr.* | *B.t.u./hr.* | *B.t.u./hr.* |
| Packing room | 690,400 | 675,600 | 990,400 |
| Office | [1] 42,000 | 47,180 | 65,090 |
| Total | 690,400 | 722,780 | 1,055,490 |

[1] Office heating load occurs only when packing room is unheated, so these loads are not cumulative.

SELECTION OF A FUEL.—Natural gas is available in the area. The average cost to a packinghouse or similar consumer is $0.10 per 100,000 B.t.u. input. With 80 percent as a normal efficiency for gas heating equipment, the cost of heat delivered is $0.125 per 100,000 B.t.u. Average oil cost in the area is $0.165 per gallon. With a fuel value of 140,000 B.t.u./gal. and 70-percent efficiency for the heating equipment, the average cost per 100,000 B.t.u. delivered is $0.168. Thus, the cost of gas is about 75 percent of the cost of oil. The first cost of the gas-fired apparatus also is less, so natural gas is cheaper. For areas not serviced by natural gas, there is a possibility of using LPG (liquified petroleum gas). The fuel cost is higher with this fuel than with oil, but the heating equipment is cheaper. Also, LPG is used in many plants as fuel for lift trucks, so storage facilities are then needed for the gas at the plant. Before a choice of fuel can be made, a detailed study must be made of heating equipment costs; some apportionment of cost of fuel-storage facilities must be charged off against handling.

SELECTION OF HEATING UNITS.—To heat the packing room, multiple, overhead, propeller-fan convection heating units were selected. They are dispersed in a manner to supply heat to the points where greatest need exists and to create satisfactory circulation in the area. The largest available sizes of this unit were selected, to minimize piping and vent connections. Each self-contained unit has its own controls, burner, and air circulation. No ducts are needed with this system.

To heat offices, restrooms, and shops, gas-fired wall heaters were chosen. They are reasonably priced, compared to other types of heaters, occupy a minimum of space, allow individual control of temperatures to suit the occupants, and require no ducts. The vents are standard shop-built components, making these items also quite economical.

An analysis of the use of rejected heat from the refrigeration system for heating the office and packing room is in the appendix.

## Construction Cost Estimates

Estimates of the cost of constructing three packing and storage houses of 50,000-, 100,000-, and 200,000-box capacity are summarized in table 5. Details are given in the appendix, table 13. The estimates are based upon the actual construction costs, indexes of materials, and labor costs in the Yakima area as of January 1, 1961.

These costs are estimates and are not guaranteed to be actual construction costs. Prices of materials, labor, and the availability of the contractor vary widely over short periods of time. The location of the building site, the nearness of labor sources, and choice of materials will also influence costs.

Equivalent construction costs of the plants vary from $1.96 to $3.01 per box from the largest to the smallest plant. In the small plant, the packing room and office construction costs are relatively the most expensive part of the plant. In the larger plants, the construction costs of the refrigerated storage rooms comprise the largest item of expense.

TABLE 5.—*Estimated construction costs of three packing and storage houses*

| Item | 50,000-box house | | 100,000-box house | | 200,000-box house | |
|---|---|---|---|---|---|---|
| | Total cost [1] | Cost per loose box [2] | Total cost [1] | Cost per loose box [3] | Total cost [1] | Cost per loose box [4] |
| | *Dollars* | *Dollars* | *Dollars* | *Dollars* | *Dollars* | *Dollars* |
| Cold-storage room | 46,720 | 0.90 | 78,230 | 0.78 | 144,070 | 0.71 |
| Machine room and refrigeration | 22,470 | .43 | 39,720 | .39 | 72,920 | .36 |
| Packing room and office | 56,030 | 1.08 | 58,930 | .58 | 105,720 | .52 |
| Heating, plumbing, and electrical equipment | 16,270 | .31 | 21,620 | .22 | 27,140 | .14 |
| Covered areas | 9,360 | .18 | 14,200 | .14 | 27,850 | .14 |
| Lot and site preparations | 5,550 | .11 | 7,000 | .07 | 17,500 | .09 |
| Total | 156,400 | 3.01 | 219,700 | 2.18 | 395,200 | 1.96 |

[1] Based on index of construction costs in the Yakima, Wash., area, Jan. 1, 1961.
[2] 51,840-loose-box capacity.
[3] 100,800-loose-box capacity.
[4] 201,600-loose-box capacity.

## MODERN DESIGN, MATERIALS, AND BUILDING TECHNIQUES CAN REDUCE FIRE LOSSES

In one recent year, in the State of Washington alone, 11 apple warehouses burned; this estimated property loss was over $3 million. Unfortunately, little can be done to hundreds of older warehouses that are counterparts of the buildings destroyed or damaged. Even with added fire-protection devices, careful operation, and a realization that plant watchmen are as necessary as cashiers in a supermarket, old and obsolete warehouses remain an industry problem.

Old mistakes in construction should not be repeated; a fresh look should be taken at the new construction techniques. The designs in this report can incorporate the safety equipment discussed below (appendix table 15).

The way a plant is designed determines not only its efficiency, but also its fire insurance rate, its resistance to a fire, and even its probability of having a fire. The plant layout that requires storage of empty boxes next to the building, or that has open wooden platforms makes it easy to start a fire with a careless match. Such plants have proven easy marks for arsonists.

Almost all plants require some shop welding work. The lack of a proper area for such work, with incombustible floors and walls, invites a fire started by a welding torch.

Insurance companies know that more obsolete plants burn down than do modern plants. It is only a matter of time before the high fire losses of apple warehouses will be paid for solely by owners of obsolete plants. Regardless of how high the total fire insurance bill is, the apportionment of premiums is based on the location and operational, structural, and fire-protective features of the individual warehouse. The operator who plans construction with safety features pays only a fraction of the average premium.

### Fire-Resistant Materials Properly Installed Cost No More

Regardless of the premium rates, the plant design should be as fireproof as possible, within reasonable cost. Normally, it costs little more, if any, to build with Underwriters' Laboratories (UL) approved materials. These materials have known resistance to fire, and usually provide a large bonus in reduced insurance premiums.

Some examples are: UL-approved masonry blocks for exterior walls and partitions are no more expensive than frame construction, and they provide 4-hour fire resistance. Furthermore, the pumice block, readily available in the Pacific Northwest, has unusually good insulation qualities that are desirable in cold-storage construction. Incombustible insulation can usually be obtained as reasonably as the combustible type. Natural flues in walls and ceilings can be eliminated by attaching the insulation directly to the roof deck and walls. Such construction eliminates combustible studs and often eliminates combustible interior finish. Proper location and design of heaters and chimneys, machinery and boiler rooms, adequate electrical circuits, and incombustible storage facilities for supplies all aid in fire prevention and the cost is only foresight in planning construction.

Fire-Resistant Wood.—The wood roof deck and supporting trusses, normally vulnerable to fire, can be impregnated with a tested and approved fire retardant that renders them incombustible. The treatment was only recently made available in the Washington State area. When the treated wood meets the specified UL requirements, it has an insurance rate equal to unprotected steel. The process, at some Pacific coast plants, costs approximately $90 per 1,000 board feet. It will reduce annual insurance premiums when used in the 100,000-box apple warehouse design located in Class 9 (unprotected) areas,[8] by $2,000 and for the same warehouse in a Class 3 town, such as Yakima, by approximately $300. It is important that the processed wood have a UL label, showing that the treatment is by impregnation, and that it has endured a 30-minute test with a flame-spread rating not over the equivalent of 25, and that there has been no evidence of significant progressive combustion.

Incombustible Insulation.—Premium savings are possible when incombustible insulation (see appendix) is used throughout, and is attached directly to the roof deck and walls. UL-approved insulation properly applied, results in a $300 annual saving for the basic 100,000-box warehouse in unprotected areas, and a saving of approximately $50 per year in a Class 3 town.

[8] Classification is based on availability of adequate fire protection.



### Water Requirements on Site

The major factor in selecting the plant site, from a fire-prevention standpoint, is proximity to adequate water supplies. For economies in insurance rates and water supplies, it is desirable to locate the warehouse near a good fire department. Adequate water supplies also facilitate the installation of fire hydrants and sprinkler systems, which are important factors in insurance rates. A secondary consideration is the nearness of other plants and operations; clear spaces should be maintained between buildings. The clear-space requirements will vary with the size and height of the buildings and the type of occupancy.

### Sprinkler Systems

The most efficient single mechanical device for industrial fire extinguishing is the automatic sprinkler system, yet it is seldom found in apple warehouses. This often reflects lack of foresight; the owner discovers, after the building is constructed, that the installation of a sprinkler system would then be relatively expensive. Two major considerations in the design stage are that there must be an adequate water supply and adequate overhead space. Sprinkler systems can generally be installed at current costs for less than 35c per square foot of the building area. In the basic 100,000-box capacity apple storage and packing-house for example, the actual cost estimate for a sprinkler system is approximately $12,000, or about 12c cost per loose box of warehouse storage capacity.

Sprinkler installation companies usually arrange terms under which the actual rate savings will pay for the sprinkler system in a few years. The economic importance of sprinklers is shown by a premium saving of almost $5,000 a year for Class 9 unprotected locations, when sprinklers are included in the apple warehouse design. This assumes an adequate water supply for the sprinkling system of 1,100 gallons per minute at a pressure of 70 to 100 p.s.i. (pounds per square inch) and 3,000 g.p.m. (gallons per minute) at 60 p.s.i. for the hydrant system. For Class 3 protected locations the actual dollar savings are less but the premium is reduced some 50 to 70 percent.

Other fire-protection devices are hand fire extinguishers (one is needed for each 2,500 square feet) and watch-clock stations that require the watchman to follow a predetermined path through the plant.

### Lower Premiums Cut Operating Costs

Research was conducted on fire-insurance rates for various locations and construction alternatives for the 100,000-box plant, based on rates estimated by the Washington Surveying and Rating Bureau (see appendix, p. 42) which serves all fire-insurance companies in the State of Washington. The results indicate several direct ways to save on premiums. Aside from lower premiums and their effect on profits, the major benefit is that the business is much less likely to be permanently interrupted or lives lost because of a disastrous fire.

By choosing a site for the basic 100,000-box warehouse (see appendix, p. 42) in an area with ample water source, clear surrounding spaces, and an efficient fire department such as a Class 3 city, versus a site in an unprotected Class 9 area, a premium savings of $3,800 per year, or 4c per box of apples, can be realized.

Wall Construction.—By using reinforced concrete walls or UL-approved masonry block walls, instead of wooden wall construction, an owner of a basic 100,000-box warehouse almost anywhere in Washington State would save $2,000 a year on insurance premiums.

Miscellaneous Factors.—Other factors affect rate and premium in a substantial manner. For example, the elimination of ammonium nitrate fertilizer storage in the apple storage or packing rooms could eliminate a penalty of $1,500 per year.

Have Plans Reviewed.—In summation, several premium-saving features have been presented. However, every prospective owner should have his specific plans reviewed by a fire-protection engineer who knows the insurance rating rules of his State. The items discussed above are only a guide, even for the State of Washington. Engineering service of the required type is often available through architects' and engineers' offices, insurance agents' and brokers' offices, and fire-insurance companies.

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## APPENDIX

### Workers Required to Operate Packing Lines

A time study analysis was made on the number of workers needed to operate the packing lines in the 50,000-, 100,000-, and 200,000-box-capacity apple packing and storage houses. The results of the analysis are in table 6. The figures are given by worker assignment.

### Packing and Storage House Designs

Figure 29 is the site plan for the 50,000-box packing and storage house. It shows the location of the important features of the layout of cold storage and the packing room. Elevations are shown in figure 30 for this same plant. A scale model was constructed of this plant and figure 31 gives two views of this model.

The site plan for the 100,000-box capacity packing and storage houses is shown in figure 32. Figure 33 shows the elevations for this plant.

Figure 34 is the site plan for the 200,000-box-capacity apple packing and storage house. It shows two storage rooms, each with a capacity of 100,000 boxes. The packing room accommodates two packing lines—one for exact sizing and one for group sizing. Figure 35 shows the elevations for this plant. Figure 36 gives two views of a scale model of the 200,000-box-capacity plant.

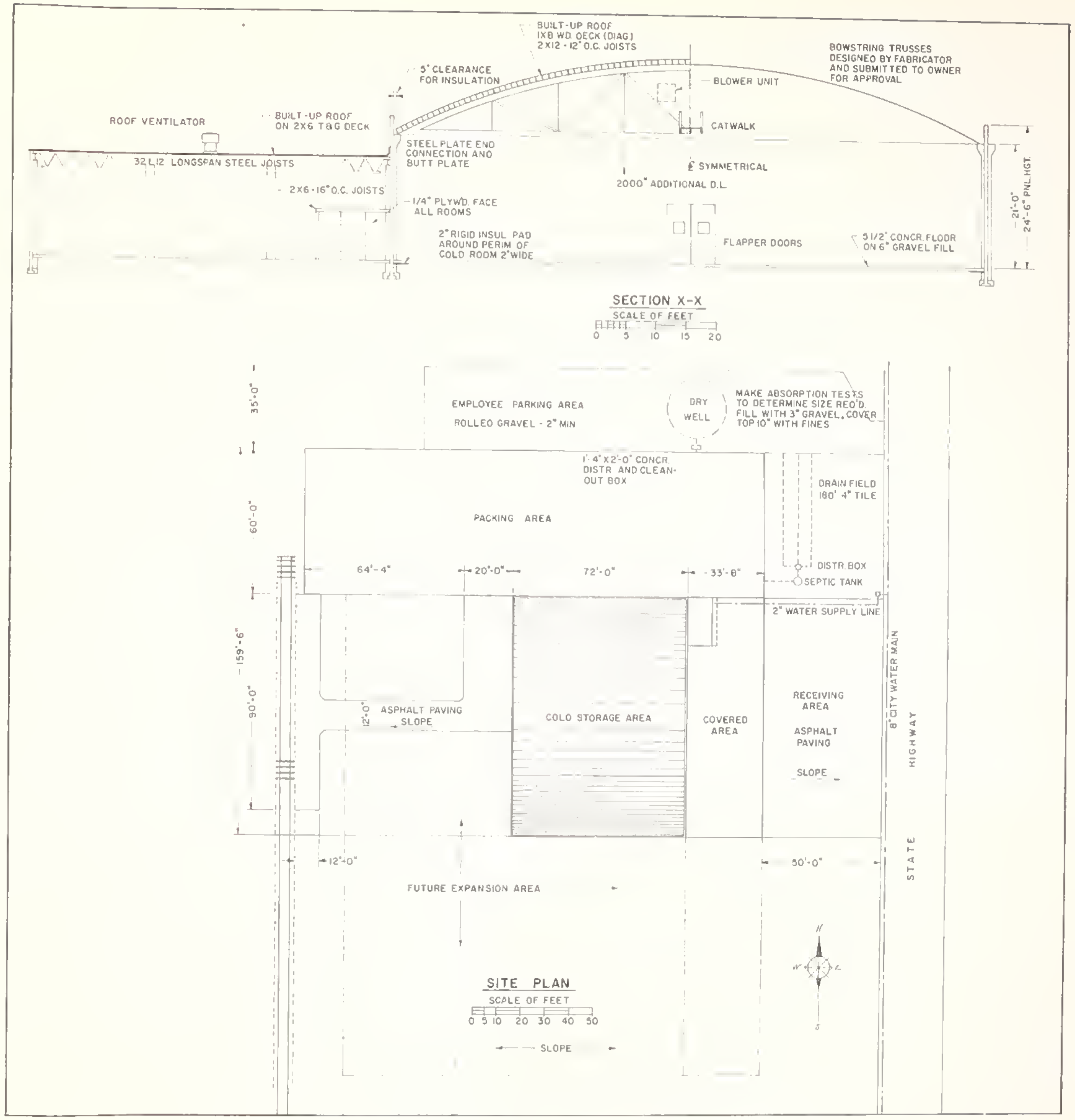



FIGURE 29.—Site plan for the 50,000-box-capacity apple packing and storage house.

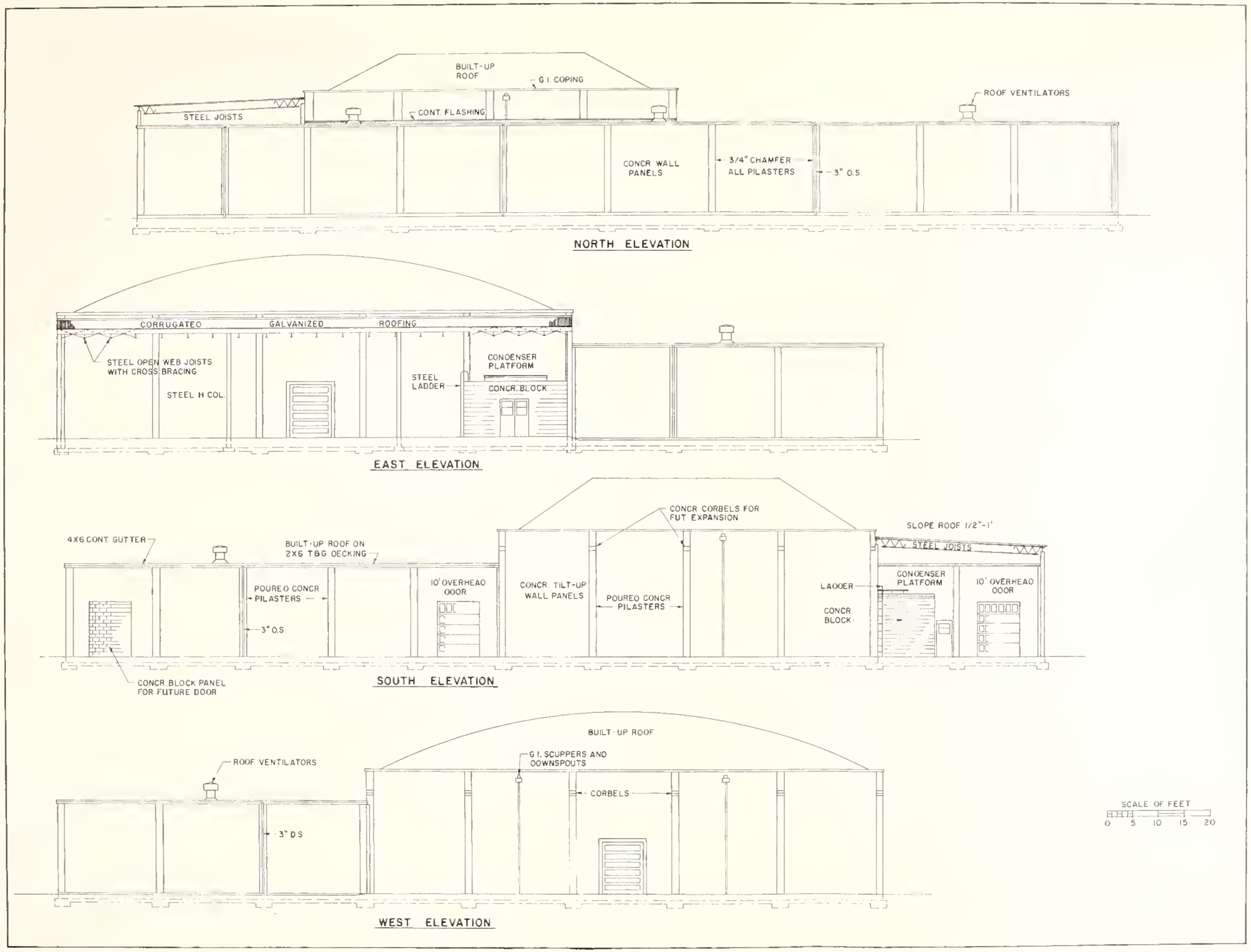



FIGURE 30.—Elevations for the 50,000-box-capacity apple packing and storage house.

TABLE 6—*Numbers of workers required to operate three packing lines with different types and amounts of equipment*

| Operation | Workers required on— | | |
|---|---|---|---|
| | One line to do exact sizing[1] | One line to do group sizing[1] | Double line to do both exact and group sizing[2] |
| Move unit loads of loose fruit, culls, empty boxes, and packed fruit by forklift truck | 1 | 1 | 2 |
| Move loose fruit from pallet to floor chain conveyor by handtruck | 1 | 1 | 2 |
| Stack empty boxes on pallets, put boxes on monorail conveyor, and handle extra small fruit from eliminator | 1 | 1 | 2 |
| Sort | 8 | 8 | 18 |
| Pack: | | | |
| Manual wrapping and packing | 18 | ........ | 18 |
| Mechanical tray packing | ........ | 8 | 9 |
| Bag | 3 | 3 | 6 |
| Stamp and weigh packed boxes | 1 | 1 | 2 |
| Lid packed containers | 1 | ........ | 1 |
| Tally | 1 | 1 | 2 |
| Label | 1 | ........ | 1 |
| Segregate | 1 | 1 | 2 |
| Supply packing material | 1 | 1 | 1 |
| Supervise | 1 | 1 | 1 |
| Maintenance | ........ | ........ | 1 |
| All operations | 39 | 27 | 68 |

[1] The average capacity of the packing lines is 420 boxes per hour; the maximum capacity is 600 boxes per hour.

[2] The average capacity of the double packing line is 920 boxes per hour; the maximum capacity is 1,300 boxes per hour.

## Estimated Electrical Load for the Plants

The estimated electrical loads for the three plants are given in the following tabulations:

### 50,000-Box Plant

| | *Horsepower* | *Watts* | *Amperes* |
|---|---|---|---|
| Motors: | | | |
| Three-phase, 230-V: | | | |
| Compressor | 25 | | |
| Compressor | 10 | | |
| Evaporator condenser | 3 | | |
| Circulator pump | 1 | | |
| Defrost pump | 3 | | |
| Total | 42 | | 95 |
| Single-phase, 230-V: | | | |
| 8 blower units | 8 | | |
| 4 unit heaters | 1 | | |
| 3 ventilators | 1 | | |
| Total | 10 | | 37 |
| Motors for packing room equipment | 25 | | 56 |

| Lighting: | Horsepower | Watts | Amperes |
|---|---|---|---|
| Cold-storage floods (22 x 150-w.) | | 3,300 | |
| RLM reflectors (12 x 200-w.) | | 2,400 | |
| Packing room lights (29 x 200-w.) | | 5,400 | |
| Office (3 x 160-w.) | | 480 | |
| Office (3 x 100-w.) | | 300 | |
| Total | | 11,880 | 56 |
| Additional packing room lighting | | 3,300 | 15 |
| Total electrical load | | | [1] 259 |

[1] Provide a 400-ampere main breaker.

### 100,000-Box Plant

| | Horsepower | Watts | Amperes |
|---|---|---|---|
| Motors: | | | |
| Three-phase, 230-v.: | | | |
| Compressor | 50. | | |
| Compressor | 20. | | |
| 2 defrost pumps (3 hp. each) | 6. | | |
| Evaporator condenser | 7.5 | | |
| Circulator pump | 1.5 | | |
| Total | 85 | | 192 |
| Single-phase, 230 v. motors: | | | |
| 14 blower units | 14 | | |
| 4 unit heaters | 1 | | |
| 3 ventilators | 1 | | |
| Total | 16 | | 58 |
| Motors for packing room equipment | 25 | | 56 |

| Lighting: | Horsepower | Watts | Amperes |
|---|---|---|---|
| Cold-storage floods (22 x 150-w.) | | 3,300 | |
| RLM. (3 x 100-w.) | | 300 | |
| RLM. (12 x 200-w.) | | 2,400 | |
| Packing room lights (33 x 200-w.) | | 6,600 | |
| Office (8 x 160-w.) | | 1,280 | |
| Office (1 x 200-w.) | | 200 | |
| Total | | 14,080 | 64 |
| Additional packing room lighting | | 3,300 | 15 |
| Total electrical load | | | [1] 385 |

[1] Provide a 400-ampere main breaker.

### 200,000-Box Plant

| | Horsepower | Watts | Amperes |
|---|---|---|---|
| Motors: | | | |
| Three-phase, 230-v.: | | | |
| Compressor | 60 | | |
| Compressor | 50 | | |
| Compressor | 20 | | |
| 4 defrost pumps (3 hp. each) | 12 | | |
| 2 circulator pumps (1½ hp. each) | 3 | | |
| 2 evaporator condensers (7½ hp. each) | 15 | | |
| Total | 160 | | 360 |

| Motors—Continued | Horsepower | Watts | Amperes |
|---|---|---|---|
| Single-phase, 230-v. motors: | | | |
| 28 blower units | 28 | | |
| 5 unit heaters | 1.25 | | |
| 5 ventilators | 1.75 | | |
| Total | 31 | | 112 |
| Motors for packing room equipment | 50 | | 113 |
| Lighting: | | | |
| Cold-storage floods (44 x 150-w.) | | 6,600 | |
| RLM. (3 x 100-w.) | | 300 | |
| RLM. (18 x 200-w.) | | 3,600 | |
| Packing room lights (52 x 200-w.) | | 10,400 | |
| Office (8 x 160-w.) | | 1,280 | |
| Office (3 x 200-w.) | | 600 | |
| Total | | 22,780 | 104 |
| Additional packing room lighting | | 6,600 | 30 |
| Total electrical load | | | [1] 719 |

[1] Provide a 800-ampere main breaker.

## Insulation Requirements

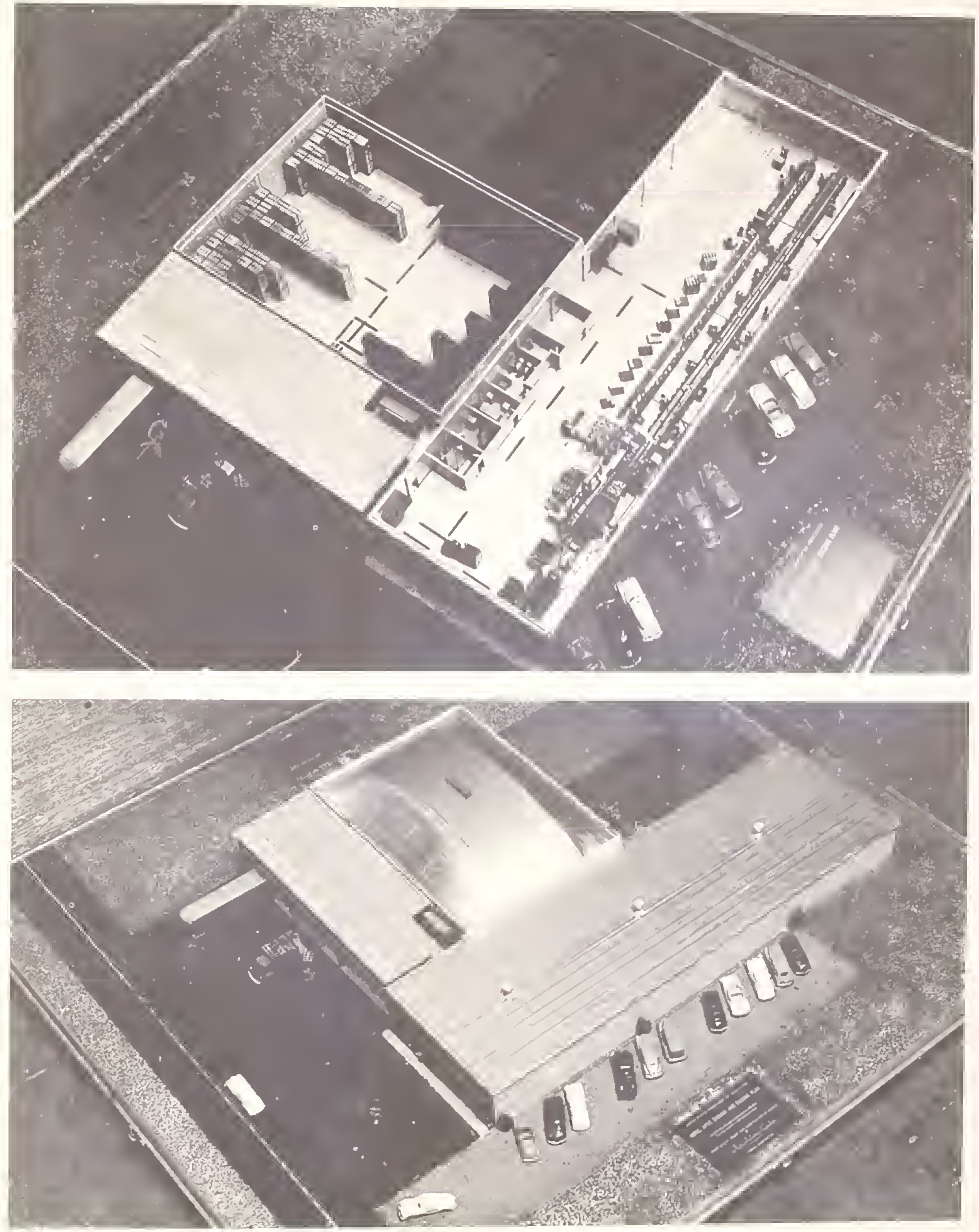
### Storage Room

Vapor Barrier.—The vapor barrier is on the outer surface of the insulation; the inner surface is vented, because, during most of the operating season, the vapor pressure inside is lower than the average vapor pressure of the outside air. In the Yakima region, the average outdoor vapor pressure for December and February is about the same as that inside a building. In January, the average outside vapor pressure is 3.3 mm. Hg, and the indoor vapor pressure is 3.8 mm. Hg, or a pressure difference of 0.5 mm. For September and June, the warmest months in which it is likely that the storage will operate, the outside vapor pressure averages 7 and 7.3 mm. Hg, giving a difference of 3.2 and 3.5 mm. between outdoor and indoor vapor pressures.

Roof Insulation.—In storages with the bowstring truss roof, the general practice has been to apply the insulation either to the roof-deck itself or between the joists of the roof structure. Although this construction method subjects the insulation to higher outside surface temperatures from direct solar load, this can be alleviated by using heavier insulation. The cost of extra insulation is offset by elimination of ceiling structure costs within the building, and by making the truss space available for the refrigeration system and air circulation.

Tests show that, at an average daily outside temperature of 65° F., the average roof surface temperature will be about 75° F. when insulation is applied to the roof deck.[9] When insulation is placed beneath a well-ventilated attic space, the top surface of the insulation will average about 68° F. With 32° F. inside temperature in each case, the temperature difference through the insulation will be about 20 percent greater in the case of the insulation applied to the roof deck. If 4 inches of corkboard, installed beneath a well-vented attic space, is taken as standard insulation for cooler service, the roof deck should be insulated with 5 inches of corkboard, to restrict heat flow to the same as that of standard. Because 5 inches of corkboard produces a U value (overall heat transmittance) of 0.056 B.t.u./sq.ft./hr./°F. Td. (temperature difference), this value is specified as representing maximum transmittance allowable for the various ceiling insulations considered.

[9] See Bibliography, reference 13.



BN-14981 (above) BN-14982 (below)

Figure 31.—Scale models of the 50,000-box-capacity apple packing and storage house.

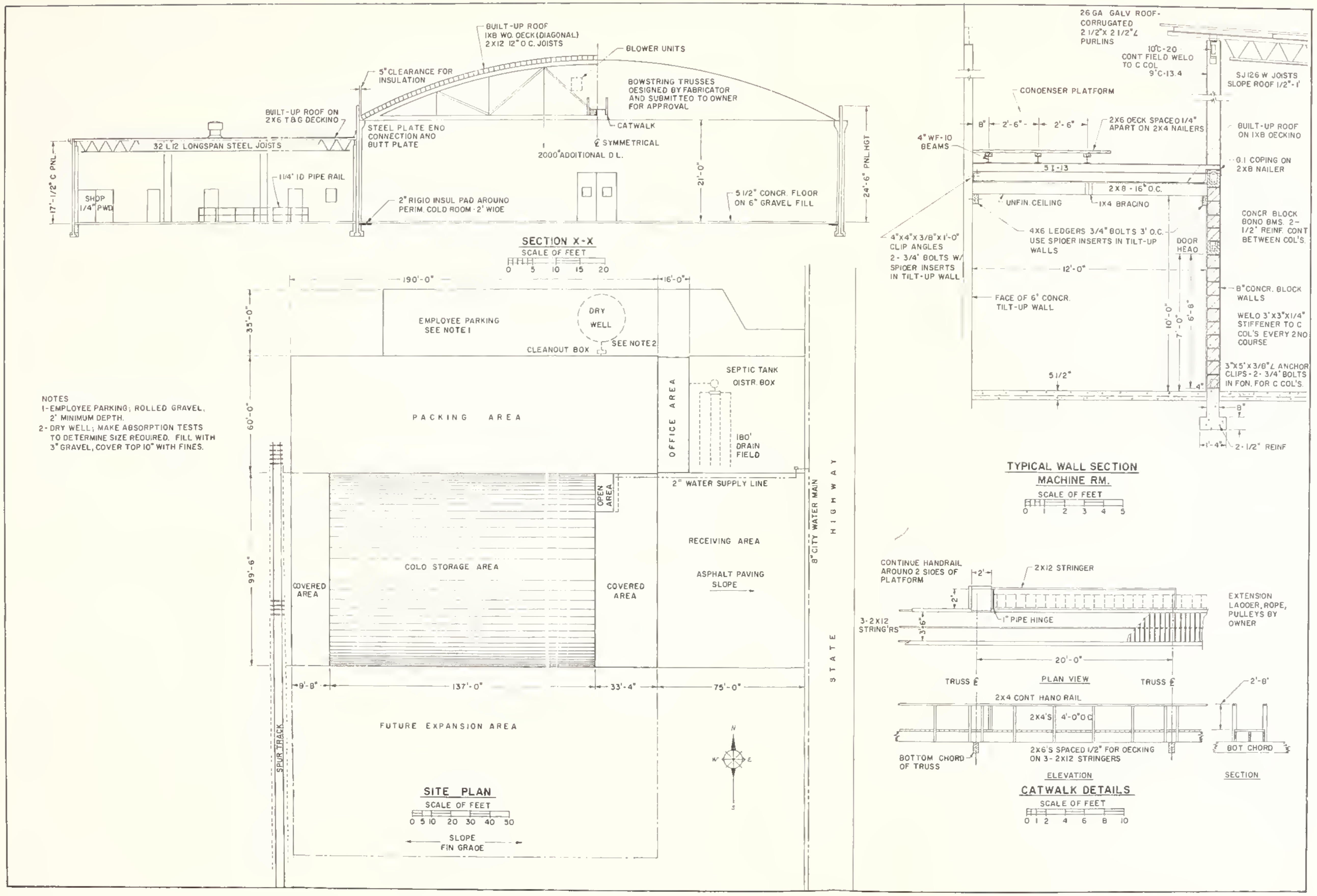



FIGURE 32.—Site plan for the 100,000-box-capacity apple packing and storage house.

This additional insulation costs about $0.20 per sq. ft. In addition, there is approximately 8 percent more area to be covered, and the cost for each sq. ft. is about ($0.80 + 0.20) x 8 percent = $0.08, for a total extra cost of $0.28 per sq. ft. A ceiling to provide an attic and support the insulation would use 2.5 board feet of lumber per sq. ft., so the extra cost of insulation on the roof-deck is offset by the material cost alone in the ceiling. When labor to install the ceiling is added to the costs, it is estimated that the savings achieved by using roof insulation will amount to between $0.25 and $0.30 per sq. ft. of horizontal area.

Table 7 is presented to compare a number of insulation treatments that have been used successfully on roof-decks or in the roof structure of apple storages. Costs per sq. ft. of roof were obtained from responsible contractors. U values were either calculated from published data in the ASRE Data Book or taken from tests of similarly insulated structures.[10]

From the comparisons given in table 7, it is apparent that the rigid insulation applied to the deck is considerably more expensive. Five inches of this material would probably have been close enough to the maximum overall transmittance required (0.050). (The cost, however, would still have been between $0.90 and $1.) The various other insulators which are installed between the joists are not greatly different in cost per square foot, and the 12-inch fill of fiber glass was selected because of the lower U value obtained with this material.

To use this information: Assume that the recommended insulating procedure is the 12-inch fiber glass fill, held in place with a sheet of 0.006-inch-thick aluminum foil, and is available at $0.46 per sq. ft. at the construction site. The U value is 0.0237 B.t.u./sq.ft./hr./°F.Td. This is to be compared with some other insulating procedure which, for the purpose of this example, will be assumed to be of equal durability but the cost at the site of the proposed construction is $0.35 per sq. ft. and the U value is 0.04 B.t.u./sq.ft./hr./°F.Td.

TABLE 7—*Installation cost and overall heat transmittance (U value) of 4 types of ceiling insulation*

| Description of insulation | Installation cost per sq. ft. | U value |
|---|---|---|
| | *Dollars* | *B.t.u./sq. ft./hr./° F.Td.* |
| 12-inch fiber glass insulating wool between joists with 0.006-inch aluminum sheet on bottom of joists | 0.46 | 0.0237 |
| Rigid insulation on top of deck, 6-inch fiber glass roof deck (3 layers of 2 inches) with 15-lb. felt slip sheet | 1.17 | .0425 |
| 6-inches P.F.-612 semirigid fiber glass insulation between joists with 0.006-inch aluminum sheet on bottom of joists | .49 | .0405 |
| 2 layers of prefabricated aluminum foil insulation having a total of 6 sheets of aluminum, between joists. Joists sealed on bottom with ⅜-inch plywood | .48 | [1].039 |

[1] Determined by field tests.

[10] See Bibliography, references 2 and 12.

The annual cost differential for a U of 0.0237 is $12.10 and for a U of 0.04, $20.50. The difference between the two is $8.40, which is the annual difference in fixed and operating costs per 1,000 sq. ft. between the two insulations being considered. The insulation cost difference between the two methods is 1,000 x (0.46—0.35)=$110. The annual fixed charge on this investment, consisting of 5 percent depreciation, 2.5 percent amortized interest, and 2 percent for insurance and taxes, or 9.5 percent of $110, equals $10.45 per year per 1,000 sq. ft. In this case, the extra equipment and operating costs encountered with the substitute insulation would be $2.05 per 1,000 sq. ft. less than the fixed costs on the heavier ceiling insulation and there would be an overall saving in using the hypothetical substitute.

In addition to showing the method of comparing the various insulations that may be considered for an application, this example serves to show that insulation types 3 and 4 in table 7 would have to be available at about $0.36 per sq. ft., in order to be considered equal to the insulation selected.

The slight differences in annual costs for several of the insulation materials that are similar in performance show the need for careful evaluation of the durability of material selected. To obtain firsthand information on the performance of the material selected for the storages in this report, tests of in-place heat transmittance and examinations of the condition of the insulating material were made at an apple storage plant. The roof was insulated with 12 inches of fiber glass between joists. The tests were made at the end of the second season's operations.

Heat flow and temperature differences through the insulation were measured with a Gier and Dunkle heat flow meter, thermocouples, and a recording potentiometer. The data were analyzed by methods described in an earlier work.[11] The observed value closely approximated the value calculated from the ASRE Data Book.[12] Duplicate samples of the insulation were withdrawn from three places in the roof, and moisture determinations were made. The insulation was exceptionally dry; all samples contained less than 0.3 percent moisture.

Because of the dryness of the insulation and its ability to restrict heat flow after two seasons' use, it seems reasonable to conclude that its characteristics and method of installation are adequate. More expensive insulation is unnecessary for the usual intermittent apple storage operations.

Wall Insulation.—The minimum requirement for wall insulation was set at a U value of 0.07, which is the equivalent of 4 inches of corkboard and is considered standard for 30° F.

Table 8 shows the wall insulations that were considered, the installed cost (determined by responsible contractors who had used the material), and the U values, as determined either by calculation or by test.

The built-up wall with reflective spaces and a mineral wool bat was finally selected because it combined low initial cost and good heat transmittance. Slight changes in contractor's pricing could change the selection to either insulation 1 or 5 (table 8) because these three cost about the same. Evaluation of the differences in prices and performance can be made as described in the discussion on roof insulation.

A heat flow test was made on the walls in a building whose construction was very nearly the same as that selected in this report. The U value for the wall was 0.034, compared with a calculated value of 0.038.

[11] See Bibliography, reference 13.
[12] See Bibliography, reference 2.

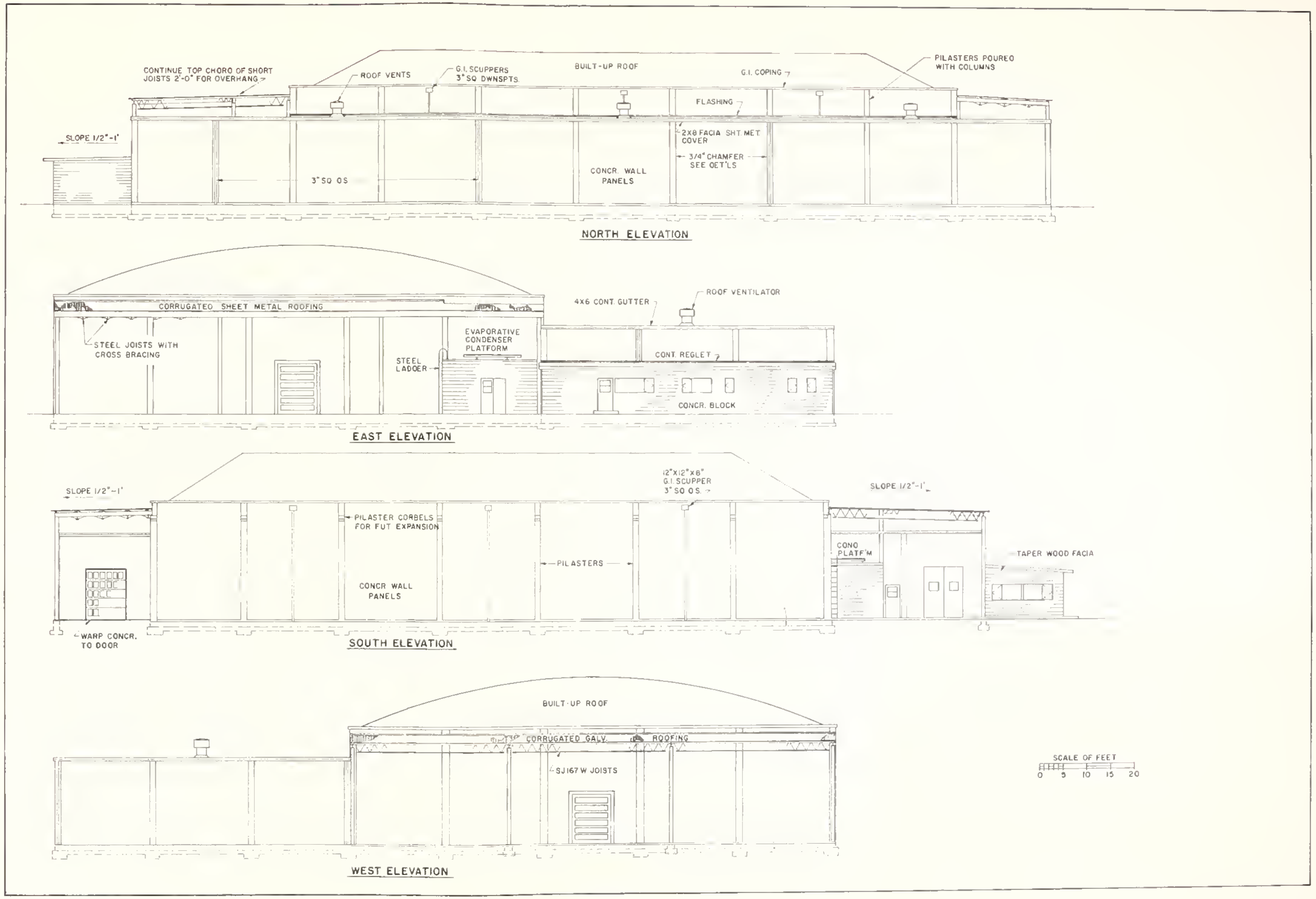



Figure 33.—Elevations for the 100,000-box-capacity apple packing and storage house.

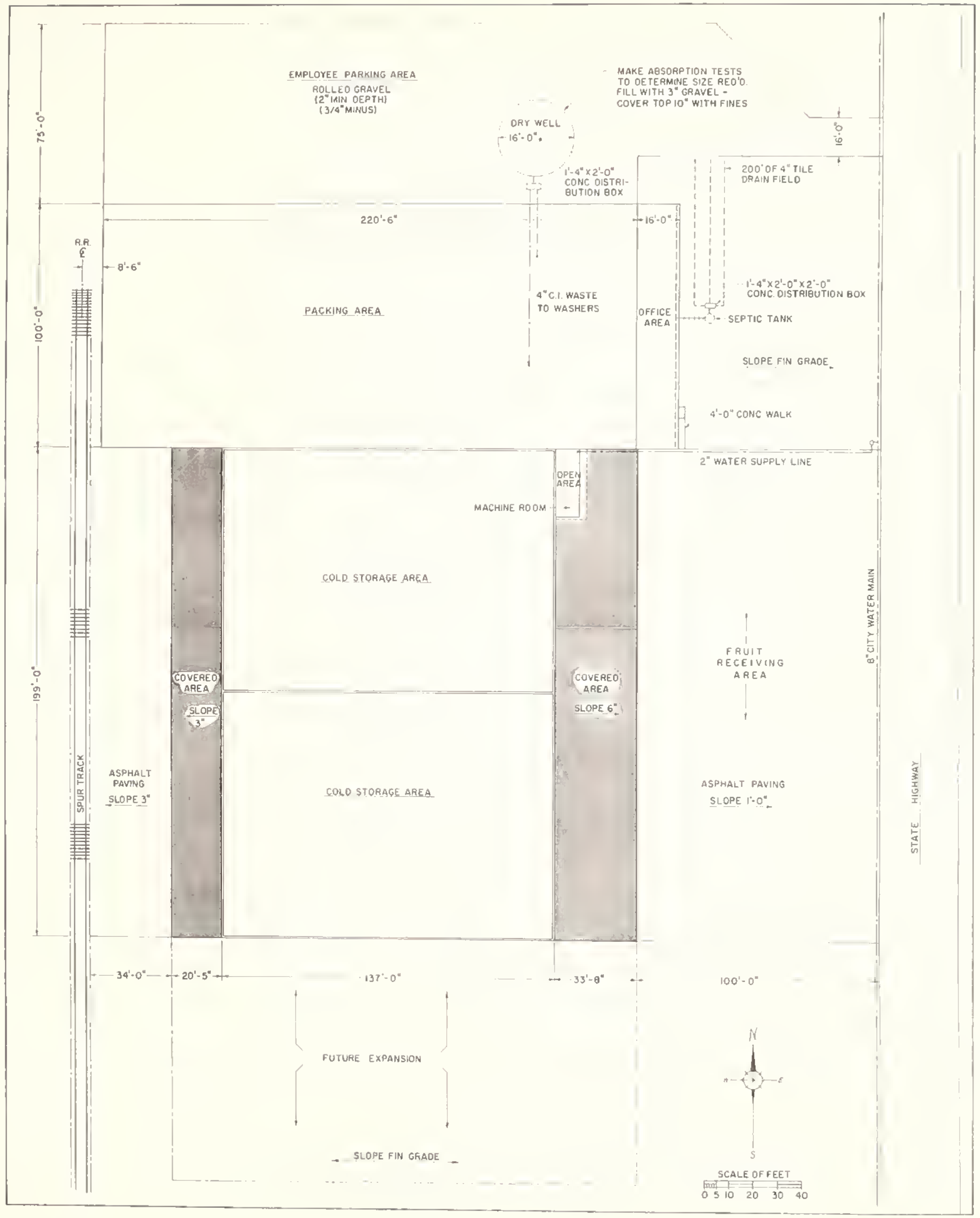



FIGURE 34.—Site plan for the 200,000-box-capacity apple storage and packing house.



TABLE 8.—*Installation cost and overall heat transmittances (U values) of 5 types of wall insulation*

| Description of insulation | Installation cost per sq. ft | U value |
|---|---|---|
| | *Dollars* | *B.t.u./sq. ft./hr./°F.Td.* |
| 4-inch P.F.612 semirigid fiber glass insulation between studs, including studding and outside vapor barrier and inside finish of ½-inch fiber glass roof deck material | 0.56 | 0.0574 |
| 4-inch fiber glass rigid AE (asphalt-enclosed) board insulation (no interior finish) applied in: | | |
| Two 2-inch layers | .74 | .0642 |
| One 4-inch layer | .64 | .0642 |
| 4-inch rigid foam-type insulation (no interior finish) applied in: | | |
| Two 2-inch layers | 1.04 | .0596 |
| One 4-inch layer | .93 | .0596 |
| Built-up wall with 2 reflective spaces, one 4-inch mineral wool bat and ½-inch fiber glass roof decking for interior finish | .50 | .0424 |
| Two layers of prefabricated aluminum foil insulation having a total of 4 sheets of aluminum, arranged between studs, inside finish of plywood | .52 | [1] .0489 |

[1] Determined by field tests.

FLOOR INSULATION.—The selection of floor insulation is more complex than wall and roof insulation. The extent to which a floor should be insulated in this type of storage depends largely upon the site. If ground water level is near the floor surface—within 10 feet for a substantial part of the season—some insulation should be placed beneath the concrete wearing floor. If the water level is lower than this, it is difficult to justify the cost of floor insulation, because dry ground is a fairly effective insulator.

As a minimum, however, when the floor is not insulated, the wall insulation should extend down below the floor onto the footings so that the concrete floor does not touch the outside wall. Where this precaution has not been taken, heat transmission rates at the wall have been observed during warm weather that are five or six times greater than at a distance of 5 feet from the wall. In the storage design in this report, the breaker strip of insulation is brought back under the floor rather than continuing down the footing; a perimeter ribbon of insulated floor is thus provided. If the insulation is extended down to the footings, the perimeter strip showing reduced heat flow is much narrower. The most economical width of the floor ribbon was not determined.

A study, during the operating season, in two storages having only perimeter insulation indicates that the total fixed cost of added refrigeration equipment, because of additional heat leakage from the uninsulated floor, would justify spending 40 to 50 cents per sq. ft. to insulate the floor with the equivalent of 3 inches of boardform insulation. The cost of a subfloor to support the insulation, however, plus the cost of the insulation, would range between $1 and $1.25 per sq. ft. It therefore seems best to limit floor insulation to the perimeter in locations where ground water level is more than 12 feet below the floor surface.

In addition to perimeter insulation, various types of inorganic fill materials, with sufficient compressive strength to be used beneath the floor were considered. Floor heat flow data from one storage built with a 9-inch layer of pumice and concrete beneath the concrete wearing floor was compared with that in storages with perimeter insulation only. It was calculated that the benefits obtained from the pumice and concrete would not justify an investment of more than $0.13 per sq. ft. The cost of such a fill is several times this amount.

At the storage plant with the pumice-concrete fill a recently added room had loose pumice rolled in place to form a 12-inch fill, for $0.35 per sq. ft. This material is somewhat superior to the pumice-concrete. Heat flow rate measured in midwinter was 1.4 B.t.u./sq.ft./hr. for the rolled pumice insulation and averaged 1.9 B.t.u./sq.ft./hr. for two locations on the floor with pumice-concrete fill. During midwinter, a floor insulated with 3 inches of corkboard, situated on similar soil and with comparable drainage, showed a heat flow rate of 0.62 B.t.u./sq.ft./hr. The 12 inches of pumice do not seem to resist the heat flow nearly as well as the 3 inches of corkboard. Had the rolled pumice fill resisted heat nearly as well as the corkboard, its use would seem justified, because its cost is slightly less than that for cork treatment.

From these comparisons, inorganic fill materials do not seem promising for insulating floors of intermittently operated apple storage rooms. Perimeter insulation only is specified because it is assumed that ground water level is never within 12 feet of the floor level. Storages without floor insulation should be cooled well before harvest so that the heat may be removed from the earth beneath the floor.

For sites where the ground water level is within a few feet of the surface for any considerable period of time, insulation beneath all of the floor surface with 3 to 4 inches of boardform insulation, preferably of the type with closed cellular structure that is impervious to moisture, is recommended.

## Packing Room

Because of the growing tendency toward packing to order during the winter months, heat loss in packing rooms was studied to see if wall and ceiling insulation is necessary.

The first step was to select a representative packing schedule and determine the number of degree-days that would be involved in heating during such a season. This step and the calculations leading from there to fixed and operating cost differentials are in the section on Economic Analyses of Wall and Ceiling Insulation. Data in that section give these differentials for overall heat transmittance ranging from 0.0 to 1.0 B.t.u./sq.ft./hr./°F.Td. The method of applying this information is essentially the same as that given earlier for similar data in the study of economic thickness of insulation for the storage walls and roof. Also shown in this section are the calculations determining the selection of wall insulation and the calculations showing why roof insulation was not recommended.

In order to make the wall insulation as simple as possible, a boardform insulation was selected that had a vapor barrier already applied to the warm side. In the packing room the vapor movement would always be from inside to outside; therefore, the insulation selected must either have a vapor barrier applied to the inside face, or must itself constitute a vapor barrier.

In addition to the economic reasons for insulating the packing room walls, there are also physical considerations. When the packing room is maintained at 60° F. and the outside temperature is −5° F., an uninsulated concrete wall would have a surface temperature of about 29° F. Besides large radiation transfers from the room occupants to this cold surface, the wall would frost whenever room humidity rose above 30 percent. At slightly higher outside temperature, and with room humidities of 35 to 40 percent, the walls would sweat.

The uninsulated ceiling will have a surface temperature of about 48° F., at a 60° F. room and −5° F. outside temperature. Sweating will not occur until the humidity in the room rises to 65 percent. Because a considerable amount of dry outside air is brought into the packing room by the apple washer ventilation system, it is not likely that the humidity in the packing room will approach 65 percent.

### Office

Insulation for walls and ceiling of the office was found to be justified, as shown in the section below. Because the office is occupied throughout the heating season, and higher temperatures are maintained there, insulation will obviously provide an even greater return per square foot of exposed area than in the packing room.

Moreover, chilling by radiation to cold, uninsulated walls when outside temperatures are low would be more noticeable, because office workers are not as active as packing room workers.

## Economic Analyses of Wall and Ceiling Insulation

### Cold Storage

Calculations for this economic analysis are based on the following assumptions:

Average outside air temperature during operating period, September through May, is 45° F.
Average roof temperature is 55° F. for season.
Average wall temperature is 45° F. for season.
Length of season is 9 months (270 days, or 6,600 hours).
Roof temperature is 75° F.
Wall temperature is 65° F.
Refrigeration equipment cost is estimated at $600/T.R.
Annual fixed charges on refrigeration equipment are 15 percent of initial cost of the equipment.
Average power required per T.R. equals 1 kilowatt (kw.).
Average power cost is 1.5¢ per kw.-hr.
Total annual fixed charges on insulation are 9.5 percent of installed cost.

Ceiling.—Heat leakage influences refrigeration capacity required and, consequently, refrigeration investment.

Change in refrigeration capacity required by a change in ceiling insulation transmittance, U, per 1,000 sq. ft. of surface is determined by:

$$\frac{(75-32)\times 1{,}000\times dU}{12{,}000}=3.58\ dU\ \text{T. R.}$$

Change in annual fixed charges on refrigeration equipment provided to meet required capacity as determined by a change in ceiling insulation transmittance is: 3.58 dU×$600×0.15=$322.00 dU (per 1,000 sq. ft.)

Change in operating cost influenced by change in ceiling insulation transmittance is calculated as follows:

Average season's heat leakage per 1,000 sq. ft. is:

$$(55-32)\times 1{,}000\times 6{,}600\times U \text{ in B.t.u.'s}$$

Change in season's heat leakage per 1,000 sq. ft. with change in U is 151,800,000 dU B.t.u. hr., or in terms of ton hours:

$$\frac{151{,}800{,}000\ dU}{12{,}000}=12{,}650\ dU.$$

Change in operating cost with change in U is: 12,650 dU × 1 kw./T.R. × $0.015 kw.-hr. = $189.80 dU. Total of changes in fixed charges and operation costs per year per 1,000 sq. ft. required by a change in ceiling insulation transmittance equals $511.80 dU.

Change in annual fixed charges, change in annual operating charges, and total of these two vs. change in U for U values from 0.01 to 0.1 are given in figure 37.

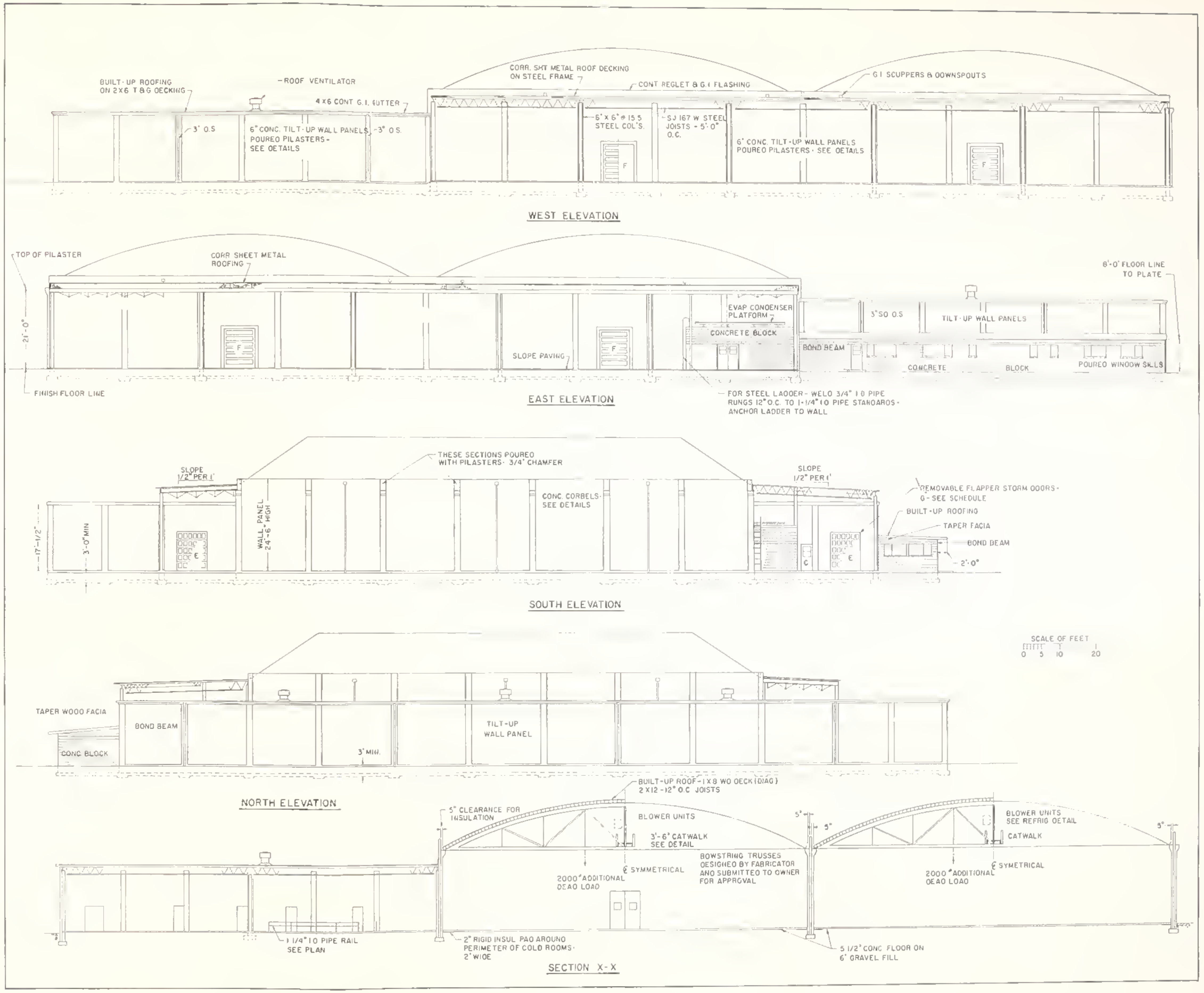
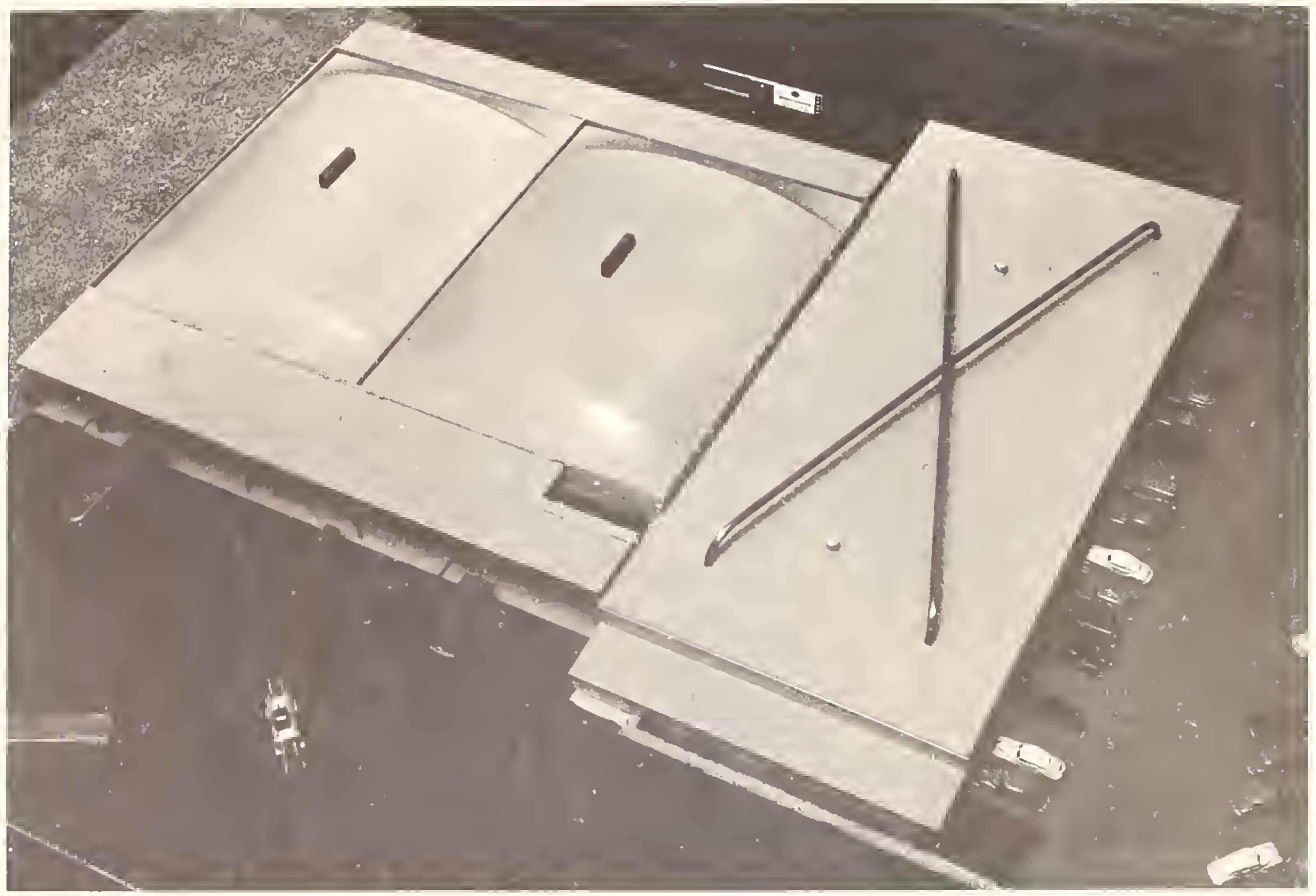



Figure 35.—Elevations for the 200,000-box-capacity apple packing and storage house.



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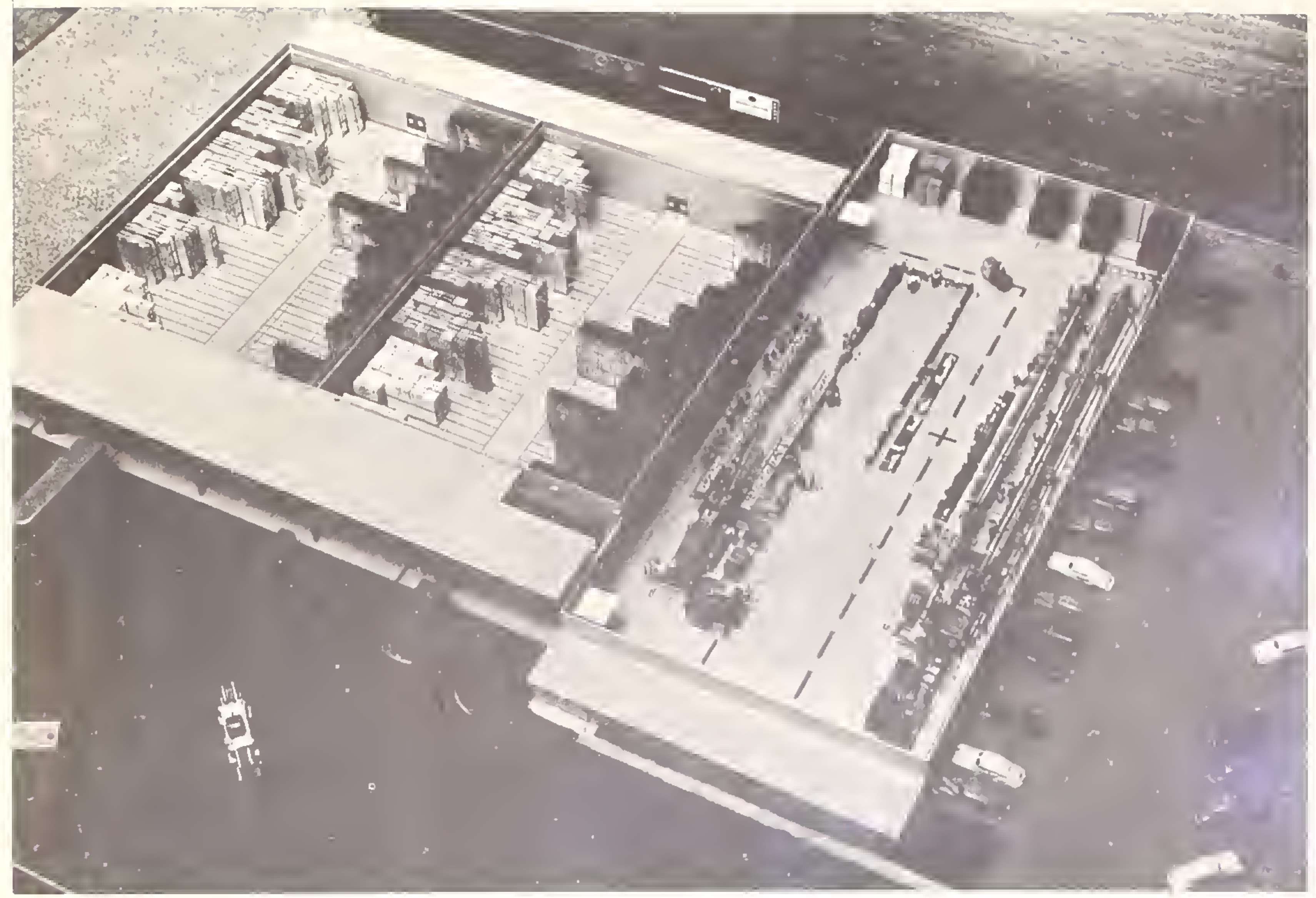

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FIGURE 36.—Scale model of the 200,000-box-capacity apple packing and storage house.

These total cost differentials arising from a change in U value may be balanced against the change in annual fixed charges per 1,000 sq. ft. of the insulating material, taken at 9.5 percent of installed cost of the material, to determine which insulating procedure offers the lowest overall cost.

WALL.—The same general approach is used to determine total cost differentials arising from a change in U value of the wall insulation; however, the actual differentials determined are not the same as for the ceiling because the outside design and outside average season temperature are different.

Change in refrigeration capacity required by a change in wall insulation transmittance, U, per 1,000 sq. ft. of surface is determined by the formula:

$$\frac{(65-32)\times 1{,}000\times dU}{12{,}000}=2.75\ dU\ \text{T.R.}$$

Change in annual fixed charges on refrigeration equipment provided to meet required capacity as determined by a change in U is: 2.75 dU × \$600.00 × 0.15 = \$247.50 dU (per 1,000 sq. ft.) Change in operating costs influenced by change in U:

$$\frac{(45-32)\times 1{,}000\times 6{,}600\times \$0.015\ dU}{12{,}000}=\$107.20\ dU.$$

Total changes in fixed and operating costs per 1,000 sq. ft. required by a change in wall insulation transmittance equals \$354.70 dU.

Figure 37 gives the fixed charges for U values varying from 0.01 to 0.1.

The foregoing analysis should be applied only to those insulation procedures deemed to have adequate performance for the duty involved and to remain efficient throughout the period set up for depreciation of the material.

## Packing Room

Calculations for this economic analysis are based on the following assumptions:

- Average inside temperature is 60° F. and outside temperature is −5° F.
- Gas heating equipment cost is estimated at \$400 per 100,000 B.t.u./hr. output.
- Annual fixed charges on heating equipment are 15 percent of initial cost of the equipment.
- Fuel cost is \$0.10 per therm (100,000 B.t.u. input).
- Heating equipment efficiency is 80 percent.
- Total annual fixed charges on insulation are 9.5 percent of installed cost.
- Degree-days during packing room operating season equal 1,667.

The number of degree-days estimated for the packing room operating season involved a number of assumptions and the final figure was derived as follows:

For a 60° F. inside temperature, the fuel consumption is estimated from the number of degree-days, using 55° F. outside temperature as a base. The data in the section "Use of Rejected Heat from the Refrigeration System," were used to determine degree-days below the base. Experience shows annual degree-days are apportioned as shown below.

| *Month* | *Degree-days at 55° F.* | *Packing room operates—* | *Degree-days during operating period* |
|---|---|---|---|
| Sept | 10 | Entire month | 10 |
| Oct | 160 | Entire month | 160 |
| Nov | 483 | 2 weeks | 225 |
| Dec | 739 | 2 weeks | 334 |
| Jan | 841 | 2⅔ weeks | 508 |
| Feb | 566 | 2 weeks | 283 |
| Mar | 326 | 2 weeks | 147 |
| Sept. to Mar | | | 1,667 |

Heat leakage influences the heating equipment capacity required, and consequently, heating equipment investment.

Change in annual fixed charges on heating equipment provided to meet required capacity as determined by a change in U is as follows:

$$\frac{(60-5)\times 1{,}000\times \$400\times 0.15\ dU}{100{,}000}=\$39\ dU\ \text{(per 1,000 sq. ft. of surface)}$$

Change in operating costs influenced by a change in U value is as follows:

The seasonal heat leakage, in B.t.u.'s per 1,000 sq. ft., for a change in U is: 1,667×24×1,000×dU=40,000,000 dU.

Change in operating cost per 1,000 sq. ft. of surface is:

$$\frac{40{,}000{,}000\ dU\times \$0.10}{100{,}000\times 0.8}=\$50\ dU$$

Total change in fixed charges and operating costs per year per 1,000 sq. ft. surface caused by a change in U=\$89 dU.

These values are shown in figure 38. The same curves are used for both walls and ceilings in this analysis, because it is not customary to allow for solar load on roofs in estimating winter heating loads.

WALL.—With fiber glass roof deck insulation applied to walls the following U values are obtained:

Uninsulated walls=0.79 B.t.u./hr./sq. ft./° F. Td.
Wall with 1" insulation=0.207 B.t.u./hr./sq. ft./° F. Td.
Wall with 1½" insulation=0.152 B.t.u./hr./sq. ft./° F. Td.
Wall with 2" insulation=0.117 B.t.u./hr./sq. ft./° F. Td.

Difference in U between uninsulated wall and insulated wall with:

1" insulation = 0.79 − 0.207 = 0.583 B.t.u./hr./sq.ft./°F. Td.
1½" insulation = 0.79 − 0.152 = 0.638 B.t.u./hr./sq.ft./°F. Td.
2" insulation = 0.79 − 0.119 = 0.671 B.t.u./hr./sq.ft./°F. Td.

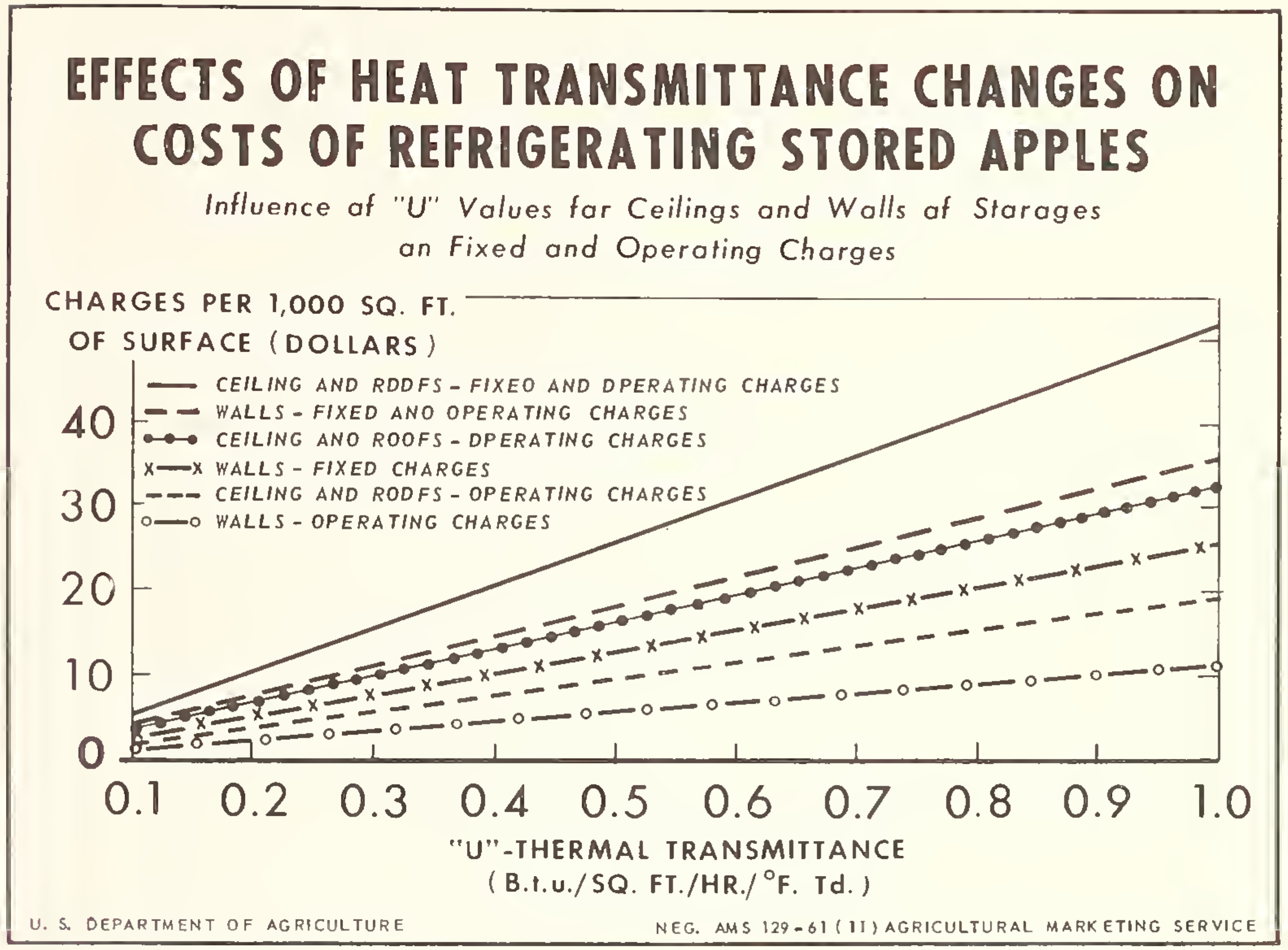


FIGURE 37

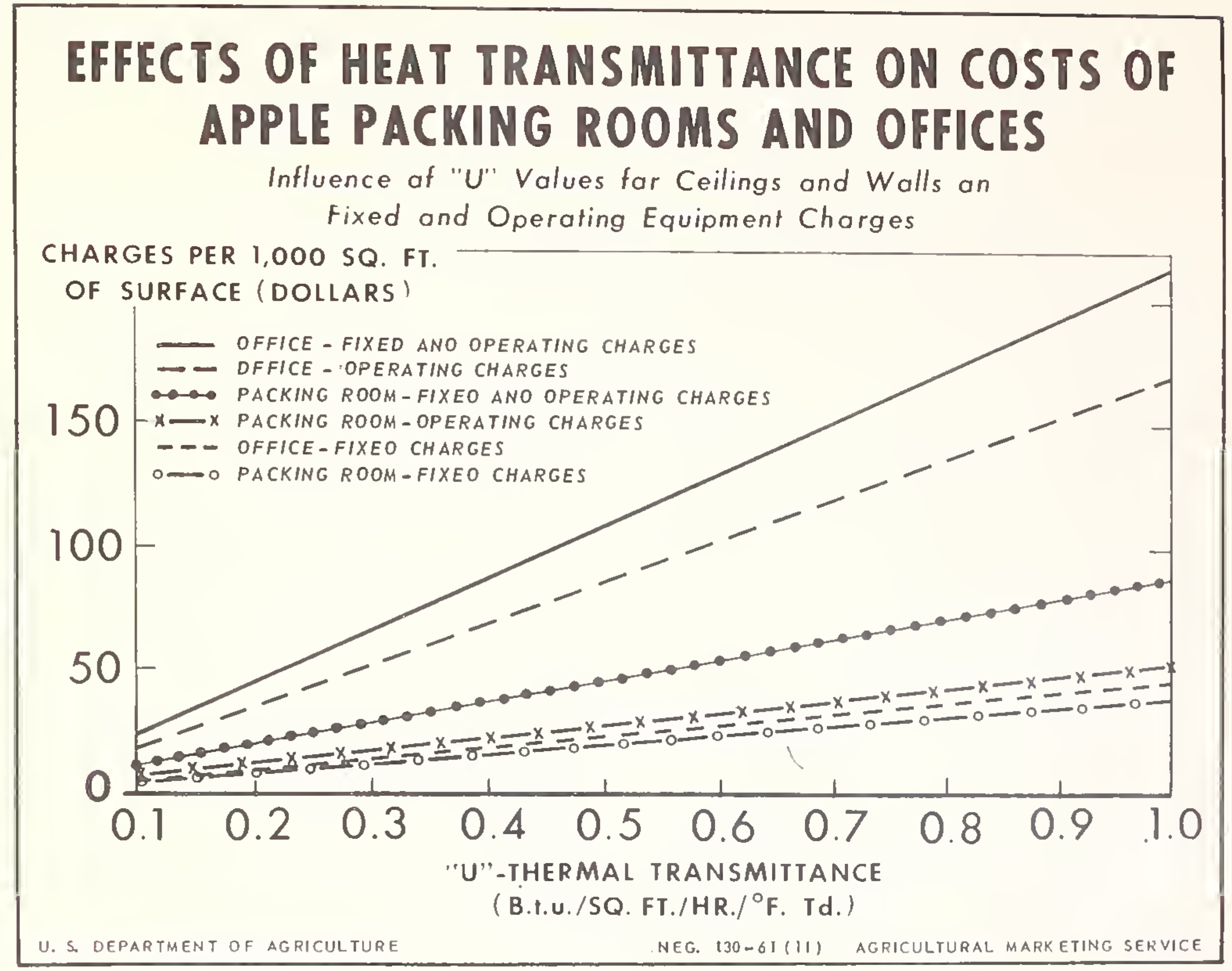


FIGURE 38

Difference in fixed and operating costs of insulated and uninsulated walls per year per 1,000 sq. ft.:

1" insulation vs. uninsulated wall = 0.583 × \$89.00 = \$51.90
1½" insulation vs. uninsulated wall = 0.638 × \$89.00 = \$56.80
2" insulation vs. uninsulated wall = 0.671 × \$89.00 = \$59.70

Insulation cost (including installation) is assumed to be \$0.30/sq. ft. for 1" material; \$0.36/sq. ft. for 1½" material; \$0.42/sq. ft. for 2" material.

Annual fixed charges on insulating are assumed to be 9.5 percent.

First cost, annual fixed charges and net savings per year per 1,000 sq. ft. of surface with the various insulating treatments are as follows:

| *Treatment* | *First Cost* | *Annual Fixed Cost* | *Net Savings* |
|---|---|---|---|
| 1" insulation | \$300.00 | \$28.50 | \$23.40 |
| 1½" insulation | \$360.00 | \$34.20 | \$22.60 |
| 2" insulation | \$420.00 | \$39.90 | \$19.80 |

One inch of insulation will provide the maximum net annual saving, and its use is therefore recommended. The material selected has a moisture-proof facing to form a vapor barrier. This inside face is sufficiently hard and smooth that the only protection required is a bumper bar in the areas where forklift trucks operate.

CEILING OR ROOF.—The use of ½" and 1" foam-type insulation in the roof will be analyzed. The U values are:

Uninsulated roof = 0.32 B.t.u./hr./sq. ft./°F. Td.
½" foam-type insulation added = 0.195 B.t.u./hr./sq. ft/°F. Td.
1" foam-type insulation added = 0.140 B.t.u./hr./sq. ft./°F. Td.

| | *Adding ½" foam-type insulation* | *Adding 1" foam-type insulation* |
|---|---|---|
| dU in B.t.u./hr/sq. ft./°F. Td | 0. 125 | 0. 18 |
| Annual fixed and operating cost differential/1,000 sq. ft | \$11. 13 | \$16. 00 |
| First cost of insulation/1,000 sq. ft | 235. 00 | 320. 00 |
| Annual fixed cost on insulation | 22. 30 | 30. 40 |

Because the annual fixed charges on the insulation are greater than the annual fixed and operating savings due to the insulation, its use cannot be justified.

Two other ceiling treatments, using reflective insulation, were considered. The first consisted of a single layer of aluminum foil on kraft paper, both sides reflective. The second treatment consisted of one layer of prefabricated aluminum foil insulation having three sheets of aluminum with paper separators between sheets. This assembly would be applied to 2 x 4 spacers attached to the under side of the roof deck.

Making allowance for penetration of the insulation by the steel of the roof joists, a U factor of 0.193 was calculated for the first treatment and a U of 0.086 for the second. Cost of the first treatment was estimated at \$110 per 1,000 sq. ft. and for the second, \$210 per 1,000 sq. ft.

A study of the justification of these insulating treatments is tabulated below.

| | *Adding 1-layer reflective material* | *Adding 3-layer assembly reflective material* |
|---|---|---|
| dU | 0. 32−0. 193=0. 127 | 0. 32−0. 086=0. 234 |
| Annual fixed and operating cost differential/1,000 sq. ft | \$11. 30 | \$20. 80 |
| First cost of insulation | 110. 00 | 210. 00 |
| Annual fixed cost of insulation | 10. 45 | 20. 00 |
| Net annual savings/1,000 sq. ft | 0. 85 | 0. 80 |

The costs of these treatments were so close to the break-even point that it did not seem worthwhile to recommend either. Either treatment could be installed after construction. If it is found that the operating season is actually much longer than estimated in these calculations, or that the cost of installing the material is less than estimated, an insulated ceiling could be justified.

## Office

Calculations for this analysis are based on the following assumptions:

Equipment selection is based on 70° F. inside temperature and −5° F. outside temperature.
Gas heating equipment cost is estimated on the basis of \$400 per 100,000 B.t.u./hr. output.
Total annual fixed charges on heating equipment are 15 percent of the initial cost of the equipment.
Fuel cost is \$0.10 per therm (100,000 B.t.u. input).
Heating equipment efficiency is 80 percent.
Degree-days per year equal 5,585.[13]

This analysis is based on office occupancy throughout the heating season, which would be normal; the number of degree-days in the office operation—5,585—contrasts with the number for the packing room operation—1,667.

The change in heating equipment annual fixed charges as influenced by a change in U value is as follows:

$$\text{d fixed charges} = \frac{(70-5) \times 1{,}000 \times \$400 \times 0.15\ \text{dU}}{100{,}000} = \$45\ \text{dU}$$

[13] See Bibliography, reference 1.

The change in operating costs per 1,000 sq. ft. of surface varies with change in U values as follows:

$$d \text{ operating costs} = \frac{5585\times24\times1000\times dU\times\$0.10}{100{,}000\times0.8} = \$167.50\ dU$$

Total of the changes in fixed charges and operating costs per year per 1,000 sq. ft. of surface caused by a change in U=$212.50 dU.

These values are shown in figure 38.

WALL.—The possibility of using 1", 1½" and 2" thicknesses of foam-type insulation (K=0.25) was considered. This material will take an interior plaster coating. Material cost is $0.17/sq. ft. in 1" thickness; $0.255/sq. ft. in 1½" thickness; and $0.34/sq. ft. in 2" thickness. Labor to install was estimated to be $0.15/sq. ft.; two coats of plaster, $0.28/sq. ft. U for uninsulated wall is 0.79 B.t.u./hr./sq. ft./° F. Td.

| *Insulation thickness* | *U value* | *dU from uninsulated wall* | *Total annual cost diff.** | *Fixed charges on insulation** | *Annual net savings** |
|---|---|---|---|---|---|
| 1" | 0.19 | 0.60 | $126.50 | $57.00 | $69.50 |
| 1½" | 0.138 | 0.652 | 137.50 | 65.10 | 72.40 |
| 2" | 0.108 | 0.682 | 144.00 | 73.20 | 70.80 |

*Per 1,000 square feet.

The 1½" insulation provides the greatest net annual savings and an acceptable degree of insulation.

CEILING.—For the ceiling, 6" of fiber-glass blowing wool, placed between the joists, is recommended. Uninsulated ceiling has U value of 0.32; insulated ceiling has a value of 0.04. The dU occasioned by the treatment is therefore 0.28 (0.32−0.04). The cost of this treatment will be about $0.24 per sq. ft. Total annual cost differential is $59.50 per 1,000 sq. ft. Fixed charges on the insulation amount to $22.80 per 1,000 sq. ft., leaving a net saving per year of $36.70 per 1,000 sq. ft. to justify the use of this insulation.

## Typical Refrigeration Load Calculation

The calculation to determine the refrigeration load for the 100,000-box storage is typical for all of the storages, and the assumptions are given in detail below.

Interior dimensions, 135 x 98 x 21 ft. high under the trusses.
Outside measurement of storage room—137 x 100 ft.
Floor area, about 14,000 sq. ft.
Ceiling insulated for U=0.0237.
Walls insulated for U=0.043.
Uninsulated floor has a heat flow of 4 B.t.u./sq. ft./hr. during the receiving period.
7,000 field boxes per day are received.
Allow 8 percent extra area on roof, because width actually is an arc of a circle having a chord of 100 ft. and rise of about 12 ft.

Heat leakage from conduction:

| | *B.t.u./day* |
|---|---|
| Ceiling=14,000×1.08×0.0237×(75−32)×24 | 370,000 |
| Walls=480×21×0.043×(65−32)×24 | 344,000 |
| Floor=14,000×4×24 | 1,344,000 |
| Total heat leakage from conduction | 2,058,000 |
| Heat due to infiltration: | |
| Lights, equipment and men working (75 percent of total heat leakage from conduction) | 1,544,000 |
| Fan motor heat equivalent $\frac{14\times2{,}545\times24}{0.8}$ | 1,070,000 |
| Total fixed loads | 4,692,000 |

Receiving load:

| | |
|---|---|
| Cooling apples=7,000×0.9×34×(65−32) | 7,066,000 |
| Cooling boxes and pallets=7,000×0.5×7×(65−32) | 807,000 |
| Respiratory heat of fruit $\frac{7{,}000\times34\times9{,}000}{2{,}000}$ | 1,072,000 |
| Total daily load | 13,637,000 |

Refrigeration capacity (T.R.) required, based on handling load with 22 hours of operating time per day:

$$\frac{13{,}637{,}000}{12{,}000\times22} = 51.6 \text{ T.R.}$$

For this storage, 52 T.R. capacity is recommended.

Similar calculations can be made for the 50,000-box and 200,000-box capacity plants.

## Determining Performance of Refrigeration Systems When Receiving Bartlett Pears

Because many apple storages are used to cool and store pears before apples are harvested, it is important to know if the storage can cool pears and hold them for shipment or sale. The average daily outside temperature and initial fruit temperature is assumed to be 85° F., and the average daily roof temperature is assumed to be 95° F. The capacity required is to receive and cool a ton of pears from 85° F. to 30° F.

| | *B.t.u.* |
|---|---|
| Cooling fruit=2,000×0.9×(85−30) | 99,000 |
| Cooling boxes & pallets=50×7×0.5×(85−30) | 9,610 |
| Respiratory heat=18,000 B.t.u./ton of fruit | 18,000 |
| Total (per ton of fruit) | 126,610 |

Calculate fixed loads encountered during the warmer receiving season, deduct these from system capacity, and calculate how many tons of pears per day the remaining capacity will handle.

Heat leakage:

| | *B.t.u./day* |
|---|---|
| Ceiling=14,000×1.08×0.237×(95−30)×24 | 559,000 |
| Walls=480×21×0.043×(85−30)×24 | 572,000 |
| Floor=14,000×4×24 | 1,344,000 |
| Total heat leakage by conduction | 2,475,000 |
| Heat due to infiltration: | |
| Lights, equipment and men working (75 percent of total heat leakage by conduction) | 1,856,000 |
| Fan motor heat equivalent: $\frac{14\times2{,}545\times24}{0.8}$ | 1,070,000 |
| Total fixed loads | 5,401,000 |
| System capacity on 22 hr. basis=52×12,000×22 | 13,730,000 |
| Less fixed load | 5,401,000 |
| Available for cooling pears | 8,329,000 |

This will handle $\frac{8{,}329{,}000}{126{,}610}$=65.8 tons of pears per day, or 3,290 lugs per day. In a normal 15-day season, the plant could receive and cool 49,350 lugs which would fill about 50 percent of the available space in the storage.



## Heating

### Load Calculations

PACKING ROOM.—Calculations for the heating of the packing room for the 100,000-box plant are given below. Except for allowing for different size and arrangement, the calculations are similar for the other two packing rooms. Assumptions are:

The room is 60 x 190 x 17 ft. under the roof deck.
149 ft. of wall adjoins cold storage and compressor rooms.
60 ft. of the front wall length is office partition, but the upper 7 ft. are exposed to the outside.
The packing room volume is 193,800 cu. ft.
Inside design temperature, 60° F.
Outside design temperature, −5° F.
Storage temperature, 30° F.
Ground temperature, 52° F.
U for storage room wall=0.0424
U for ground=0.10
U for outside packing room wall with 1-in. insulation=0.19
U for uninsulated packing room roof=0.32
U for 2–8 x 10 ft. doors=0.69
Ventilation—one 5,000-c.f.m. fan is used in cold weather to vent fumes from washer.

Heat leakage by conduction:

| | *B.t.u./hr* |
|---|---|
| Ceiling=60×190×0.32×(60−−5) | 237,000 |
| Storage room wall=17×149×0.424×(60−30) | 3,220 |
| Floor=60×190×0.1×(60−52) | 9,100 |
| Doors=2×8×10×0.69×(60−−5) | 7,180 |
| Outside walls: | |
| =17×291=4,950 sq. ft. | |
| =7×60=420 sq. ft. | |
| Less doors=2×8×10=−160 sq. ft. | |
| 5,210×0.19×(60−−5) | 64,400 |
| Total conduction loss | 320,900 |
| Ventilation=$\frac{5{,}000\times60\times0.24\times(60-{-5})}{13.2}$ | 354,700 |
| Total heating load | 675,600 |

OFFICE.—These calculations show the heating load for the office, rest rooms, and shop space in the 100,000-box plant, and are typical of the calculations for all of the storages. Assumptions are listed below:

Office and other service space 60 x 16 x 10 ft. high.
Office volume is 9,600 cu. ft.
One wall adjoins packing room.
Inside temperature, 70° F.
Outside temperature, −5° F.
Packing room temperature during nonoperating periods, 40° F.
Ground temperature, 52° F.
U for partition=0.30.
U for outside walls—with 1-in. insulation=0.19.
U for 156 sq. ft. of office windows=1.13.
U for insulated office ceiling=0.0395.

Heat leakage by conduction:

| | *B.t.u./hr* |
|---|---|
| Windows=156×1.13×(70−−5) | 13,200 |
| Outside walls=[(10×92)−156]×0.19×(70−−5) | 10,900 |
| Inside walls=10×60×0.3×(70−40) | 5,400 |
| Ceiling=60×16×0.0395×(70−−5) | 2,850 |
| Floor=60×16×0.1×(70−52) | 1,730 |
| Total conduction loss | 34,080 |

Ventilation load based on one air change per hour:

| | |
|---|---|
| $=\frac{9{,}600\times0.24\times(70-{-5})}{13.2}$ | 13,100 |
| Total heating load | 47,180 |

## Use of Rejected Heat from Refrigeration System

In connection with the heating requirements for packing rooms and offices, a study was made of the possibilities of using heat rejected from the refrigeration system for this purpose.

Because the 200,000-box plant has the most favorable relationship between the size of the storage and the size of the packing room, the study was made for this plant. The available rejected heat in the 50,000-box storage and the 100,000-box installation is roughly 25 percent and 50 percent, respectively, of the amount available for the 200,000-box plant. At the same time, the heating requirement is about 70 percent of that of the large plant. So, it does not appear that the use of heat from the storage rooms is practical in these smaller plants.

The amount of heat available from cooling the storage in the 200,000-box plant in the winter was calculated for outside conditions of −5° F., the normal outside design temperature for Yakima, Wash.; for +12.5° F., which is the coldest average monthly temperature recorded for January; and for 27.7° F., which is the normal average monthly temperature for January. When outside temperatures are lower than normal storage temperature, heat is lost to the outside through the ceiling, outside walls, and air leakage. The floors and wall between the storage and packing rooms conduct heat. Also contributing to the heat gain is the heat from fan motors, lights, men and equipment working, and respiratory heat from the fruit in storage. In making the calculation for January, which is the critical month of the year for heating, it has been assumed that the storage will be two-thirds full of fruit. A number of midwinter heat flow observations from uninsulated floors indicate that 1.25 B.t.u./sq. ft./hr. is average heat leakage through floors for this time of the year.

The heat available from storage has been plotted on figure 39, showing how this quantity varies with outside temperature. Also shown is the relationship between total heat requirement of the office and packing room, and outside temperature. These curves show that the heat from the storage rooms is not adequate to handle the office and packing room needs below a 46° F. outside temperature.

Reflective insulation for the ceiling of the packing room would just pay for itself by off-setting the cost of heat lost. Because savings are so little above the break-even point, it is not recommended where gas heating is to be used. However, when the use of heat from the storage is planned, insulation on the ceiling is recommended because it reduces the load on the packing room to the point where heat from the storage can be used a greater portion of the time.

Because the saving in fuel consumption with gas will just justify the insulation investment, a comparison will be made with use of heat from the refrigeration system for a packing room with an insulated ceiling.

Figure 39 shows the heat requirement for the packing room, with a ceiling insulated with a three-layer assembly of reflective material, that gives an overall ceiling U value of 0.086 B.t.u./sq. ft./hr./° F. Td. Also shown is the combined requirement of the office and packing room after insulation of the ceiling. In addition, there is plotted the combined heat requirement of the office and packing room when the ventilation fan is not operating, which would be the case at night. Because the ventilating fan operates only 8 hours a day, the average operating period load has been calculated and is shown as condition 3 on figure 39. Finally, the heat requirement for the office plus the heat required to maintain the packing room at 40° F. without the ventilation fan

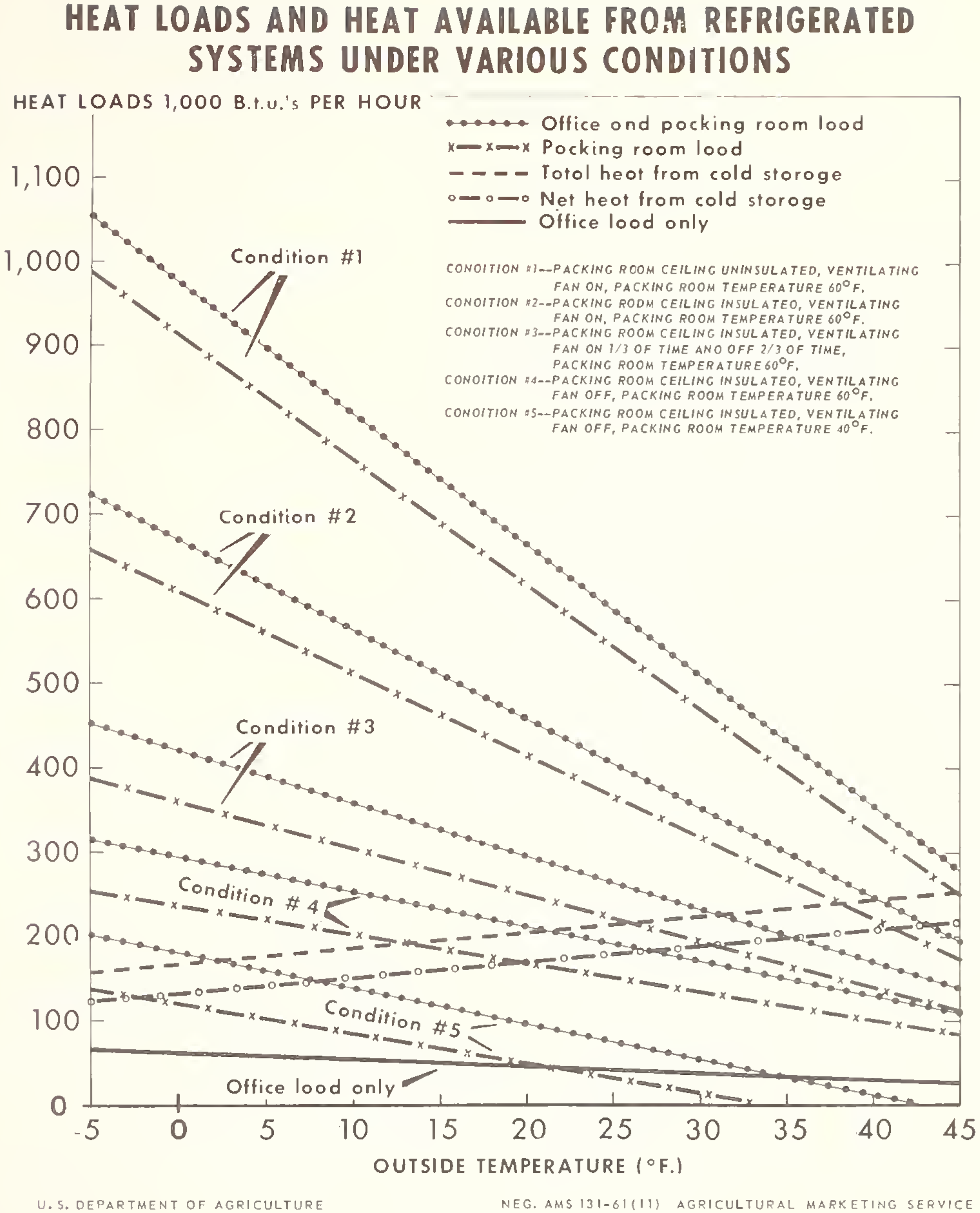


FIGURE 39

in operation is shown. This last line represents the heating requirements for the plant when the packing room is not in operation.

The curves show that the heat from the refrigeration system is adequate to handle the office and daytime packing room load down to an outside temperature of 40° F., to handle the average operating period load down to 35° F., to handle the office and nighttime packing room load down to 26.5° F., and to handle the office and nonoperating packing room load down to 7.5° F. The heat available is adequate to handle the office load at all times.

There are several possibilities for making the best use of the heat from the storage and these possibilities shall be designated as Systems A, B, and C.

System A discharges the heat from the refrigeration system to the packing room only, through an air-cooled condenser coil, and would allow the elimination of one gas heater. The other heaters would be used during periods when maximum heat was required.

Although this system is quite simple, one very major change from the system originally specified is required. Ammonia refrigerant in a condensing coil that discharges air into a space where a number of people are at work creates a serious hazard. This can be avoided by the use of a Freon-12 refrigerating system.

System B uses the heat from the cold storage to heat the office and as much of the packing room as possible, with supplemental packing room heating by fewer gas heaters. System B would use panels heated by pipes in the floor and in the partition wall between packing room and offices. A comparison was made for performance and installation costs when the pipes carry either the refrigerant condensing directly in the pipes, or water which has been passed through a shell and tube condenser, to transfer the heat from the condensing refrigerant to the water, which eventually conveys the heat to the panels. The panels are adequate for all heating in the offices. In the packing room the panels are located beneath the packing and sorting stations only.

System C is similar to system B, except that supplemental heat is secured by operating idle portions of the refrigeration system on a reverse-cycle or heat-pump system. All heat will be discharged through the heating panels.

When supplemental heat is required, the smallest compressor is all that is needed to refrigerate the storage. The two larger compressors and the evaporative condensers will be idle. They can be used as a heat pump to pick up heat at a low temperature level from the outside air and discharge this heat at a high temperature level inside to provide the required supplemental heat in the packing room. It was found that at an outdoor temperature of −5° F., there is sufficient capacity for the average 24-hour needs in the packing room. Since a floor-panel system has a large heat storage capacity, it seems reasonable to balance the system capacity against the average 24-hour period of 8 hours operation with the ventilating fan on, and 16 hours with it off.

When the outside temperature is +10° F. or lower, the system will operate on compound compression using the middle-size compressor as the second-stage machine, which will handle the discharge from the first, or low-stage, machine or machines. This compressor will also handle the refrigeration of the storage, because the interstage pressure will be very close to the suction pressure required for the storage rooms. Above 20° F. outside temperature, the low-stage machine can be cut off, and the heat pump system operated on simple compression. A condensing coil in the defrost water tank will heat the defrost water.

As in system B, a comparison was made for the performance and installation costs when the pipes in the heating panels carry either the refrigerant condensing directly or water that has been heated in a shell and tube condenser (i.e., an indirect system).

In systems B and C, where direct condensing is used, ammonia has been retained as the refrigerant because, with the refrigerant carried in full-weight iron pipe encased in concrete, the leakage hazard was slight, and the safety hazards were similar to those encountered with a direct-expansion ice-skating rink. A number of such rinks have been built.

To investigate the economic feasibility of these systems, an analysis was made of the cost of heating the packing room and office with gas. The packing room heating cost was based on actual days of operation, p. 34; office heating cost was based on the full season (September to March). These costs were then compared with the cost of heating with heat rejected from the refrigeration system, supplemental gas heat for systems A and B, and for supplemental heat from the heat pump for system C.

Under systems A and B, the refrigeration equipment operates at somewhat higher condensing temperature than when operated as a straight refrigeration system, and requires more horsepower per ton of refrigeration. The cost of the heat derived from the refrigeration of the storage has been calculated by charging the extra power requirement against the heating operation. Using 80° F. condensing temperature as a normal average winter condensing temperature, operating at 96° F. condensing temperature for the direct condensing systems involves an increase of 0.24 brake horsepower (b. hp.) per T. R. Operating at 105° F. condensing temperature for the indirect systems necessitates an increase of 0.35 b. hp./T.R. In addition, the indirect system must bear the cost of operating pumps to circulate the heat transfer medium.

To estimate the cost of supplemental heat for systems A and B, and to estimate the cost of producing heat from the heat pump with system C, it was necessary to use some weather data that is not available from the Heating, Ventilating, Air Conditioning Guide (see Bibliography, reference 1). Fortunately, weather data for more than a 40-year period is available for Yakima. To minimize the labor of developing this data, a record for the given month was selected that most nearly approximated the average temperature and number of degree-days for that month. Records for typical months from September through March were analyzed. The temperature scale was divided into 5-degree increments from −10° to 65° F. The average temperature for each day during the month was calculated as the average of the maximum and the minimum and the number of days with average temperature in each 5 degree division of the temperature scale was noted for each month. From this, the percentage of time in a given division of the temperature scale was calculated. Also the number of degree days below any required temperature base could be calculated. This latter information was used in determining the amount of supplemental gas heat required for systems A and B.

For system C the equipment balance points for output, heat requirements, and power requirements were determined for outside temperatures at −5°, 10°, and 20° F. and the cost of heat per 100,000 B.t.u. was determined at each point. These values were plotted on figure 40 to form a curve that showed a cost that decreased as outside temperatures increased until a minimum was reached at the point where heat from the storage was adequate to handle the load. At temperatures above this point, the cost of heat produced was constant.

From this curve, the average cost of heat was determined for each temperature increment that had been used in the weather analysis. This cost was multiplied by the percentage of time in the increment and the sum of these products for each month yielded an average cost of heat for a particular month.

This type of analysis was applied to both the direct and indirect condensing systems and the values are plotted on figure 41. Also shown on this figure are costs for a direct condensing system during December, January, and February when the weather is colder than average. The January values are for the coldest month on record in this locality. These calculations are for January 1950, February 1950, and December 1951.

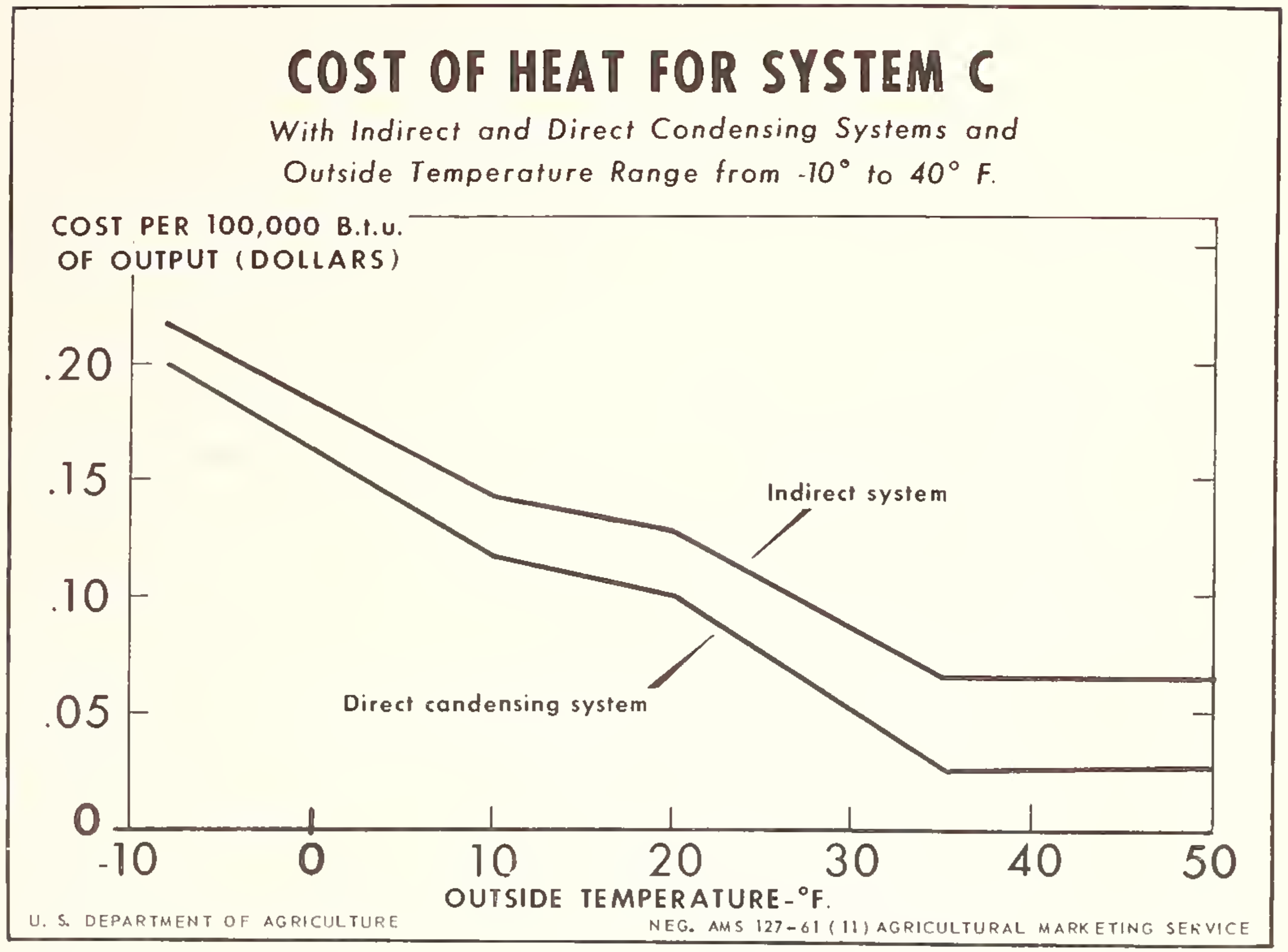


FIGURE 40

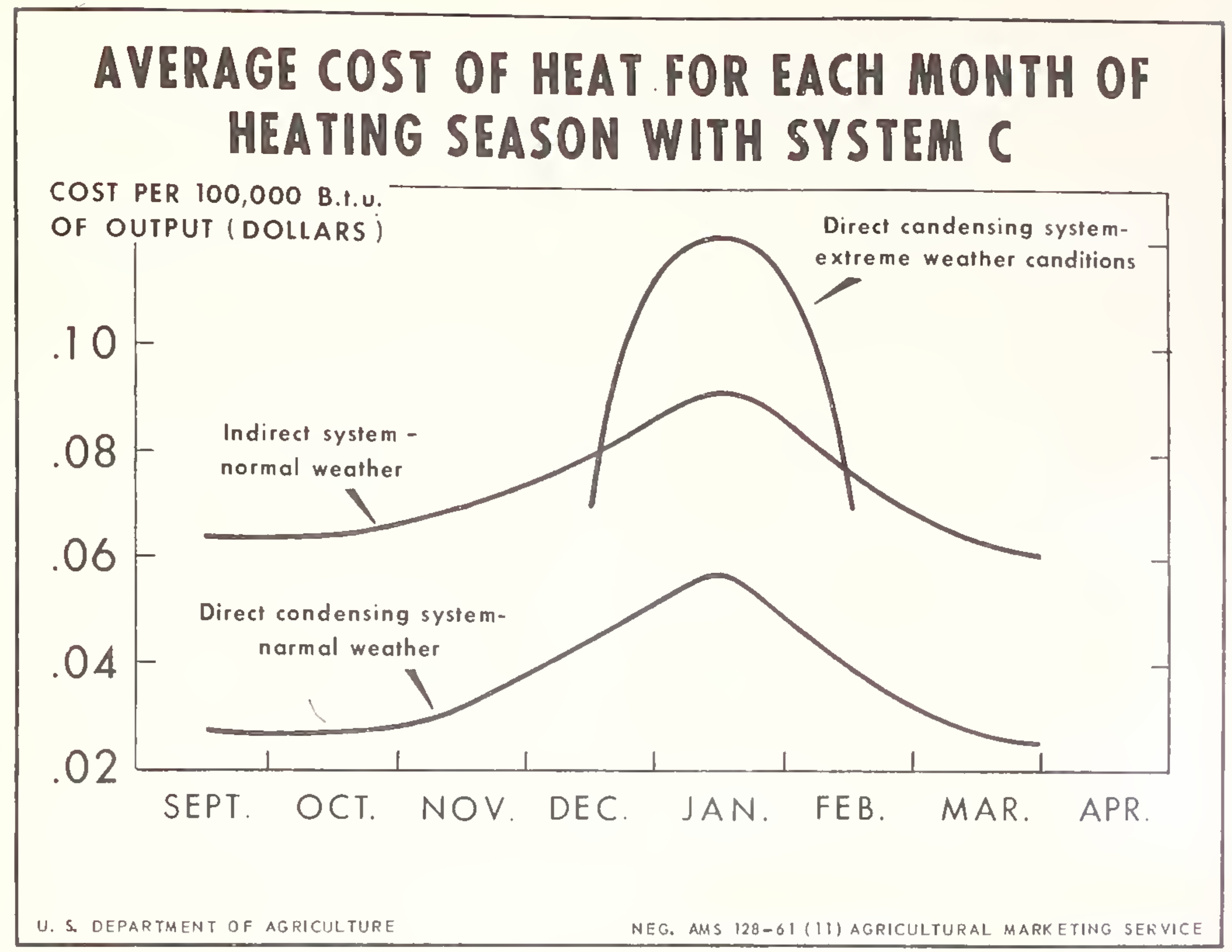


FIGURE 41

These values indicate just how severely the cost of producing the required heat would be affected by "unusual" weather, but for the purposes of this analysis the figures from the normal months are used.

The heating cost per season was determined as shown in the calculations below by using the average cost of heat for a given normal month from figure 41 and the number of degree-days for the month.

The difference between the heating cost for the season with gas and for heating with the various other systems has been calculated. This difference has been divided by 15 percent to determine investment that may be justified by the annual saving of operational costs. This percentage has been used previously to represent the total of fixed costs on refrigeration and heating equipment. The cost of gas heating equipment eliminated by each system has been added to the investment, justified by savings, to give the total investment allowable for each system, and these total figures are shown in table 9. Included in the table are the figures for the design arrangement where natural gas is the fuel, and figures for installations remote from gas service where LPG would be used.

Table 10 estimates the cost of installing the major items of additional equipment required for each of the various systems.

A comparison of the equipment estimates in table 10 with the amounts justifiable in table 9 shows that when natural gas is available the indirect condensing system cannot be justified, the direct system using the heat pump for supplemental heat cannot be justified, and the investments and benefits for systems A and B are only a little better than break-even. When LPG is used, system C will break even on a direct condensing system, but is not justified on an indirect system; systems A and B offer substantial savings.

The annual net savings, over and above fixed charges, are calculated in table 11 for the circumstances where there will be a net saving. From this tabulation it appears that where LPG is the fuel, direct condensing, with system B is the best selection. It offers the greatest annual return on the net investment.

The comparison between the direct and indirect versions of system B is also of interest. The indirect system requires more equipment and has a higher operating cost, because of the higher condensing temperature required for its operation. Although the first handicap is the more serious, both cut the net annual savings to a quarter of that of the direct condensing arrangement of system B. When natural gas is available, it does not appear that even the saving available with system B operating on direct condensing is sufficient to recommend its use in the standard plant layout.



Calculations determining the feasibility of using heat rejected from the cold storage in the 200,000-box plant are based on:

Storage rooms—2 each with inside measurement 135 x 98 x 21 ft. under trusses and outside measurement of 199 x 136 ft.
Floor area=28,000 sq. ft.
Cubic content beneath trusses=570,000 cu. ft.
Ceiling insulated for U=0.0237
Walls insulated for U=0.043
Floor uninsulated having heat flow 1.25 B.t.u./sq. ft./hr. during January
Figure 8 percent extra area on roof
Figure storage ⅔ full during January
Figure fruit respiring at the rate of 660 B.t.u./day/ton of fruit
Figure annual fixed charges on refrigeration equipment=15 percent
Figure average power cost at $0.015/kw.-hr.—subject to 14 percent discount for months when maximum plant demand is over 100 hp.
Figure natural gas cost at $0.10/therm (100,000 B.t.u. input)
Average seasonal efficiency of gas heating apparatus 80 percent
Cost of heat per 100,000 B.t.u. output=$0.125
Figure oil cost at $0.165/gal.; 140,000 B.t.u./gal.
Average seasonal efficiency of oil heating apparatus 70 percent
Cost of heat per 100,000 B.t.u. output=$0.168
Figure LPG at $0.18/gal.; 92,500 B.t.u./gal.
Average seasonal efficiency of heating apparatus 80 percent
Cost of heat per 100,000 B.t.u. output=$0.243
Heating load design conditions as set forth earlier in the appendix in the section, "Economic Analyses of Wall and Ceiling Insulation in Packing Room and Office Space."
Size of packing room 99 x 220 x 17 ft. under roof deck.
Size of office 99 x 16 x 10 ft. under roof.
Packing room ventilation fan capacity 6,000 c.f.m.—operated during working hours only in winter.
During non-working hours figure infiltration at rate of 200 cu. ft./hr./ft. of crack around a total of 92 ft. perimeter for 3 doors=18,400 c.f./hr.

Calculations to determine heat available under winter design conditions with outside temperature to −5° F., outside design condition; to +12.5° F., lowest average January temperature on record; and to 27.7° F., average January temperature are given in the tabulation below:

TABLE 9.—*Investment that can be justified to heat packing room and offices in winter with heat rejected by refrigeration system and from reverse cycle operation of idle refrigeration equipment for the 200,000-box storage*

| System | Direct condensing (96° condenser temperature) | | Indirect heating (105° condenser temperature) | |
|---|---|---|---|---|
| | Nat. gas | L.P. gas | Nat. gas | L.P. gas |
| | *Dollars* | *Dollars* | *Dollars* | *Dollars* |
| A—Heating packing room only by using air cooled condenser to reject heat from storage | 2,520 | 4,490 | ........ | ........ |
| B—Heating office and a portion of packing room by panel heating to reject heat from storage only and other part of heat in packing room supplied by gas heaters | 4,540 | 7,350 | 4,100 | 6,900 |
| C—Heating office and packing room by panel heating to reject heat from storage and heat from reverse cycle operation of refrigeration equipment normally idle in winter. No supplemental gas heat required | 5,640 | 8,670 | 4,733 | 7,767 |

TABLE 10.—*Estimated cost of additional equipment required for heating packing room and offices of a 200,000-box capacity apple storage and packinghouse with heat rejected from the refrigeration system*

| System | Direct condensing | Indirect heating |
|---|---|---|
| | *Dollars* | *Dollars* |
| A—Air cooled condenser | 2,000 | .......... |
| Fan connections and controls | 500 | .......... |
| Total | 2,500 | |
| B—7100'-1" piping @ 50c per ft | 3,550 | 3,550 |
| Controls | 750 | 750 |
| Condenser | [1] N. R. | 1,600 |
| Circulating pump | N. R. | 200 |
| Total | 4,300 | 6,100 |
| C—12500'-1" piping @ 50c per ft | 6,250 | 6,250 |
| Defrost water heating coil | 150 | 150 |
| Controls D. X. gas cooled and alteration to evaporative condensers | 2,000 | 2,000 |
| Condenser | N. R. | 4,000 |
| Circulating pump | N. R. | 350 |
| Total | 8,400 | 12,750 |

[1] N. R. means "Not Required"

TABLE 11.—*Annual savings from use of heat rejected from refrigeration system*

| System | Fuel compared | Net investment | Costs: Fixed [1] | Costs: Operating | Costs: Total | Gas heat cost | Net annual savings |
|---|---|---|---|---|---|---|---|
| | | *Dollars* | *Dollars* | *Dollars* | *Dollars* | *Dollars* | *Dollars* |
| A (direct) | LPG | 2,500–800 = 1,700 | 255 | 384 | 639 | 937 | 298 |
| B (direct) | LPG | 4,300–2,100 = 2,200 | 330 | 150 | 480 | 937 | 457 |
| B (direct) | Natural gas | 4,300–2,100 = 2,200 | 330 | 116 | 446 | 482 | 56 |
| B (indirect) | LPG | 6,100–2,100 = 4,000 | 600 | 216 | 816 | 937 | 121 |
| C (direct) | LPG | 8,400–3,440 = 4,960 | 744 | 152 | 896 | 937 | 41 |

[1] Assumed to be 15 percent of net investment.

| | Heat available per day at— −5° F. | 12.5° F. | 27.7° F. |
|---|---|---|---|
| | *B.t.u.* | *B.t.u.* | *B.t.u.* |
| Heat loss and gain from conduction: | | | |
| Ceiling=199×136×1.08 ×0.0237×24×(to−30) | −584,000 | −292,000 | −38,250 |
| Outside walls=21×520 ×0.043×24×(to−30) | −394,500 | −197,250 | −25,900 |
| Part walls=21×150 ×0.043×24×(60−30) | 97,500 | 97,500 | 97,500 |
| Floor=199×136×1.25 ×24 | 812,500 | 812,500 | 812,500 |
| Total transmission | −68,500 | 420,750 | 845,850 |
| Air leakage = 570,000×0.24×(to−30) / 12.4 | −386,000 | −193,000 | −25,400 |
| Lights=1,400×8×3.415 | 38,200 | 38,200 | 38,200 |
| Trucks working=4 hr.×10 hp.×2545 | 101,800 | 101,800 | 101,800 |
| Fan motor load = 28×2545×24 / 0.8 | 2,015,000 | 2,015,000 | 2,015,000 |

| | Heat available per day at— −5° F. | 12.5° F. | 27.7° F. |
|---|---|---|---|
| | *B.t.u.* | *B.t.u.* | *B.t.u.* |
| Respiration of fruit = 200,000×0.67×35×660 / 2,000 | 1,480,000 | 1,480,000 | 1,480,000 |
| Net heat available from evaporators—(at 96° F. compressor temperature and 25° F. evaporator temperature, 236 B.t.u./min./ton is rejected at condenser) | 3,180,500 | 3,862,750 | 4,455,450 |
| Add 18 percent for heat of compressor | 573,000 | 695,000 | 802,000 |
| Total heat available per day | 3,753,500 | 4,557,750 | 5,257,450 |
| Average heat available per hour | 156,500 | 190,000 | 219,000 |

Calculate heat required for defrosting—heat four tank loads per day from 40° to 55°=4×224 cu. ft. ×62.4 (55−40)=839,000 B.t.u./day

On average hourly basis=35,000 B.t.u./hr.

Deduct this from values calculated for heat rejected from cold storage refrigeration system and plot as net heat available from cold storage (fig. 39).

At −5° F. outside: net heat =156,500−35,000=121,500 B.t.u./hr.

At 12.5° outside: net heat =190,000−35,000=155,000 B.t.u./hr.

At 27.7° outside: net heat =219,000−35,000=184,000 B.t.u./hr.

Calculation of heat required by packing room with and without ventilating fan in operation for outside temperatures of −5° and +25° F. is:

| | Heat required per hour at— 5° F | +25° F |
|---|---|---|
| | *B.t.u.* | *B.t.u.* |
| Conduction losses: | | |
| Ceiling=99×220×0.32×(60−to) | 453,500 | 244,000 |
| Floor=99×220×0.1×(60−52) | 17,500 | 17,500 |
| Storage room walls=17×150×0.043 ×(60−30) | 3,200 | 3,200 |
| Outside wall: 17×389=6610; 7× 99= 693 | | |
| 7303×0.19×(60−to) | 90,200 | 48,600 |
| Total heat loss by conduction | 564,400 | 313,300 |
| Infiltration during non-working hrs. = 18,400×0.24×(60−to) / 13.2 | 21,700 | 11,700 |
| Total load during nonworking hrs. | 586,100 | 325,000 |
| Infiltration when ventilating fan is operating= 6,000×60×0.24×(60−to) / 13.2 | 426,000 | 229,000 |
| Total load with ventilating fan operating | 990,400 | 542,300 |
| Average daily load with ventilating fan operating 8 hours—off 16 hours | 720,600 | 397,500 |

If ceiling is insulated with 3 layers of reflective material to attain U=0.086, then the above calculated loads are revised as follows:

| | Heat required per hour at— −5° F. | +25° F. |
|---|---|---|
| | *B.t.u.* | *B.t.u.* |
| Deduct from above calculations: | | |
| Ceiling loss =99×220×(60−to)×(0.32 −0.086) | −332,000 | −178,500 |
| Revised total heat loss without ventilator fan | 254,100 | 146,500 |
| Revised total heat loss including ventilation | 658,400 | 363,800 |
| Revised average daily heat loss with fan operating 8 hours—off 16 hours | 389,000 | 218,900 |

Calculate heat requirement for packing room when it is not in use and is maintained at 40° F. and ventilating fan is off, for to=−5° and to=+25° F.

| | Heat required per hour at— −5° F. | +25° F. |
|---|---|---|
| | *B.t.u.* | *B.t.u.* |
| Conduction losses: | | |
| Ceiling=99×220×0.086×(40−to) | 84,400 | 28,100 |
| Floor=99×220×0.1×(40−52) | −26,100 | −26,100 |
| Storage room walls 17×150×0.043 ×(40−30) | 1,100 | 1,100 |
| Outside walls=7303×0.19×(40−to) | 62,400 | 20,800 |
| Total conduction loss | 121,800 | 23,900 |
| Infiltration= 18,400×0.24×(40−to) / 13.2 | 15,100 | 5,000 |
| Total heat loss | 136,900 | 28,900 |

Calculation of office heating load when outside temperature drops to =−5° F. 25° F. and 60° F.

| | Heat required per hour at— 5° F | 25° F. | 60° F. |
|---|---|---|---|
| | *B.t.u.* | *B.t.u.* | *B.t.u.* |
| Conduction losses: | | | |
| Ceiling=16×99×0.0395×(70−to) | 4,700 | 2,820 | 630 |
| Floor=16×99×0.1×(70−52) | 1,600 | 1,600 | 1,600 |
| Windows=174×1.13×(70−to) | 14,740 | 8,850 | 1,970 |
| Outside walls=10×131= 1310; −174 | | | |
| 1136×0.138×(70−to) | 13,350 | 7,060 | 1,570 |
| Inside walls=10×99×0.3×(70−40) | 8,900 | 8,900 | ........ |
| Total transmission | 43,490 | 29,230 | 5,770 |
| Ventilation (1 air change per hr.) = 15,840×0.24×(70−to) / 13.2 | 21,600 | 12,950 | 2,880 |
| Total heat requirement | 65,090 | 42,180 | 8,650 |

On figure 39 are plotted five conditions: Heat available from the storage vs. outside temperature; the heat requirement of the packing room without ceiling insulation and with ventilation fan in operation vs. outside temperature; the heat requirement of the packing room with ceiling insulation with and without the ventilating fan in operation vs. outside temperature; average heat load of the packing room when ventilating fan is on one-third of the time and off two-thirds of the time vs. outside temperature; and the heat requirement of the packing room maintained at 40° F. without the ventilating fan in operation vs. outside temperature. Also plotted is the heat requirement of the office vs. outside temperature, and to each of the foregoing curves for packing room heat requirement, the office heat requirement was added and plotted as total heat requirement vs. outside temperature.

Total heat available from storage balances the combined office and packing room load at 46° F. outside temperature, when the packing room ceiling is uninsulated and the ventilating fan is in operation (condition 1 in fig. 39). This balance point drops to 40° F. when the packing room ceiling is insulated (condition 2 in fig. 39). Because both of these loads would occur only in the daytime (the load is considerably reduced at night), the defrost water would be heated at night, when extra heat is available.

When panel heating is used, a large amount of heat is stored in the panels; so the balancing of the weighted average of the night and daytime loads against the net heat available from the system is reasonable. The net heat available and the total office and packing room load for condition 3 balance at 35° F. outside temperature. When the packing room is not in operation, but is held at 40° F., the net heat available to heat the office and maintain this condition in the packing room balances the load at 7.5° F. (condition 5 in fig. 39).

Cost Comparison With Natural Gas.—Base consumption of heat in the packing room on the number of degree-days for the operating season is based on assumptions given in the section, "Economic Analyses of Wall and Ceiling Insulation." Weighted average of day and night design loads were used for figuring fuel consumption costs given below:

Office heating cost was computed as follows:

$0.10×0.0043×0.09375×5,585×65=$146 (formula from Heating, Ventilating, Air Conditioning Guide, Bibliography, reference 1, applied to design load of 65,000 B.t.u./hr. and 5,585 degree-day season)

Packing room heating during operating period was computed as follows:

$$\frac{389{,}000\times24\times1{,}667\times0.10}{65\times0.8\times100{,}000}=\$300.$$

Packing room heating during nonoperating period calculated on the basis of heat loss per degree Td. times the difference between 40 and the average monthly temperature times the number of nonoperating days in the month. Months are November, December, January, and February.

Td. for Nov.=40−39=1; Number of nonoperating days=16
for Dec.=40−31.3=8.7: Number of nonoperating days=17
Td. for Jan.=40−27.7=12.3; Number of nonoperating days=13
Td. for Feb.=40−35.2=4.8; Number of nonoperating days=14
Cost of heat=

$$\frac{136{,}900\times24\times[(16\times1)+(17\times8.7)+(13\times12.3)+(14\times4.8)]\times\$0.10}{(40-5)\times0.8\times100{,}000}=\$36.$$

Total season's gas heating costs $146+$300+$36=$482.

With LPG the cost equals $\frac{0.243}{0.125}\times\$482=\$937$

Calculate cost of season's heat system A, which discharges heat from storage through an air cooled condenser in the packing room. The office is heated by gas, and gas heaters supply supplemental heat in the packing room. The air-cooled condenser capacity was selected to equal the balance point of the daytime packing room load and the total heat available from this system. In figure 39, this capacity equals 240,000 B.t.u./hr. output $=\frac{240{,}000}{236\times60}=17$ T.R. from the evaporator. A condenser suitable for a 17-ton system with 60° F. air and 96° condensing temperature was selected and cost approximately $2,000 installed.

The net heat available from the system balanced the average packing room operating load at 30° F., and it balances the packing room nonoperating load at −2.5°. In figuring heating costs, it was assumed that all of the nonoperating period would be handled by the heat from the refrigeration system, and that heating down to 30° in the operating period would be delivered by the refrigerating system.

Cost of heat rejected from the refrigeration system is the extra power cost occasioned by operating at a higher condensing temperature than is normal for the winter operation. Use 80° C.T. (condenser temperature) as normal winter operation. For direct condensing systems, use 96° C.T., and for indirect heating systems use 105° C.T. On the winter load the evaporators in the room will balance out the room load with approximately 30° room and 27.5° E.T. (evaporator temperature). Determine the capacity, b. hp. and b. hp./T.R. for this small compressor at 27.5° E.T. and the various condensing temperatures specified above to establish the extra b. hp./T.R. occasioned by the higher condensing temperatures. These are listed in the following tabulation:

| | *Normal refrigeration system* | *Heat by direct condensing* | *Indirect heating* |
|---|---|---|---|
| Condenser temperature (C.T.) | 80° F. | 96° F. | 105° F |
| Tons of refrigeration (T.R.) | 18.9 | 17.4 | 16.8 |
| b. hp | 15.5 | 18.45 | 19.6 |
| b. hp/ton | 0.82 | 1.06 | 1.17 |
| Added b. hp./T.R. due to higher C.T. | ........ | 0.24 | 0.35 |

Cost per 100,000 B.t.u. output with direct condensing is:

$$\frac{100{,}000\times0.24\times0.746\times\$0.015}{60\times236\times0.85}=\$0.022.$$

Cost of season's heat with system "A" are:

Gas heating of office as per previous calculations ........ $146

Supplemental gas heat in packing room for 129 days in operating season below 30° base $=\frac{389{,}000\times24\times129\times0.10}{65\times0.8\times100{,}000}$ ........ 23

Heating by refrigeration system in operating period for 1538 degree-days above 30° base $=\frac{389{,}000\times24\times1538\times0.022}{65\times100{,}000}$ ........ 49

Heating by refrigeration during non-operating period $=\frac{136{,}900\times24\times[(16\times1)+(17\times8.7)+(13\times12.3)+(14\times4.8)]\times\$0.022}{45\times100{,}000}$ ........ 6

Total season's heat cost ........ $224

Annual savings in fuel cost=$482−224 ........ $258

With LPG for supplemental heat:

Cost of season's heating=

Gas $=\frac{(146+23)\times\$0.243}{0.125}$ ........ $329

Refrigeration=49+6 ........ 55

$384

Annual savings compared with all LPG heat=$937−384=$553.

This installation also will eliminate one large gas heater in packing room and save $800.

Investment justified when natural gas is used

$=\frac{258}{0.15}+\$800=1720+800=\$2520.$

Investment justified when LPG is used

$=\frac{553}{0.15}+800=3690+800=\$4490.$

Calculate the cost of a season's heat with system B, direct condensing, which discharges heat from the storage through panel heating coils in office and packing room floor and in a partition between office and packing room. Gas heaters supply supplemental heat to the packing room in extreme weather. The net heat available from the system balances the average daily operating load down to 35° outside temperature for office and packing room, and balances office and nonoperating packing room load down to 7.5° outside temperature. Capacity of gas heaters for supplemental heating will equal approximately 330,000 B.t.u./hr. Capacity required for all gas heating is 660,000 B.t.u./hr. Savings in heater investment = $1,300 in packing room and $800 in office = $2,100.

Cost of heating office entirely by rejected heat from refrigeration:
$\frac{65{,}090\times24\times5585\times\$0.022}{(75)\times100{,}000}$ ........ $26

Heating by refrigeration for 1,484 degree days above 35° base during operating season in packing room:
$\frac{389{,}000\times24\times1484\times\$0.022}{65\times100{,}000}$ ........ $48

Heating by refrigeration during nonoperating period (from previous calculations) ........ $6

Supplemental gas heating for 183 degree-days below 35° base during operating period:
$\frac{389{,}000\times24\times183\times\$0.10}{65\times0.8\times100{,}000}$ ........ $33

Supplemental gas heating for the packing room during the nonoperating season estimated at 10 percent of all gas heating for this portion of load ........ $3

Total season's cost with natural gas for supplemental heat ........ $116

If LPG is used for the supplemental heat, the gas heat

cost required $=\frac{(33+3)\times0.243}{0.125}=\$70.$

Total season's heating cost with LPG supplementing = $80 + $70 = $150.

Annual savings in fuel cost compared with natural gas = $482 − $116 = $366.

Annual saving in fuel compared with LPG = $937 − $150 = $787

Investment that can be justified when natural gas is available $=\frac{\$366}{0.15}+\$2{,}100=\$2{,}440+\$2{,}100=\$4{,}540.$

Investment that can be justified when LPG is to be used as a fuel $=\frac{\$787}{0.15}+\$2{,}100=\$5{,}250+\$2{,}100=\$7{,}350.$

To discharge the heat rejected by the refrigeration system approximately 920 ft. of 1-inch condensing coil in partition wall, 1,500 ft. in office floor, and 468 ft. in the packing room floor for a total of 7,100 ft. of 1-inch pipe are required.

To calculate the cost of a season's heat with System B—indirect heating, circulating warm water through the pipes in the floor panels and heating the water by condensing the refrigerant in a shell and tube condenser—select condenser to balance total heat rejection at 35° F. outside temperature=

233,000 B.t.u./hr. $=\frac{233{,}000}{242\times60}=16$-ton condenser:

select condenser for average water temperature of 96° F., circulate 5 g.p.m./ton, and 6° F. temperature range (or 80 g.p.m. of water on at 93°—off at 99°): select condenser for leaving terminal difference of 6° F.=105° C.T.; and size of 8 sq. ft./ton or 128 sq. ft.

Increased hp. above normal refrigeration system operating in winter—0.35 b. hp./ton: and also required is the operation of 1½-hp. water circulating pump.

Compressor operating cost per 100,000 B.t.u./output

$=\frac{100{,}000\times0.35\times0.746\times0.015}{60\times242\times0.85}$ ........ $0.0317.

Pump operating cost per 100,000 B.t.u./output

$=\frac{1.5\times0.746\times0.015}{0.85\times2.33}$ ........ 0.0085.

Total cost per 100,000 B.t.u. output ........ 0.0402.

To obtain cost of season's heating with system B indirect heating apply factor of $\frac{0.0402}{0.022}=1.82$ to costs for portions of heat furnished by refrigeration system calculated for System "B" direct condensing:

With natural gas for supplemental heating season's heating cost = ($80×1.82) + $36 = $182.

With LPG for supplemental heating season's heating cost = $146 + $70 = $216.

Annual saving in fuel consumption compared with natural gas = $482.00 − $182.00 = $300.

Annual savings in fuel consumption compared with LPG = $937.00 − $216.00 = $721.

Investment that can be justified when natural gas is available:
$=\frac{\$300}{0.15}+\$2.100=\$2{,}000+\$2{,}100=\$4{,}100.$

Investment that can be justified when LPG is to be used as fuel:

$=\frac{\$721}{0.15}+\$2{,}100=\$4{,}800+\$2{,}100=\$6{,}900.$

With system C, reverse-cycle operation of idle refrigerating equipment is used to obtain the required supplemental heat from the outside air. Evaporative condensers are used as dry coil evaporators to pick up heat from outside air. Capacity of each unit is approximately 10 T.R. at 20° F. Td. between air and refrigerant. Using compound compression arrangement with largest and smallest compressors on low-stage duty and middle-size compressor to handle second stage duty, plus the load from the storages, under design condition of −5° F. outside temperature, the equipment balances out at −29° F. evaporator temperature with 24.5 T.R. from the evaporators. With heat of compression, this amounts to 28.7 T.R. for the second stage compressor. Add to this 11 T.R. from the storage, at this outside design condition, giving a total load of 39.7 T.R. for the second stage compressor. Balance point between low and high stages is approximately 20° F. intermediate temperatnre.

Heat rejected per hour from second state = 39.7×236×60 = 562,000 B.t.u./hr.

From figure 39 the average hourly heat requirement for office and packing room at −5° outside temperature is 454,000 B.t.u./hr. The capacity is such that 35,000 B.t.u./hr. defrost heating requirement can be met and also allow 2 to 3 hours shutdown time for defrosting reverse cycle evaporators. Two tanks of defrost water are used. Heating coil fed from discharge line for defrost water heating is used.

At 10° outside temperature, operate the reverse cycle system on compound compression, but let storage operate independently on small compressor. Operate evaporative condenser fans at low speed. Let large compressor run at 50-percent capacity and balance evaporators at −12° F. evaporator temperature to pick up 15 T.R. which will constitute a load of 18 T.R. on the second stage machine. Let second-stage compressor run at one-third capacity at 30° F. intermediate temperature for its suction.

At 20° outside temperature, operate the reverse cycle system on simple compression; the middle-size compressor at one-third capacity will produce 9.5 ton at 7.5° E.T. where it balances the two evaporators.

The heat produced by the system, the hp. and the various components, the power chargeable to the heating operation, and the cost per 100,000 B.t.u. output at the foregoing balance points are tabulated below. The condition for 35° F. outside temperature, where the heat from the refrigeration system is adequate for the heating duty, is also shown.

| Outside temperature | −5° F. | +10° F. | +20° F. | +35° F. |
|---|---|---|---|---|
| Total heat from refrigeration system—B.t.u./hr | 156,500 | 186,000 | 204,000 | 233,000 |
| Heat from reverse cycle operation—B.t.u./hr | 405,500 | 255,000 | 134,000 | .......... |
| Total heat available—B.t.u./hr | 562,000 | 441,000 | 338,000 | 233,000 |
| Deduct heat to defrost storage room evaporators and reverse cycle evaporators—B.t.u./hr | 52,000 | 52,000 | 43,000 | 35,000 |
| Net heat available for load—B.t.u./hr | 510,000 | 389,000 | 295,000 | 198,000 |
| Calculated average hourly load—B.t.u./hr | 454,000 | 357,000 | 292,000 | 197,000 |
| Hp. on auxiliaries for heating system—h.p. | 15.0 | 5.0 | 5.0 | .......... |

| | | | | |
|---|---|---|---|---|
| Actual hp. on refrigeration system—hp | [1] | 14.2 | 16.2 | 18.4 |
| Hp. on low stage compressor—hp | 28.9 | 14.0 | .......... | ..... |
| Hp. on high stage compressor—hp | 49.7 | 18.0 | 14.5 | .......... |
| Total hp | 93.6 | 51.2 | 35.7 | 18.4 |
| Deduct hp. required for refrigeration at normal operation | 9.0 | 11.0 | 13.0 | 14.3 |
| Net hp. for heating—hp | 84.6 | 40.2 | 22.7 | 4.1 |
| Cost per 100,000 B.t.u. produced | [2] $0.188 | [2] 0.117 | 0.101 | 0.027 |

[1] Included in high-stage compressor hp.

[2] For conditions of 10° F. and lower, figure 14-percent discount on power rate as total load will put power consumption into a different discount bracket. Cost per 100,000 B.t.u. output at −5° F. outside temperature.

$$=\frac{84.6\times 0.746\times 0.015\times 0.86\times 100{,}000}{0.85\times 510{,}000}=\$0.188.$$

These values are plotted on figure 40 and, with the weather data on table 12, determine the average monthly cost of heat delivered with system C. Typical average monthly cost of heat calculation is given below for typical month (January 1951 in table 12).

| *Average daily temperature* | *Cost of heat* [1] | *Percent of time* [2] | *Product of col. 2 & 3* |
|---|---|---|---|
| 5 to 10 | $0.129 | 9.7 | $0.0125 |
| 10 to 15 | 0.113 | 3.2 | 0.0036 |
| 15 to 20 | 0.105 | 3.2 | 0.0034 |
| 20 to 25 | 0.0875 | 6.5 | 0.0057 |
| 25 to 30 | 0.0625 | 22.6 | 0.0141 |
| 30 to 35 | 0.038 | 32.3 | 0.0123 |
| 35 to 40 | 0.027 | 19.4 | 0.0052 |
| 40 to 45 | 0.027 | 3.2 | 0.0009 |
| Average monthly cost/100,000 B.t.u. | | | 0.0577 |

[1] Taken from figure 40.

[2] Taken from table 12.

Values similarly determined for other months are plotted in figure 41.

The season's heating cost with system C, direct condensing, is given below.

Packing room—operating period—use heating costs from figure 41 and number of operating degree-days assumed in section, "Economic Analyses of Wall and Ceiling Insulation."

$$\text{Sept. \& Oct.}=\frac{389{,}000\times 24\times(10+160)\times \$0.027}{65\times 100{,}000} \quad \$6.60$$

$$\text{Nov.}=\frac{389{,}000\times 24\times 225\times \$0.0325}{65\times 100{,}000} \quad 0.50$$

$$\text{Dec.}=\frac{389{,}000\times 24\times 334\times \$0.0439}{65\times 100{,}000} \quad 21.10$$

$$\text{Jan.}=\frac{389{,}000\times 24\times 508\times \$0.0577}{65\times 100{,}000} \quad 42.20$$

$$\text{Feb.}=\frac{389{,}000\times 24\times 283\times \$0.0388}{65\times 100{,}000} \quad 15.80$$

$$\text{Mar.}=\frac{389{,}000\times 24\times 147\times \$0.0273}{65\times 100{,}000} \quad 5.80$$

Total for operating season ........ 102.00

For nonoperating period practically entire load will be carried by heat from refrigeration system only—use same figures as for system B.

=6.00

Total packing room heating cost ........ 108.00

Office heating cost—figure months of Dec., Jan., Feb., and Mar., at average cost of heat prevailing for each month. Figure rest of heating season at $0.027/100,000 B.t.u. since heat from storage is adequate for the requirement in other months.

$$\text{Dec.}=\frac{65{,}090\times 24\times 1050\times 0.0439}{75\times 100{,}000} \quad \$9.60$$

$$\text{Jan.}=\frac{65{,}090\times 24\times 1125\times 0.0577}{75\times 100{,}000} \quad 13.50$$

$$\text{Feb.}=\frac{65{,}090\times 24\times 837\times 0.0388}{75\times 100{,}000} \quad 6.50$$

$$\text{Mar.}=\frac{65{,}090\times 24\times 624\times 0.0273}{75\times 100{,}000} \quad 3.40$$

1949

$$\text{Other months}=\frac{65{,}090\times 24\times(5585-3636)\times 0.027}{75\times 100{,}000} \quad 11.00$$

Total office heat cost ........ 44.00

Total packing room heating cost ........ 108.00

Total season's heating cost ........ 152.00

Annual savings compared to natural gas = $482.00 − $152.00 = $330.00.

Annual savings compared to LPG = $937.00 − 152.00 = $785.00

Use of system C eliminates $2,640 from packing room heating investment and $800 for office. Total = $3,440.

Investment that can be justified when natural gas is available:

$$=\frac{330}{0.15}+3{,}440=2{,}200+3{,}440=\$5{,}640.$$

Investment that can be justified if LPG is to be used:

$$=\frac{785}{0.15}+3440=5230+3440=\$8670.$$

To operate as outlined for system C requires the installation of a direct-expansion gas cooler between the low and high stage machines, a suction trap, float valve, connections and valves. The two evaporative condensers may be operated as evaporators when required. Also needed are a control system to actuate the proper portions of the machinery when supplemental heat is required, a water heating coil in the defrost tank, and condensing coils in the floors of the office and packing room totaling 72,500 ft. of 1-inch pipe.

For system C, indirect heating, a shell and tube condenser is installed to condense the refrigerant and heat the water circulated through the floor panels. The condenser selected for the system output at −5° F. outside temperature = 562,000 B.t.u./hr. which represents 39.5 tons input to second stage. Using 8 sq. ft./ton will require approximately 320 sq. ft. of surface. Circulate 5 g.p.m./ton—or 200 g.p.m. on at 93° F., off at 99°—leaving terminal difference of 6°, condensing temperature = 105°.

A 5-hp. circulation pump was selected for 200 g.p.m. at 50 ft. head.

Average monthly output costs are obtained in the same manner as with the direct condensing system. The amount of heat produced at the various balance points is about the same as for the direct condensing system but the power inputs are high due to higher condensing temperature and more auxiliary power being required.

In the tabulation below are listed heat outputs and requirements, power requirements, and cost of heat production at various outside conditions for system C, indirect heating:

| | | | | |
|---|---|---|---|---|
| Outside temperature—°F. | −5 | +10 | +20 | +35 |
| Total heat from refrigeration system—B.t.u./hr. | 156,500 | 186,000 | 204,000 | 233,000 |
| Heat from reverse cycle operation—B.t.u./hr. | 417,000 | 259,000 | 137,000 | .......... |
| Total heat available—B.t.u./hr. | 573,500 | 445,000 | 341,000 | 233,000 |
| Deduct heat required to defrost storage room evaporators and reverse cycle evaporators—B.t.u./hr. | 52,000 | 52,000 | 43,000 | 35,000 |
| Net heat available for load—B.t.u./hr. | 521,500 | 393,000 | 298,000 | 198,000 |
| Calculated average hourly load—B.t.u./hr. | 454,000 | 357,000 | 292,000 | 197,000 |
| Hp. on auxiliaries for heating system—hp. | 20.0 | 10.0 | 10.0 | 5.0 |
| Actual hp. on refrigeration system—hp. | ......... | 15.1 | 16.6 | 19.0 |
| Hp. on low stage compressor—hp. | 28.4 | 14.4 | .......... | .......... |
| Hp. on high stage compressor—hp. | 55.1 | 20.7 | 15.5 | .......... |
| Total hp. | 103.5 | 60.2 | 42.1 | 24.0 |
| Deduct hp. required for refrigeration at normal operation—hp. | 9.0 | 11.0 | 13.0 | 14.3 |
| Net hp. for heating—hp. | 94.5 | 49.2 | 29.1 | 9.7 |
| Cost per 100,000 B.t.u. produced | $0.205 | $0.142 | $0.129 | $0.064 |

TABLE 12.—*Analysis of weather data at Yakima, Wash., to determine normal number of days and percentage of time in each month during packing season in average temperature brackets of 5 degrees progressing from −10 to +70*

| Average daily temperatures | Normal months | | | | | | | | | | | | | | Lower than normal months | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sept. 1951 | | Oct. 1947 | | Nov. 1950 | | Dec. 1952 | | Jan. 1951 | | Feb. 1951 | | Mar. 1949 | | Dec. 1951 | | Jan. 1950 | | Feb. 1950 | |
| *°F.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* | *Days* | *Pct.* |
| −10 to −5 | | | | | | | | | | | | | | | | | 1 | 3.2 | 3 | 10.7 |
| −5 to 0 | | | | | | | | | | | | | | | | | 3 | 9.7 | | |
| 0 to 5 | | | | | | | | | | | | | | | | | 7 | 22.6 | | |
| 5 to 10 | | | | | | | | | 3 | 9.7 | | | | | | | 6 | 19.4 | | |
| 10 to 15 | | | | | | | | | 1 | 3.2 | | | | | | | 2 | 6.5 | 1 | 3.6 |
| 15 to 20 | | | | | | | | | 1 | 3.2 | 1 | 3.6 | | | 6 | 19.4 | 5 | 16.1 | 1 | 3.6 |
| 20 to 25 | | | | | | | 2 | 6.5 | 2 | 6.5 | | | | | 13 | 42.0 | 2 | 6.5 | 4 | 14.3 |
| 25 to 30 | | | | | 2 | 6.7 | 9 | 29.0 | 7 | 22.6 | 4 | 14.3 | | | 4 | 12.9 | 3 | 9.7 | 6 | 21.4 |
| 30 to 35 | | | | | 8 | 26.7 | 8 | 25.8 | 10 | 35.7 | 10 | 35.7 | 1 | 3.2 | 3 | 9.7 | 1 | 3.2 | 10 | 35.7 |
| 35 to 40 | | | | | 6 | 20.0 | 10 | 32.3 | 6 | 19.4 | 10 | 35.7 | 2 | 6.5 | 4 | 12.9 | | | 3 | 10.7 |
| 40 to 45 | | | 4 | 12.9 | 10 | 33.3 | 2 | 6.5 | 1 | 3.2 | 1 | 3.6 | 14 | 45.2 | 1 | 3.2 | | | | |
| 45 to 50 | 1 | 3.3 | 11 | 35.5 | 4 | 13.3 | | | | | 1 | 3.6 | 13 | 42.0 | | | | | | |
| 50 to 55 | 1 | 3.3 | 11 | 35.5 | | | | | | | 1 | 3.6 | 1 | 3.2 | | | | | | |
| 55 to 60 | 10 | 33.3 | 2 | 6.5 | | | | | | | | | | | | | | | | |
| 60 to 65 | 9 | 30.0 | 1 | 3.2 | | | | | | | | | | | | | | | | |
| 65 to 70 | 9 | 30.0 | 2 | 6.5 | | | | | | | | | | | | | | | | |
| Recorded degree-days | | 125 | | 432 | | 774 | | 1,002 | | 1,127 | | 838 | | 658 | | 1,194 | | 1,625 | | 991 |
| Normal degree-days | | 125 | | 409 | | 783 | | 1,049 | | 1,151 | | 846 | | 636 | | 1,049 | | 1,151 | | 846 |
| Recorded average temperature (°F) | | 61.6 | | 51.2 | | 38.9 | | 32.5 | | 28.4 | | 34.9 | | 43.7 | | 26.3 | | 12.5 | | 29.4 |
| Normal average temperature (°F) | | 62.6 | | 51.9 | | 39.0 | | 31.3 | | 27.7 | | 35.2 | | 44.5 | | 31.3 | | 27.7 | | 35.2 |

These values are plotted on figure 40 and then in the same manner as used for system C for direct condensing; the average monthly cost of heat delivered by the system was determined and plotted on figure 41.

Season's operating cost for indirect heating with system C was calculated by adjusting previously obtained monthly costs in proportion to cost of heat for the month for the two systems.

Packing room operating period:

$$\text{Sept. \& Oct.}=\frac{0.064}{0.027}\times 6.60=\$15.60$$

$$\text{Nov.}=\frac{0.070}{0.0325}\times 10.50=22.60$$

$$\text{Dec.}=\frac{0.080}{0.0439}\times 21.10=38.40$$

$$\text{Jan.}=\frac{0.0917}{0.0577}\times 42.20=67.00$$

$$\text{Feb.}=\frac{0.0754}{0.0388}\times 15.80=30.70$$

$$\text{Mar.}=\frac{0.0644}{0.0273}\times 5.80=13.70$$

188.00

Packing room nonoperating period:

$$=\frac{0.064}{0.027}\times 6.00=14.00$$

Total packing room heating cost=$202.00

Office heating cost:

$$\text{Dec.}=\frac{0.080}{0.0439}\times 9.60=17.50$$

$$\text{Jan.}=\frac{0.0917}{0.0577}\times 13.50=21.50$$

$$\text{Feb.}=\frac{0.0754}{0.0388}\times 6.50=12.60$$

$$\text{Mar.}=\frac{0.0644}{0.0273}\times 3.40=8.10$$

$$\text{Other months}=\frac{0.064}{0.027}\times 11.00=26.30.$$

Total office heating cost=$86.

Total season's cost of heating $288.

Annual savings, compared to natural gas: $482−$288=$194.
Annual savings, compared to LPG: $937−$288=$649.
Investment that can be justified when natural gas is available:

$$\frac{194}{0.15}-3440=1293+3440=\$4733.$$

Investment that can be justified if LPG is to be used:

$$\frac{649}{0.15}-3440=4327+3440=\$7767.$$

## Construction Cost Estimates for Three Packing and Storage Houses

The estimated construction costs of the 50,000-, 100,000-, and 200,000-box packing and storage houses are given in table 13. These costs include lot and site preparation, construction costs, and installation of heating, plumbing, electrical, and refrigeration equipment. These estimates are for the Yakima, Wash., area, and could be materially changed by individual requirements and location. The cost of the land is not included. These estimated costs are based on the construction cost index for Yakima as of January 1, 1961.

## Fire Insurance for Apple Packing and Storage Houses

Fire insurance rates for the 100,000-box apple packing and storage house are listed in table 14. There is little difference in rate for a building with outside walls of certified hollow concrete blocks (8" thick or greater) or with walls of reinforced concrete (6" thick or greater). Minor rate differentials result when substituting masonry walls of one type with masonry walls of another type; great differences may occur when combustible walls (i.e., frame) are substituted for masonry. Assumptions are:

Apples in storage valued at $3.75 per box.

Storage capacity equal to 100,000 standard boxes having a total value of $375,000.

Length of storage period is assumed to be 6 months.

Insurance on packing and storage house worth $200,000; this represents 80 percent of insurable value.

Rates are for State of Washington only; promulgated by Washington Surveying and Rating Bureau and based on its review of drawings and specifications for a 100,000-box storage and packinghouse. Bureau rates are tentative only and for the facilities under assumed conditions only.

The premium calculations were performed for the above conditions and following Washington State rules for rating the building with 80-percent coinsurance clause and the contents at 100 percent of value on a monthly reporting form basis. The foregoing allows 50 percent of values to be prorated and 50 percent to be short rated developing approximately 55 percent of the annual content premium for a 6-month storage period. Other monthly storage periods would not necessarily develop proportionate premium savings and would have to be calculated for each storage period.

Fire insurance premiums based on the above assumptions are developed and presented in table 15 for class 3 and 9 locations and for different types of construction.

Location, has a very significant influence on the size of premium. The annual difference in premium for a 100,000-box plant is $5,600 minus $1,700 or $3,800 or approximately 4c per box saving by locating in a class 3 town as compared to a class 9 unprotected town.

Comparison of the figures for the frame construction plant and the basic (masonry) plant indicates that, in a class 3 town, saving with masonry construction is $3,900 minus $1,700 or $2,200

TABLE 13.—*Estimated construction costs for three different size apple storage and packing houses*

| Item | 50,000-box house | 100,000-box house | 200,000-box house |
|---|---|---|---|
| | *Dollars* | *Dollars* | *Dollars* |
| Lot and site preparation: | | | |
| Site grading | 150 | 150 | 300 |
| Excavation and back fill | 300 | 350 | 490 |
| Gravel fill | 700 | 970 | 1, 250 |
| Asphalt paving | 2, 370 | 2, 530 | 8, 620 |
| Rolled gravel (parking lot) | 600 | 1, 270 | 3, 550 |
| Septic tank and drain field | 450 | 550 | 630 |
| Dry well | 50 | 50 | 90 |
| 2" water tap and meter | 170 | 170 | 170 |
| Taxes, insurance, margin, etc., at 16 percent | 760 | 960 | 2, 400 |
| | 5, 550 | 7, 000 | 17, 500 |
| Packing room: | | | |
| Foundation, walls, pilasters, floor, roof construction, roof ventilators, insulation, millwork, and painting, plus taxes, insurance, margin, etc., at 16 percent | 53, 450 | 51, 490 | 93, 420 |
| Office (floor cost included above) | | | |
| Walls, ceiling, millwork, painting, and vents plus taxes, insurance, margin, etc., at 16 percent | 2, 580 | 7, 440 | 12, 300 |
| Cold-storage room: | | | |
| Foundation, walls, pilasters, floor, roof construction, insulation, painting, doors, and catwalk plus taxes, insurance, margin, etc., at 16 percent | 46, 720 | 78, 230 | 144, 070 |
| Machine room: | | | |
| Condenser platform, doors, machine mounts, painting, plus taxes, insurance, margin, etc., at 16 percent | 1, 770 | 1, 770 | 3, 230 |
| Covered area: | | | |
| Concrete floor, foundations, and steel work | 9, 360 | 14, 200 | 27, 850 |
| Heating | 6, 550 | 7, 820 | 8, 970 |
| Plumbing | 1, 900 | 2, 070 | 2, 530 |
| Electrical | 7, 820 | 11, 730 | 15, 640 |
| Refrigeration | 20, 700 | 37, 950 | 69, 690 |
| Total | 156, 400 | 219, 700 | 395, 200 |



and in an unprotected town is $7,900 minus $5,600 or $2,300. The annual saving possible by using masonry construction in preference to frame construction is $2,000 in Washington towns.

Use of an approved sprinkler system probably offers the greatest possible annual monetary saving. For example, savings in a class 3 town are $1,000 ($1,700−$700) and in an unprotected area savings amount to $4,800 ($5,600−$800). Using treated lumber roof construction in a class 3 town will save $400 ($1,700−$1,300) and in a class 9 area will save $2,000 ($5,600−$3,600).

If incombustible insulation is applied directly to the roof deck and walls, the savings at a class 3 location amount to $50 ($1,700−$1,650) and at a class 9 location amount to $340 ($5,620−$5,280).

It should be understood that to realize the savings indicated above, additional expenses may be incurred. Plant operators will need to make their own determinations as to whether the saving in premiums justifies the expense.

Plant operators contemplating constructing a new packing and storage house or remodeling older houses should consult with their insurance company representative and have him review the plans for modification and a resulting lower insurance rate.

TABLE 14.—*Tentative insurance rates for building and contents per $100 for 100,000-box capacity apple storage and packinghouse for three risk categories, Washington State, 1960*

| Roof type for building and risk category [1] | Basic [2] | | B 1 [3] | | B 2 [4] | | B 3 [5] | | B 4 [6] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bldg. | Contents | Bldg. | Contents | Bldg. | Contents | Bldg. | Contents | Bldg. | Contents |
| Building with combustible roof: | | | | | | | | | | |
| 3d (80% rates) | 0. 264 | 0. 637 | 0. 264 | 0. 637 | 0. 262 | 0. 637 | 0. 247 | 0. 628 | 0. 255 | 0. 637 |
| 6th (80% rates) | . 555 | . 846 | . 555 | . 846 | . 555 | . 846 | . 519 | . 819 | . 537 | . 828 |
| 9th (flat rates) | 1. 37 | 1. 47 | 1. 37 | 1. 47 | 1. 36 | 1. 46 | 1. 28 | 1. 41 | 1. 32 | 1. 44 |
| Building with incombustible roof: [7] | | | | | | | | | | |
| 3d (80% rates) | | | . 174 | . 573 | . 159 | . 564 | . 144 | . 555 | . 152 | . 564 |
| 6th (80% rates) | | | . 328 | . 683 | . 229 | . 701 | . 269 | . 646 | . 286 | . 655 |
| 9th (80% rates) | | | . 919 | 1. 10 | . 883 | 1. 07 | . 837 | 1. 04 | . 865 | 1. 06 |

[1] Risk category is based on availability of adequate fire protection.
[2] This is the plan of the 100,000-box capacity plant as indicated in the text of this report.
[3] The basic plan, except that combustible insulation is used in roof space and combustible insulation is used in walls and partitions.
[4] The basic plan, except that incombustible insulation is used on roof deck and there is to be no roof space below roof deck and combustible insulation is used in walls and/or partitions.
[5] The basic plan, except that incombustible insulation is used on roof deck and there is to be no roof space below roof deck and incombustible insulation is used in walls and/or partitions.
[6] The basic plan, except that incombustible insulation is used on roof deck and there is to be no roof space below the roof deck and combustible insulation board is used in walls and/or partitions with no interior sheathing or air space.
[7] Roof is of wholly incombustible construction. Incombustible as referred to herein is a roof deck of unprotected metal supported by unprotected metal girders, beams, trusses, etc., and either masonry or unprotected metal vertical supports. In addition, the term incombustible includes a roof deck and all supporting members of fire-retardant impregnated wood.

TABLE 15.—*Comparison of tentative annual premiums for fire insurance for a 100,000-box capacity apple packing and storage house located in Washington State by the type of construction and class of protection* [1]

| Type of construction and class of protection [2] | Town | Building [3] | | Contents [4] | | Total premium |
|---|---|---|---|---|---|---|
| | | Rate [5] | Premium | Rate [5] | Premium | |
| | | *Dollars* | *Dollars* | *Dollars* | *Dollars* | *Dollars* |
| Basic (masonry): | | | | | | |
| Class No. 3 | (Yakima) | 0. 264 | 528 | 0. 573 | 1, 180 | 1, 708 |
| Class No. 9 | Unprotected | 1. 37 | 2, 740 | 1. 40 | 2, 880 | 5, 620 |
| Frame: | | | | | | |
| Class No. 3 | (Yakima) | . 946 | 1, 880 | 1. 05 | 2, 160 | 3, 940 |
| Class No. 9 | Unprotected | 1. 97 | 3, 940 | 1. 90 | 3, 950 | 7, 890 |
| Basic with sprinkler: | | | | | | |
| Class No. 3 | (Yakima) | . 160 | 320 | . 190 | 390 | 710 |
| Class No. 9 | Unprotected | . 190 | 380 | . 216 | 425 | 805 |
| Basic with treated lumber roof structure: | | | | | | |
| Class No. 3 | (Yakima) | . 144 | 288 | . 500 | 1, 030 | 1, 318 |
| Class No. 9 | Unprotected | . 837 | 1, 674 | . 970 | 2, 000 | 3, 674 |
| Basic with incombustible insulation applied directly to roof deck and walls: | | | | | | |
| Class No. 3 | (Yakima) | . 247 | 495 | . 565 | 1, 160 | 1, 655 |
| Class No. 9 | Unprotected | 1. 28 | 2, 560 | 1. 34 | 2, 720 | 5, 280 |

[1] The rates and premiums shown here are tentative and are given for comparison purposes only. They are applicable to the specific building under consideration and are not necessarily the rates and premium which would be charged for any other building. Prepared from data supplied by the Washington Surveying and Rating Bureau.
[2] Yakima and other fire-protected towns are rated as class No. 3, unprotected areas are rated as class No. 9.
[3] Building valued at $200,000.
[4] Contents value based on 55 percent annual content.
[5] Rates are per $100 value.

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The marketing research in this report is part of a broad, continuing program of USDA's Agricultural Marketing Service to bring marketing services to farmers, industry, and consumers. The seal shown below is the symbol of the 50th year of organized marketing service. In 1913, the first marketing agency, the Office of Markets, was established in USDA. It was the predecessor of the Agricultural Marketing Service.

This report is one of a group that has helped to improve the marketing of apples. It summarizes research that will help bring reasonable returns to the producer, help hold down marketing costs, and give the consumer a product with less decay and fewer bruises.

In the last decade alone, the Agricultural Marketing Service has been instrumental in developing mechanized and automated equipment for packing and sizing, a new type of bagging chute, cull chutes, a high piler for boxes, new packing stations, mechanical handling of fruit boxes with forklift trucks, a loose box filler, and the recently developed and patented automatic pallet-box filler. Continued research is planned.

50 YEARS 1913 1963 OF MARKETING SERVICE USDA AMS