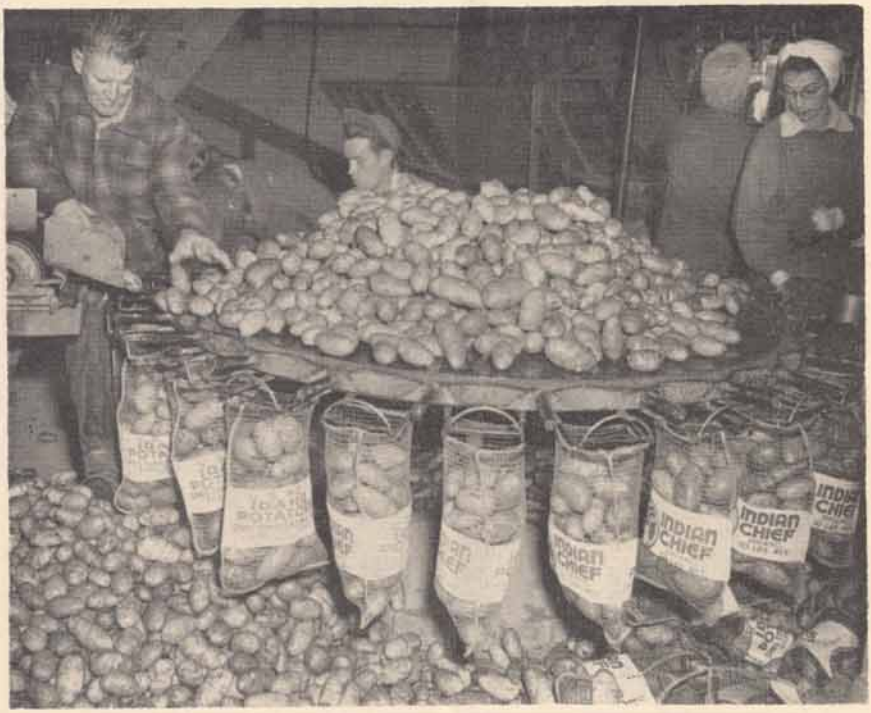
UNIVERSITY OF IDAHO
College of Agriculture

PACKING IDAHO POTATOES

A Study of Plant Design, Equipment Layout, and Costs

GLENN SALO AND KERMIT BIRD



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IDAHO potatoes reach the consumer after going through a number of marketing operations. Shipping-point packers perform some of these, such as washing, sizing, grading, and packaging. These processes require buildings, labor, machinery, and power; the costs of which make up a large portion of the marketing margin. Potato marketing is, therefore, important to growers and consumers as well as to packers.

The purpose of this report is to help packers reduce their packing costs. Outlined are some general principles on building design. Analyzed are building and equipment replacement costs. Also discussed are fixed costs. In addition, some hints are given on plant layout. One section is devoted to new ideas in equipment.

A survey of 110 Idaho potato packing plants, made in the fall of 1954, provided the information. Many of the recommendations are judgments based on observations of plants and discussions with plant managers. The project is a cooperative effort of the Departments of Agricultural Engineering and Agricultural Economics. Much of the material was summarized from a master's thesis prepared by Glenn Salo.

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Packing Idaho Potatoes

A study of plant design, equipment layout, and costs

By Glenn Salo and Kermit Bird*

EFFICIENCY in packing depends to a large extent on the way potatoes flow through the plant. This in turn depends on plant layout, building design, and equipment used.

Buildings

Types of Buildings

Many types of potato packing buildings are used in Idaho. This report is concerned mainly with above-ground sheds, of which there are two general types, single and double story.

Many newer sheds are of single-story type similar to the one shown in Figure 1. This building has a split-level floor with the unloading section at ground level. The main packing floor is a concrete slab at the same height as a railroad car deck. Hand-trucking is thereby made easy. Consolidation of packing operations on one floor improves use of floor areas. Costs of constructing one-floor and two-floor plants are about the same. However, a one-floor plant has these advantages:

1. More efficient equipment layout.
2. More flexibility in layout of equipment.
3. Easier to convert to another type of warehouse.
4. Uses a concrete-slab floor which is stronger and longer lasting than a wooden-joist floor.

Figure 2 illustrates a two-story warehouse common in Idaho. Receiving and temporary storing is on the lower floor. Processing is done on the top floor. In the following instances it may be advisable to build a two-floor plant:

1. Where this type plant is required by size or shape of building lot, or where cost of property is exceptionally high.
2. Where the lower floor is needed for potato storage.

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Figure 1.—Single-story, trussed roof packing plant of recent design.

Figure 2.—Double-story, concrete block potato packing plant of the type used most widely in Idaho.

Figure 3 shows a potato storage cellar under construction. This shed will also house a packing line. Poor working conditions are common in cellar-type plants since these sheds are often cold and damp. Because of rough unfinished interiors, they generally have poor lighting. Quite often drainage is poor. These conditions not only affect the comfort and health of the workers, but reduce worker efficiency. These disadvantages may be partially corrected, however, and since this cellar serves a dual purpose, economy in building expense is possible.

Some storage cellars are combined with above-ground plants (Figure 4). Such a building allows a packer to process potatoes directly from storage, an advantage in sub-zero weather. When potatoes are trucked from distant farm cellars, they may freeze en-route.

Aids in Building Planning

Limitations in plant layout are due largely to poor building design. The following guides will help in selecting a floor plan and design for a new plant:

1. Use clear-span roof trusses. These eliminate interior posts and allow greater flexibility in layout of packing equipment. Each interior column reduces usable space by 9 to 16 square feet. Improved travel routes and better in-plant transportation are results of using clear-span roof trusses.
2. Nearly square floor plans are ideal designs from the standpoint of construction costs. Long narrow buildings have a higher proportion of wall surface compared to floor area.
3. Select a single-story building for efficiency and flexibility in equipment layout. Where potato storage space is needed consider the two-story plant.

Plant Layout

The over-all objective in plant layout is to organize the plant so potatoes move smoothly and with few interruptions. Machine operations, such as sizing and washing, should be arranged to get efficient use of equipment. Hand jobs, such as grading and bagging, should be set up with safety, convenience, and output of workers first in mind. The following guides may be used to select and arrange equipment:

1. Use bulk handling and receiving methods wherever possible. They pay for themselves in labor savings.

Figure 3.—Cellar-type packing shed with concrete block ends and straw roof and sides. Roof will be covered with a light layer of soil.

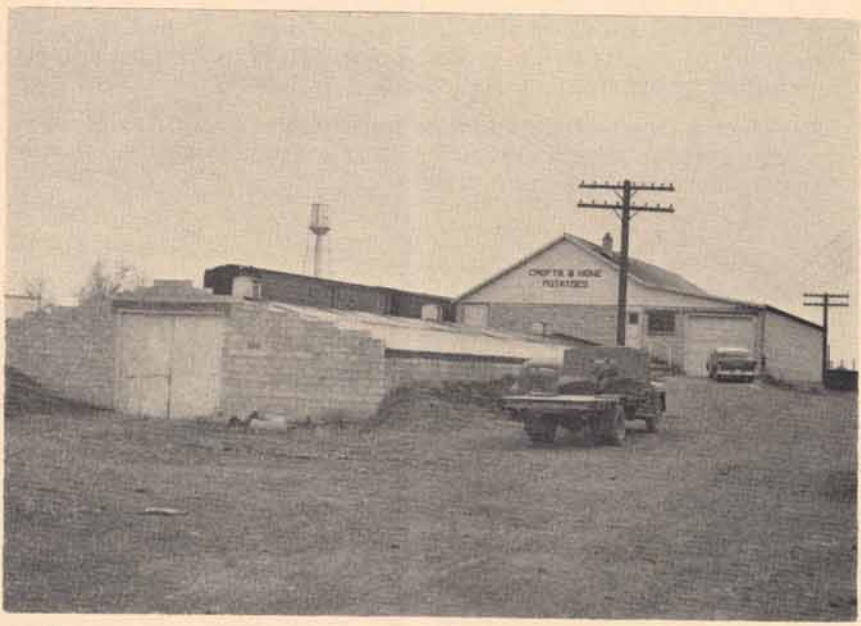


Figure 4.—A small two-story packing plant built in conjunction with a potato storage cellar.

2. Have variable speed controls for the receiving and grading operation. Locate controls within reach of head grader.

3. Have potatoes flow through eliminating, washing, sizing, and grading in a straight line if possible. Conveyors connecting these units should be short, but not so steeply inclined that potato rollback occurs.

4. Use gravity flow wherever feasible. Be certain no drop is over 8 inches. All drops should be rubber-padded to reduce bruising.

5. Select a grading table long enough to provide space for workers. The number of graders needed will depend on the flow and quality of potatoes. A rule of thumb is to provide one grader for every 25 cwt. of packed potatoes per hour. Each worker should have about 3 feet of space along the table.

6. Use a divided table to keep potatoes within graders' reach. Use two short tables rather than one long one if higher packing rates are desired. Shorter tables keep each worker more fully occupied.

7. Have the grading table at a convenient height for workers. Tables of about elbow height ease the back strain.

8. Put mechanical sizer after grading table, not before. Potatoes differ in size proportions from lot to lot. If potatoes are sized before grading, these differences place uneven work loads on the two sides of the table.

9. Locate packing operations near loading platform to reduce transport distances to car.

10. Put baker and No. 2 jigger fronts near each other. One man can handle both sacking operations if necessary.

11. Make hand trucking routes as level as possible and free of sharp turns. A right angle turn slows the truck and valuable momentum is lost.

Model Plant

The plant, as diagrammed on pages 10 and 11, follows the above guides. The unloading and receiving section is on ground level. It has a high ceiling and provides easy access for farm trucks. The trussed roof eliminates interior posts and permits new equipment arrangement with a minimum change of the building framework.

Large bulk storage bins maintain a supply of field-run potatoes at all times. Conveyors feeding the packing line have variable-speed motors controlled by head grader.

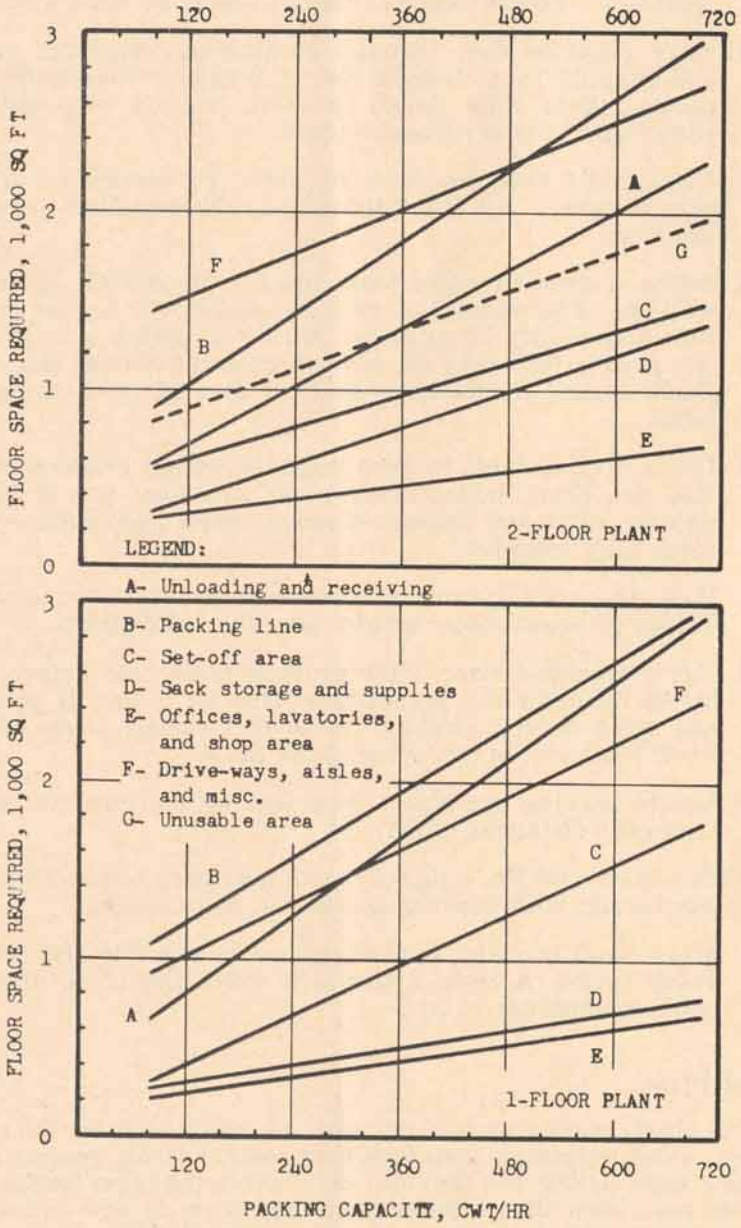


Figure 5.—The effect of potato packing capacity on floor space requirements for one-floor and two-floor potato packing plants. Floor space requrements are based upon typical layouts of efficient plants. Requirements for individual plants may vary from these estimates.

Potatoes flow through the pre-grading operations in a straight line. The grading table is divided and has separate side tables for No. 2's and bakers. The mechanical sizer is on the discharge end of the grading table. The short hand-sizing table can be used with the mechanical sizer or separately. Packaging operations are on the packing line nearest the railroad siding.

Lighting Requirements

Good lighting for graders and weighers is necessary for high efficiency. It makes work easier, faster, and safer. Both incandescent and fluorescent lights are widely used. Fluorescent illumination is better because it produces a more uniform light and less glare.

Fifty foot-candles of light are needed on the potato grading table, while five foot-candles are adequate for general plant lighting. Foot-candles may be measured with a photographic exposure meter. To prevent undue eyestrain, the light over the grading belt should not be more than 10 times brighter than the surrounding area.

A light colored grading belt reduces glare and makes potato defects easier to see.

Sanitation

Since food products are being handled, proper personal sanitation is a necessity. A packing plant should have adequate toilet and washroom facilities for the workers.

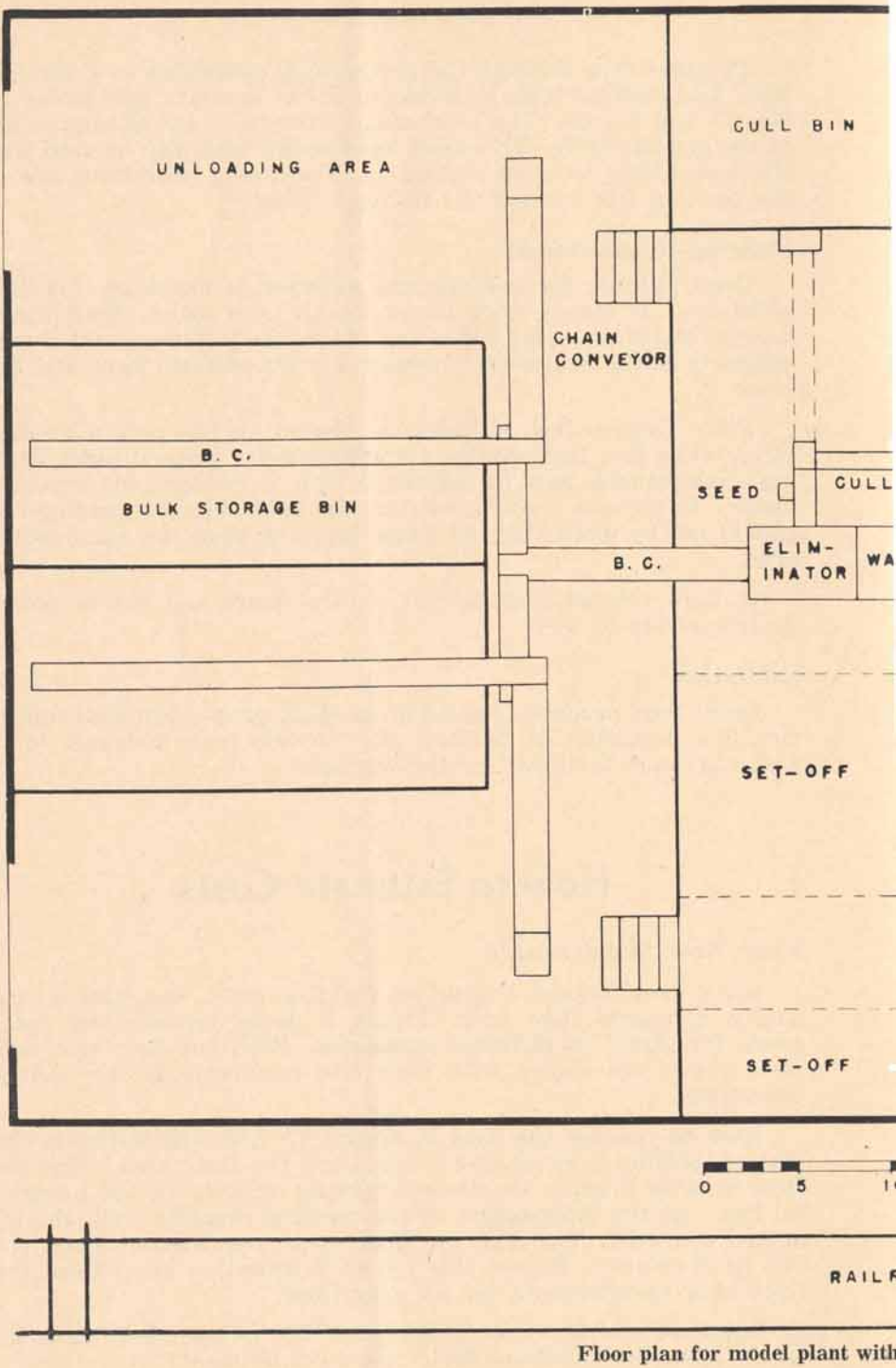
How to Estimate Costs

Floor Area Requirements

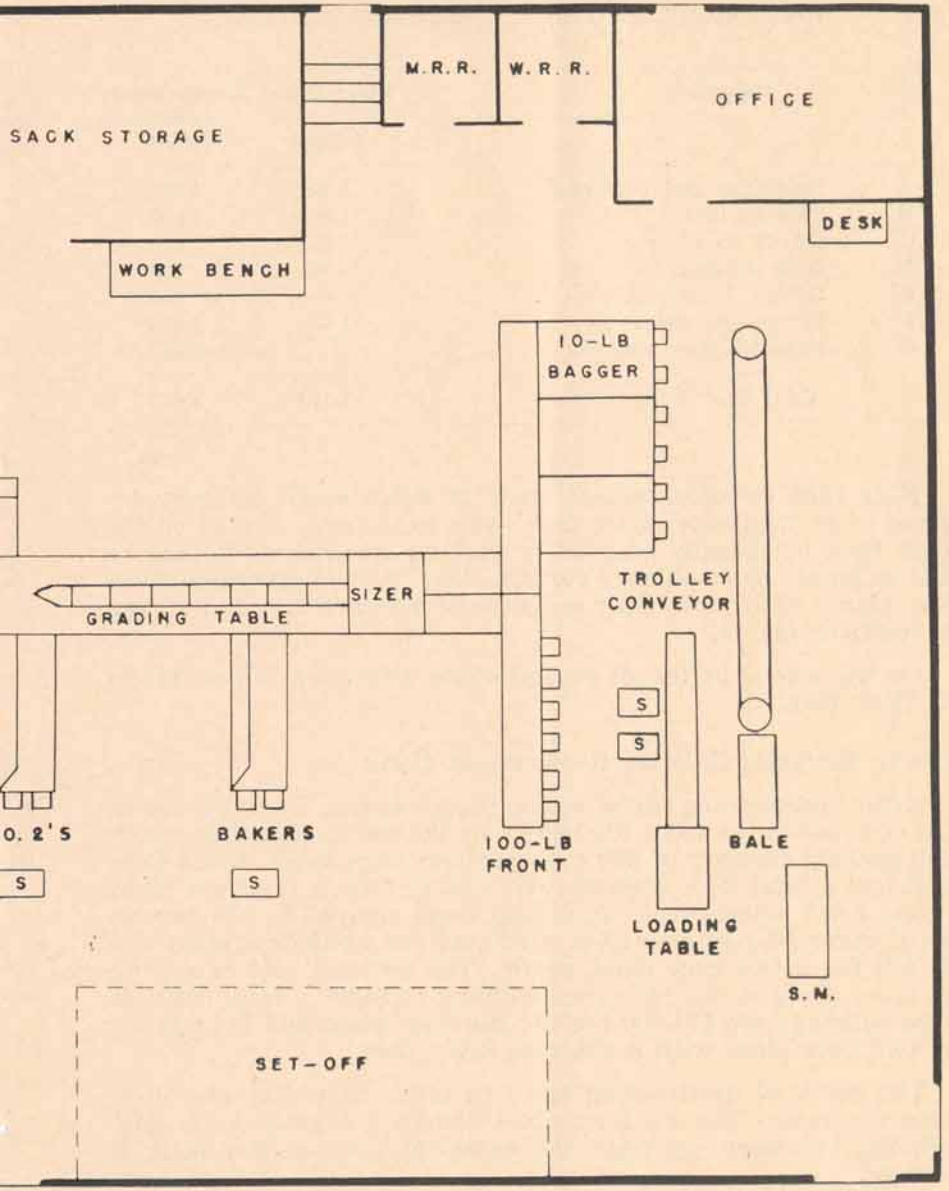
Floor area largely determines building costs, and packing capacity influences floor area. Figure 5 shows typical floor space needs for plants of different capacities. Both one-floor and two-floor plants are shown with floor size requirements for various operations.

How do you use the data in Figure 5? You may estimate the cost of building a warehouse if you know the floor area. Find the floor area by locating the desired packing capacity on the horizontal line. At the intersection of the packing capacity with the diagonal operation line read the floor space requirement from the left hand column. Repeat this for each operation line. Total the floor area requirements for all operations.

One-floor and two-floor buildings of 360 cwt per hour capacity would have the following floor space requirements:



Floor plan for model plant with



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g capacity of 360 cwt. per hour.

Line	Operation	Floor Space Requirements	
		1-floor	2-floor
A	Unloading and receiving	1,700	1,300
B	Packing line	1,900	1,800
C	Set-off area	950	950
D	Sack storage	500	800
E	Offices, lavatories, etc.	400	450
F	Driveways, aisles, etc.	1,600	2,025
G	Unusable floor area	.....	1,300
	Total floor area	7,050	8,625

Note that two-floor plants have an extra space category referred to as "unusable" floor area. This is the area located on the lower floor not readily adapted to packing operations. It may be used as potato or machinery storage. Due to building design, two-floor plants need more floor space for driveways and aisles than do one-floor plants.

On the whole, better all around space utilization is possible in one-floor plants.

How to Estimate Building Replacement Costs

After determining floor space requirements from Figure 5, find cost estimates from Figure 6. In the above example, plants with packing capacity of 360 cwt. per hour were used. A one-floor plant had a total floor area of 7,050 square feet, a two-floor plant needed 8,625 square feet. Applying these figures to the bottom line of Figure 6, cost estimates of $31,000 for a one-floor plant and $27,500 for a two-floor plant result. The optional cost of paving the lower floor of the two-story building is $4300. Total costs of these buildings are $31,000 for the one-floor plant and $31,800 for the two-floor plant with a concrete lower floor.

The costs of constructing the two types of plants are then, about the same—the one-floor plant having a slightly lower cost than the two-story, provided the basement floor of the latter is concrete.

How to Estimate Equipment Replacement Costs

As with building costs, the big factor affecting equipment costs is the expected volume of potatoes to be run. Figure 7 shows packing capacity and equipment replacement costs for various classes of equipment needed.

The example shows how Figure 7 may be used to estimate equipment replacement costs for a 360 cwt. per hour packing

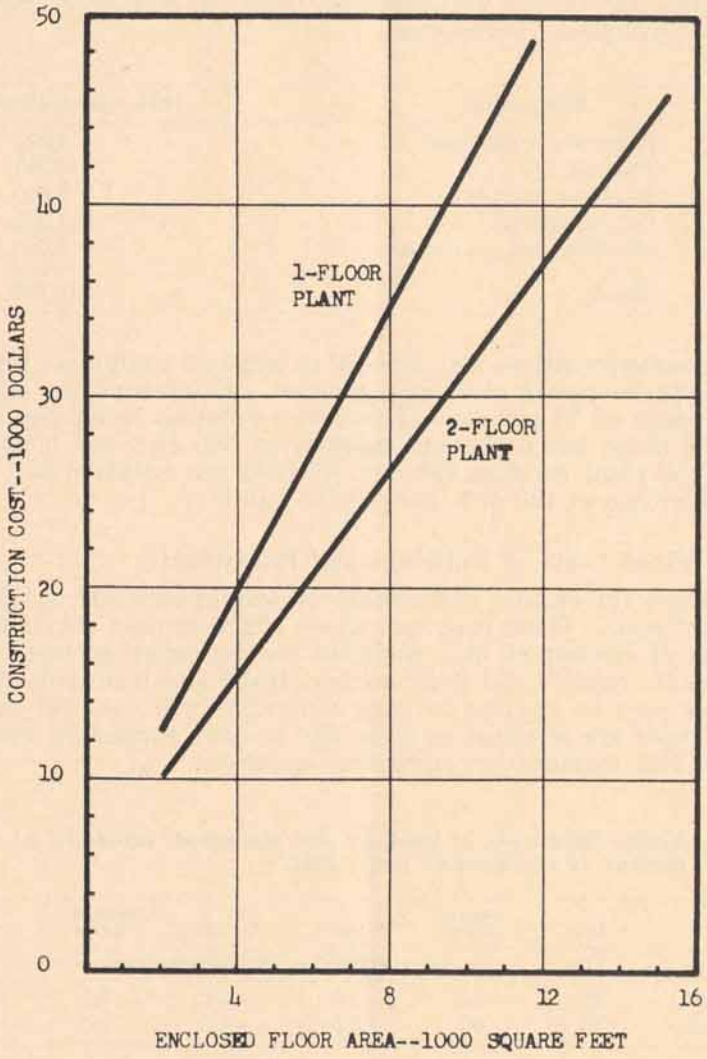

Figure 6.—The effect of floor area on estimated construction costs for one-floor and two-floor potato packing plants. Cost estimates are based upon the building designs as illustrated in Figures 1 and 2 at the 1954 price level. Construction costs in individual plants may vary from these estimates depending upon selection of materials, location, and current price level. If a paved ground floor is desired for the two-floor plant, add $.50 per square foot of ground floor area.

plant. Select a packing capacity on the bottom line. At the intersection of the packing capacity line and the diagonal line, read equipment cost on the vertical scale. Add the equipment costs to get total equipment investment.

Line	Equipment	1954 replacement costs
A	Receiving equipment	$ 5,300
B	Packing line	10,000
C	10-pound equipment	3,000
D	Cull equipment	1,600
E	Miscellaneous equipment	2,800
	Total	$22,700

The same procedure may be used to estimate equipment replacement costs for plants of other capacities. Equipment was selected on the basis of 75 per cent of field-run potatoes being No. 1's or 2's. If a plant has a packing capacity of 360 cwt. per hour, this means the plant receives 480 cwt. of field run potatoes per hour. The difference of 120 cwt. goes to the cull bin.

Yearly Fixed Costs of Buildings and Equipment

Charges for owning and upkeep of warehouses and equipment are fixed costs. Fixed costs are those which remain the same regardless of amount of use. Included are depreciation, interest on investment, repairs and maintenance, taxes and insurance. Some of these such as repairs do vary somewhat wih use, but in this report these are assumed as fixed and to have a constant cost per season. Not included are operating expenses.

Table 1—Yearly fixed costs of buildings and equipment, expressed as a percentage of replacement costs, 1954.*

	Life	Depreciation	Repairs	Interest	Insurance Taxes	Total
	Yrs.	percent of replacement costs				
Buildings	40	2.5	1.5	3.0	2.0	9.0
Equipment	15	6.7	8.3	3.0	2.0	20.0

Using Table 1, yearly building and equipment fixed costs for plants of given capacities may be estimated. In the previous example a one-floor building with a packing capacity of 360 cwt. per hour was found to cost $31,000. Investment in equipment for this building was $22,700. Annual fixed costs of the warehouse are then ($31,000 x .09) or $2790. Annual fixed machinery costs

*Repair costs are averages based on plants keeping detailed records. Other costs are averages selected as being typical for the industry. These percentages may be adjusted to fit individual plants where appropriate.

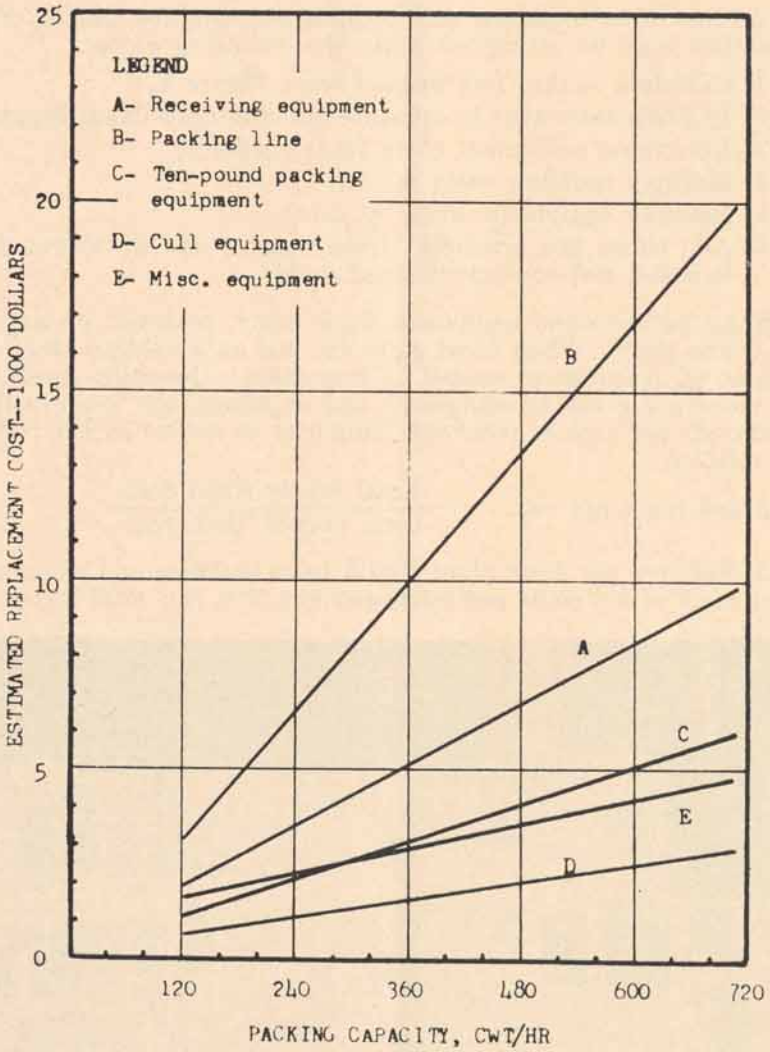

Figure 7.—Effect of potato packing capacity on the replacement cost of plant equipment. Equipment replacement costs are based on equipment used in typical plants at 1954 installed prices. Purchase and installation costs in individual plants may vary depending on location, quality and make up of equipment, and year of purchase. Ten pound banging equipment costs apply to wheel or sacking front bag fillers. For automatic cut-off baggers, replacement costs as shown by line C should be doubled.

amount to ($22,700 x .20) or $4540. Total fixed costs for building and equipment of a plant this size are $7,330.

Annual fixed building and equipment costs for plants of all capacities may be estimated using the following steps:

1. Calculate square feet needed from Figure 5.
2. Use this floor area to estimate building costs from Figure 6.
3. Determine equipment costs from Figure 7.
4. Multiply building costs by .09.
5. Multiply equipment costs by .20.
6. Add these two products (from steps 4 and 5) to get total building and equipment fixed costs.

Total building and equipment fixed costs, however, do not tell the whole story. When fixed costs are put on a volume basis, the amount of potatoes processed is important. Generally speaking, the more use given to equipment and buildings, the lower will be fixed costs per sack of potatoes. This may be shown by the following relation:

$$\text{Fixed costs per cwt.} = \frac{\text{Total yearly fixed costs}}{\text{Cwt. packed that year}}$$

A 360 cwt. per hour plant would have building and equipment fixed costs of 3.5 cents per hundreweight if it ran 1200 hours per

Figure 8.—A well-designed electrical control panel in a recently built plant. All electrical wiring is encased in metal conduit. Control switches for drive units are conveniently located on this panel. Note the readily accessible CO-2 fire extinguisher.

year at 50 per cent capacity. If this same plant operated 1300 hours at 60 per cent capacity, fixed costs per cwt. would be 2.5 cents.

Increasing the volume packed in a given plant is one way to reduce the unit costs of building and equipment. Another way is to invest only in buildings and equipment actually needed. A third way is to prolong the life of the equipment and building by proper upkeep, and by selecting items less likely to become obsolete in a short time.

New Ideas in Equipment

Certain devices, controls, and systems are being developed by the packing industry. These reduce labor requirements, improve plant safety conditions, and increase plant efficiency. In the following section some of the innovations used by the industry are pictured.

Figure 9.—A remote control unit for regulating potato flow to the packing line. Such a convenient location allows the head grader to adjust potato flow with changes in potato quality. Stop-start switches for all drive motors in the packing line are within easy reach of the head grader.

Figure 10.—An automatic-fill bulk storage bin. The inclined shelf at the back of the bin allows potatoes entering first to roll gently to the bottom. Potatoes are distributed in the bin by the tilted belt conveyor. All points of potato fall are rubber-padded to lessen injury.

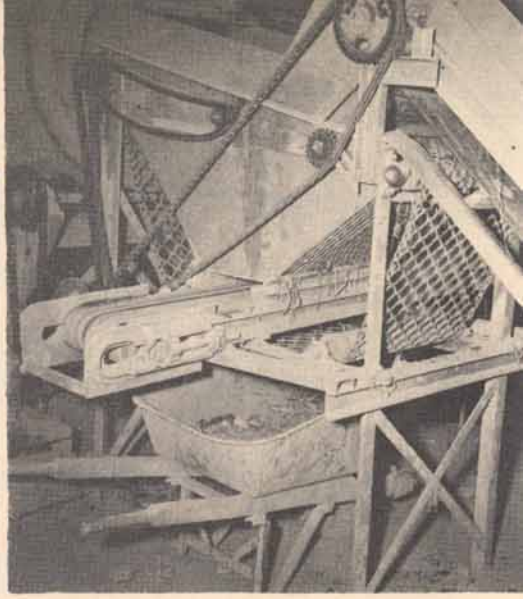

Figure 11.—A wheelbarrow placed under a chain eliminator to catch soil, rocks and vines which sift through the chain. This simple arrangement eliminates hand shoveling of this debris and prevents it from scattering around the packing area.

Figure 12.—The Figure 10 bin being filled with potatoes. The rear of the bin fills first and then the tubers are distributed forward by the inclined belt. A belt conveyor under the bin moves the potatoes out of storage. The only labor required to operate the system is that of starting and stopping the drive motors.

Figure 13.—Portable sump for potato washer. Most of the mud and debris from the washer settles in the bottom of this sump. The water is screened and recirculated in the washer by the centrifugal pump. The tank is portable and may be wheeled onto a truck bed and emptied when filled with sludge.

Figure 14.—A bagging wheel designed and built in an Idaho plant. This bagger features a conveyor to return over-flow potatoes to supply conveyor for re-feeding. The wheel is rotated by the feet. This frees both hands to adjust the bag fill-level.

Figure 15.—Loading a hand truck with the aid of a power conveyor and loading table. This system eliminates the lifting of each sack from floor level. It also assembles sacks at a central loading point.

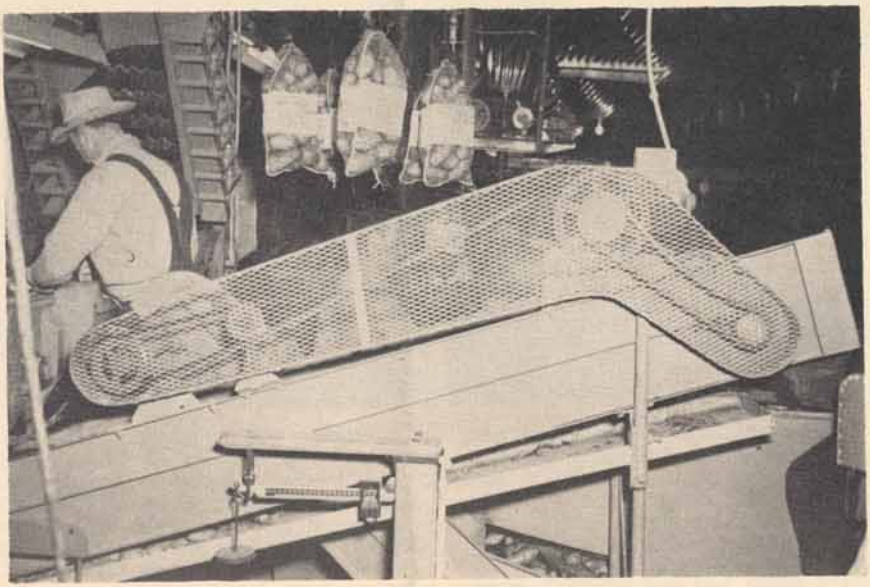

Figure 16.—A well designed protective guard over the power drive of a conveyor. The use of guards over moving chains, V-pulleys, and sprockets is a necessary safety precaution. They also reduce liability insurance rates.

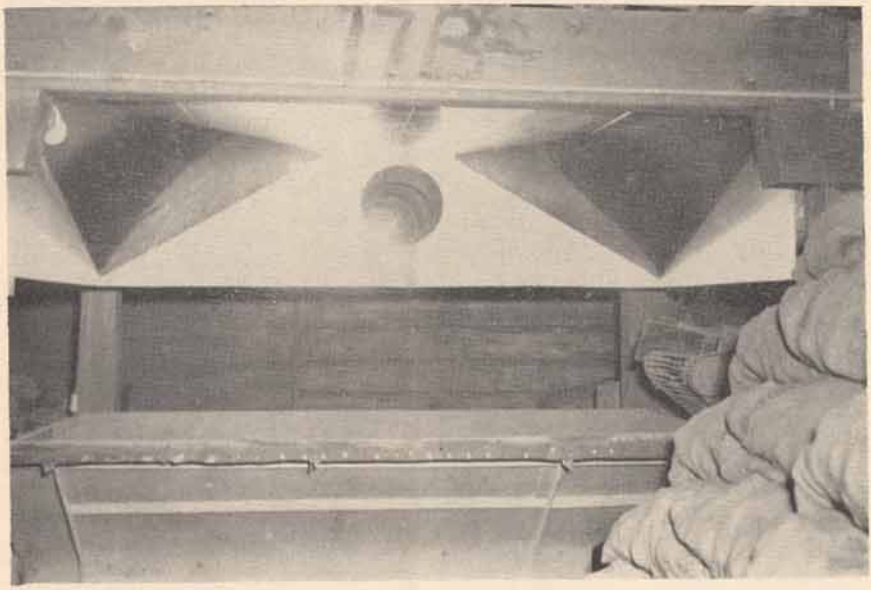

Figure 17.—Potato receiving hopper with metal hood for dust exhaustion. Loading field-run potatoes releases fine dust in the plant which is injurious to worker health and comfort. With this system, much of the dust is taken from the packing plant by a large electric fan.