



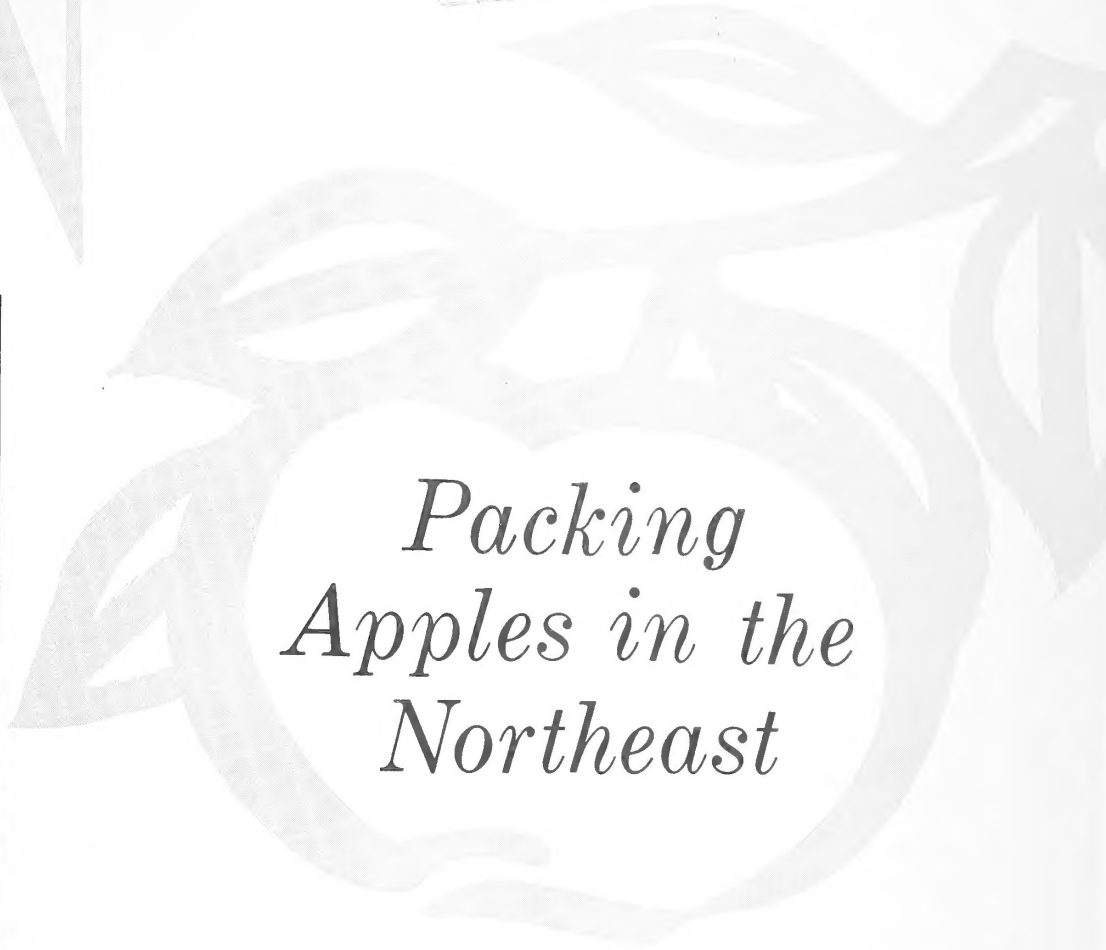
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*Packing
Apples in the
Northeast*

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MARKETING RESEARCH REPORT NO. 543
U.S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE
TRANSPORTATION AND FACILITIES RESEARCH DIVISION
IN COOPERATION WITH
MAINE AGRICULTURAL EXPERIMENT STATION

Preface

The research on apple packing in the Northeast, on which this report is based, furthers the long-range apple handling and packing research which was started in the Pacific Northwest, and which has already resulted in large savings to the industry. The apple most commonly grown in the Northeast is the easily bruised McIntosh variety, whose characteristics present problems that could not be handled by the packing equipment used for apple varieties commonly grown in the Northwest.

In 1950, research was initiated in the Northwest to reduce costs of handling and packing fruit, and minimize losses from bruising. By 1955, industry estimated that, by adoption of the results of this research, packing-houses in that area alone were saving \$1 million annually. It is now estimated that more than twice that amount is being saved yearly. Application of research findings in the Northeast can result in great savings to the apple packing industry in that area.

This study is part of a broad program to increase the efficiency with which agricultural products are marketed, and to deliver to the consumer unblemished, uniformly sized produce. Many firms and individuals have given time, facilities, and counsel to this study, and their contributions are acknowledged.

The study on which this report is based was under the general supervision of Joseph F. Herrick, Jr., marketing research analyst, Transportation and Facilities Research Division, Agricultural Marketing Service. Fred Perkins, formerly with the Maine Agricultural Experiment Station, made valuable contributions to all phases of the study. The station also furnished both professional and technical assistance and supplied some of the photographs which illustrate this report.

Other Department of Agriculture publications of interest to packing-house operators include:

Apple Handling Methods and Equipment in Pacific Northwest Packing and Storage Houses. Carlsen, E. W., Hunter, D. L., Duerden, R. S., and Herrick, Jr., J. F. MRR-49, June 1953.

Handling and Storage of Apples in Pallet Boxes. Herrick, Jr., J. F., Mc-Birney, S. W., and Carlsen, E. W. AMS-236, April 1958.

Apple Sorting Methods and Equipment. Hunter, D. L., Kafer, F., and Meyer, C. H. MRR-230, August 1958.

An Experimental Packing Line for McIntosh Apples. Burt, S. W. AMS-330, August 1959.

Apple Handling and Packing in the Appalachian Area. Burt, S. W. MRR-476, June 1961.

For information concerning movies dealing with apple handling and packing write the Marketing Information Division, Agricultural Marketing Service, U.S. Department of Agriculture, Washington, D.C.

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SUMMARY

This report compares four types of apple packing lines in common use in the Northeast. Studies were made in eight plants that used the tender, easily bruised McIntosh variety of apples.

An all-manual sorting-sizing-packing operation had the lowest labor and equipment cost of the four packing lines studied, 13.7 cents per container at a volume of 50,000 crates annually. There was no mechanical damage to the apples. This method was the most efficient, as long as skilled packers were not difficult to obtain, the wage rate remained low, and the daily volume did not exceed the space available for packing stations. There were great differences in the abilities of individual workers to sort, size, and pack apples simultaneously, so that within a given lot of packed fruit, a wide disparity in sizes and grades became the rule rather than the exception.

The packing line in which apples were dumped manually, sized by chains, and sorted and rechecked for size by the packers was the most costly. Many apples were bruised, and the sorting and sizing were poorly done. Also, the capacity of this packing line was below that of other mechanized lines. At a volume of 50,000 crates annually, labor and equipment cost 22.8 cents per packed container.

The other two packing lines studied showed almost identical costs. The one using mechanical dumping, sorting at a roller table, weight sizing,

and manual packing from a return-flow belt, had a labor and equipment cost of 20.8 cents per container at an annual volume of 50,000 crates; when the annual volume was 75,000 crates, the unit cost was reduced to 18.3 cents per container.

The second mechanized line employed a drum dumper and a reverse-roll sorting table with dimension sizing, and packing from a return-flow belt. Its labor and equipment cost was 19.6 cents per container at 50,000 crates annually, and 17.4 cents at 75,000 crates annually. With both of these packing lines, the sorting and sizing were highly accurate, and bruising was not serious. Each line had a built-in capacity far beyond that of either the all-manual line or the one using chain sizers.

In all cases, labor cost more than equipment, even when the assumed wage rate was as low as \$1.25 per hour. Should the cost of labor rise, then the manual operations would rapidly become more costly, and the mechanized packing lines would become relatively more efficient. Or, if skilled labor should become difficult to hire, the manual packing line would become less efficient, because it requires greater skills of its workers than do the other more mechanical lines.

The following comparison summarizes the advantages and disadvantages of the four packing lines:

Method	Advantage	Disadvantage
Manual dumping and chain sizing, with sorting and packing from a return-flow belt.	Low equipment cost. Low maintenance.	Low capacity. Damage to fruit. Low productivity of labor. Difficult to standardize quality.
Mechanical dumping, sorting at a roller table, weight sizing, and manual packing from a return-flow belt.	High capacity. High labor productivity. Standardized quality and sizes.	High equipment cost. Division of space on return-flow belt restricted. High total cost at low volumes.
All-manual sorting, sizing, and packing.	Very low equipment cost. Low total cost at low volumes and low wage rates. Least total bruising to fruit. Very little power and maintenance cost.	Dependent on adequate labor supply. Wide range in grading and sizing. Difficult to increase volume.
Drum dumper and reverse-roll sorting table, with dimension sizing and packing from return-flow belt.	High capacity. High labor productivity. Standardized quality and sizes. Wide freedom in division of space on return-flow belt.	High equipment cost. High labor cost at low volumes.

PACKING APPLES IN THE NORTHEAST

by STANLEY W. BURT, *industrial engineer*, Transportation and Facilities Research Division,
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INTRODUCTION

Over 20 percent of our Nation's apple crop is grown and packed in the Northeast (Maine, Vermont, New Hampshire, Connecticut, Massachusetts, Rhode Island, and New York). Apples are an important part of agriculture in the area; in 1961, these States produced 32 million bushels of apples, valued at more than \$50 million. Most were of the tender, easily bruised McIntosh variety that was used in the tests.

Wide variations exist among the types of operations in apple packing plants. There are great differences in the volumes handled, and many different types of equipment, methods, and containers are used. The constant development of new equipment and new operating methods, all meant to

benefit packinghouse operators, are accompanied by new marketing procedures, changing consumption patterns, and evolving marketing services and institutions.

How is an operator to know which methods and which equipment are best suited to his requirements? Which will perform at the least cost to him? The purpose of this report is to provide cost and performance data for packing lines in common use in the Northeast, so that each operator can determine the relative advantages of each line according to his own requirements. Eight plants were studied, typical of four widely used types of plants in the area.

MANUAL DUMPING AND CHAIN SIZING, WITH SORTING AND PACKING FROM A RETURN-FLOW BELT

Apples in the Northeast have for years been dumped manually, sized by chains, and packed from a return-flow belt, with the packers also sorting. This is the method used in many plants—both large and small—throughout the area. In fact, except for a completely manual method, it is probably used more than any other. A representative layout for this way of packing apples is shown in figure 1. The component parts of the layout are described in the following sections.

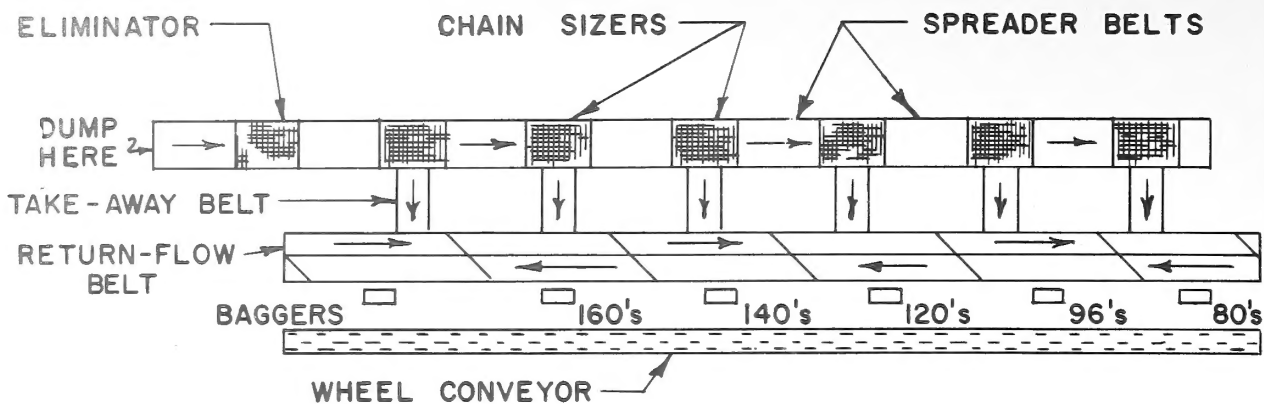
Dumping

Where dumping was done manually the only equipment used was a spreader belt onto which apples were emptied from their crates. Either one or two men worked in this operation. Where two men together dumped apples, one kept a crate in readiness for the other who tipped the fruit out onto a spreader belt (figure 2). Empty crates were placed either in a stack beside the dumping station or on a conveyor which carried them away.

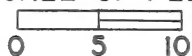
Where only one worker was used, his duties included keeping fruit near the dumping station, as well as tipping the fruit onto the spreader belt and

disposing of the empty crates. For most packing lines only one worker was needed. A worker dumping manually was confined to his immediate work area by the nature of his job; he could not work in other parts of the plant.

Apple crates were emptied at carefully spaced intervals. To vary this interval by even a few seconds could have disrupted a closely synchronized packing operation. Close attention to the dumping rate was essential so that (1) fruit would not overcrowd on the sizer chains, (2) the return-flow belt would not become overloaded, and (3) packers would not have to speed up to pack all the apples that were supplied them. Against all these consequences of overdumping, the dumper still had to maintain a rate which would assure a constant supply of apples from which those packing could work. Thus, the dumper became more than a box-emptier; he was in fact the regulator of the entire packing line. It was his responsibility to arbitrarily adjust his dumping rate as changes occurred in the size and quality of fruit dumped, or as too much or too little fruit accumulated on the return-flow belt. To do this required him to be constantly alert and attentive to his duties.



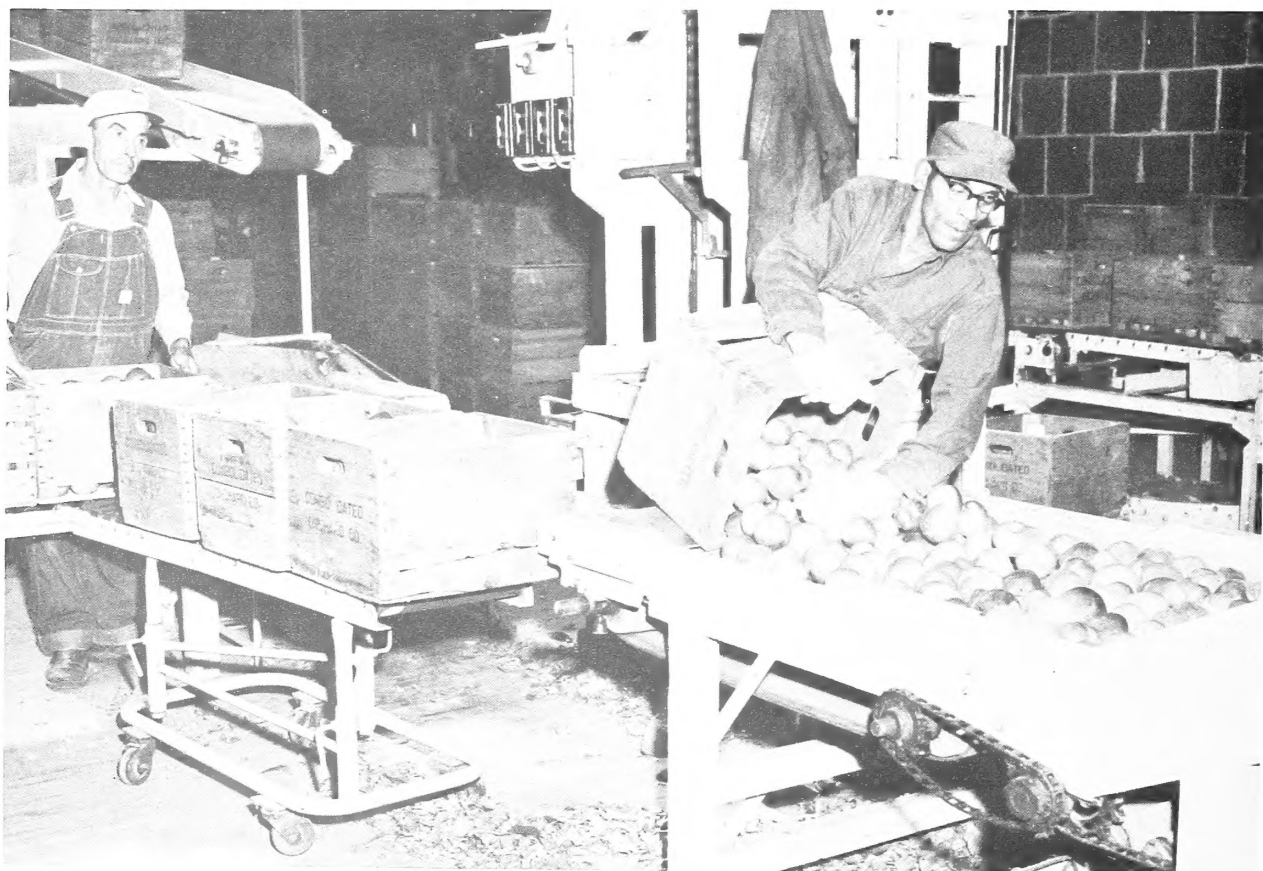
SCALE OF FEET



MANUAL DUMPING
CHAIN SIZING
PACKING FROM BELT
PACKERS SORT

BN-14258-X

FIGURE 1.—Layout of an apple packing line that incorporates manual dumping and chain sizing, with workers sorting and packing from a belt.



BN-15085

FIGURE 2.—Two workers dumping apples manually. One keeps a full crate in readiness for the second who tips the apples out onto a spreader belt.

Sizing

Sizer chains have been used for many years in the New York-New England area; large quantities of apples are sized with this equipment. The sizes are determined by the number or count of the apples required to fill a carton. The units into which apples are sized are variable, but a representative size grouping might be:

<i>Minimum diameter</i>	<i>Size or count per carton</i>
2 $\frac{1}{4}$ inches.....	180
2 $\frac{1}{2}$ inches.....	160
2 $\frac{5}{8}$ inches.....	140
2 $\frac{3}{4}$ inches.....	120
3 inches.....	96
3 $\frac{1}{2}$ inches.....	80

Sizing was done with a series of sizer chains (usually six) separated by spreader belts (fig. 3). For fruit to get from the dumper to the sizer it first passed over an eliminator to remove small apples and leaves, and then rolled onto a spreader belt like that onto which it was first dumped. The spreader belt carried it to the first of the chain sizers. The smallest size to be packed dropped through this chain. All the other apples rode

over and rolled off onto another spreader belt which carried the fruit forward to the second chain. The second smallest size apples dropped through here. With each succeeding chain, larger apples were moved on, until eventually all the fruit had been separated into size groups.

When an apple dropped through a chain sizer it fell 6 to 10 inches to a conveyor belt. This belt delivered the apple to that section of the return-flow belt designated for its particular size, and from that section of the belt it was sorted and packed out.

Sorting and Packing

Sorting and packing were done by the same worker. Whoever packed apples first sorted them into their proper grades. This work was done by packers standing at a return-flow belt (fig. 4). Shunts divided this return-flow belt into sections, one for each size of fruit packed. Apples were delivered from the sizer to these sections by short conveyor belts.

Normally, one worker was assigned to each packing station. However, two workers were often positioned at those sections which received



BN-10010

FIGURE 3.—Sizer chains and spreader belts used for apples in the Northeast area.



BN-7507

FIGURE 4.—Worker sorting and packing apples from a return-flow belt.

the more common sizes. Where this was done, each packed a separate grade, selecting from the belt only apples which were of the grade assigned to her. Another method was for each packer to have two packing stands—one for each grade packed—and to sort and pack apples into each grade. Whichever way of packing was used, the utility and cull apples were always boxed separately.

Invariably, fancy and extra-fancy grade apples of sizes 80 through 160 were cell-packed into cartons. Size-180 fruit was bagged, sometimes in combination with larger apples. Apples larger than size 80 were usually jumble-packed into wood or corrugated containers. Bagging was done manually or with single-head weigh-baggers fitted into the packing line. When weigh-baggers were used, one worker at each bagging machine filled bags and placed them in cartons, and another worker sealed the cartons.

Although all the fruit passed over a chain sizer, many apples were improperly sized, and were delivered to the wrong section of the return-flow

belt. Because of this the packer, in addition to sorting and packing, had to watch for incorrectly sized fruit. She either left such apples on the belt and worked around them, or else picked them out and collected them in a box. Either way, they were eventually transferred to the correct section of the belt.

An Evaluation of the Method

Appraisal of a method of dumping, sizing, sorting, and packing apples involves: (1) The dollar cost of labor and equipment, (2) the amount and severity of bruising, (3) accuracy of sorting, and (4) accuracy of sizing. Labor and equipment are clearly direct costs of apple packing; they are easy to recognize. The other costs, however, are harder to assess. At best, the number of dollars lost from bruising, inaccurate sorting, and improper sizing can be only approximated. Because these particular costs are difficult to see, they are easy to overlook. Still, some measurements were made of bruising, sorting, and sizing as they occurred on this packing line, and these data are presented.

Labor and Equipment

With this method of dumping, sizing, sorting, and packing, labor accounted for 79 percent of the total cost, and equipment 21 percent. Of the total labor cost of \$165 per 1,000 packed containers, \$145 was for the 14 workers who sorted and packed apples from the return-flow belt, and \$20 was for the dumpers. There was no labor cost for sizing (table 1).

Equipment for 1,000 packed containers cost \$44.16. The return-flow belt, shunts, packing stands, and wheel conveyor used in the sorting-packing operation made up \$24.93 of this; sizing equipment cost \$17.09; and dumping equipment only \$2.14 per 1,000 packed containers.

The combined labor and equipment cost with the method used here was equivalent to 20.9 cents per packed container, which was the highest cost for the methods studied.

Bruising

The amount of bruising of apples by mechanical graders is governed largely by (1) firmness of the fruit, and (2) the number of sizing chains that apples ride over. This packing line had the worst record for bruising fruit; the chain sizers were particularly damaging.

Every place on a packing line where apples could strike each other, rub against equipment, or drop to a lower level was a potential place for bruising of apples. The packing line discussed here had many such places. Bruise points should be padded, drop distances minimized, and rates of travel reduced.

TABLE 1.—*Labor and equipment required to dump, sort, size, and pack 1,000 containers of apples daily, by use of manual dumping and chain sizing, with workers both sorting and packing from a return-flow belt*¹

Operation	Labor required		Cost		
	Workers	Man-hours	Labor ²	Equipment ³	Total
	Number		Dollars	Dollars	Dollars
Dumping-----	2	16. 00	20. 00	⁴ 2. 14	22. 14
Sizing-----				⁵ 17. 09	17. 09
Sorting-packing-----	14	116. 00	145. 00	⁶ 24. 93	169. 93
Total-----	16	132. 00	165. 00	44. 16	209. 16

¹ 560 containers were cell-packed cartons, and 440 were jumble-filled crates. 1.14 field crates were dumped for each container packed.

² Based on \$1.25 per hour per worker.

³ Based on 50,000 crates dumped annually.

⁴ One spreader belt, one 20-foot wheel conveyor.

⁵ Includes seven sizer chains and six spreader belts.

⁶ Includes one 60-foot return-flow belt, seven power shunts, twelve packing stands, and one 90-foot wheel conveyor.

Bruise-free apples were used in testing the effects of this type of packing line on bruising of fruit. The fruit had a firmness of 16 pounds as measured with a Magness-Taylor pressure tester (this was the pressure required to force a 7/16-inch diameter plunger 1/4 inch into the flesh of an apple). The apples were sent through the packing line up to the point of packing. Here the fruit was removed by hand and carefully collected in padded boxes, instead of being cell-packed. The boxes were set aside in the packing room, and the fruit was examined after 24 hours.

Of every 100 apples tested 15.8 were bruised; 1.6 to a moderate degree, and 14.2 to a slight degree.¹ For apples as firm as these, the amount of bruising was considerable. Moreover, additional bruising occurs when the apples are cell-packed; see the discussion under the all-manual method of sorting, sizing, and packing, p. 19.

Injuries that occur in the packing line are costly beyond the immediate loss of the fruit that is picked out. Because these bruises are incurred only minutes before packing, they are still fresh, and difficult to detect. Consequently, many of the damaged apples are packed, and shipped to buyers. By the time the cartons are opened for inspection, the bruises have discolored, and are clearly visible—to the discredit of the shipper.

Apple bruising is a major source of concern to every packer. Good will and good reputation are valuable assets, which can be jeopardized by continuous and excessive bruises on packed apples.

Sizing

Apples were sized twice; first by chains, and then by packers as they sorted and packed the fruit. Sizer chains did most of the sizing, with packers performing a minor role.

¹ See page 33, appendix, for definition of the degrees of bruising.

How well this system of chain sizers performed could best be determined by an examination of the fruit after it had been packed. The findings from this examination are presented in table 2.

TABLE 2.—*Accuracy of sizing when initial sizing was by sizer chains and final sizing by the packer*

Apples packed in carton	Standard diameter	Sized apples whose diameters were—			
		Within 1/8 inch of standard	Within 1/4 inch of standard	More than 1/4 inch from standard	
Size	Inches	Percent	Percent	Percent	
160-----	2 1/2	86	98		2
140-----	2 3/8	49	95		5
120-----	2 3/4	87	99		1
96-----	3	71	100		0

If a 1/4-inch variation from the standard diameter (either over or under size) is acceptable, then there can be no criticism of the sizing job that was done: 95 to 100 percent of the apples in each size fell within this tolerance. However, if no more than 1/8-inch variation from the standard diameter (giving a range of 1/4 inch) is acceptable, then chain sizing is not adequate, since only 49 to 87 percent of the sized apples fell within this range.

At the time of the test, only four sizes were cell-packed; had there been more, the results might have been different. There was considerable difficulty in getting the proper apples into size 140 cartons. There was no separate sizer chain for this size of fruit. Apples with a diameter of 2 5/8 inches would fall through either the 2 1/2-inch chain (size 160) or the 2 3/4-inch chain (size 120). From

among these smaller and larger apples, packers had to pick out those for the 140-count pack. Consequently, 140-count cartons had the greatest range in sizes, and the least uniformity.

Sorting

Apples are commonly divided into U.S. Extra Fancy, U.S. Fancy, U.S. No. 1, and U.S. Utility grades and culls. More often than not U.S. Extra Fancy and U.S. Fancy grades are packed as a combination grade, as are sometimes the U.S. No. 1 and U.S. Utility grades. Where grades are combined in this manner, there are three classifications into which sorter-packers put apples: (1) Combination U.S. Extra Fancy and U.S. Fancy, (2) Combination U.S. No. 1 and U.S. Utility, and (3) culls.

The different ways a packer can sort apples are described. Whichever method is used doubtless has some bearing on the proportion of apples that are improperly sorted. However, it would appear that the preponderance of incorrect sortings is attributable to the basic method itself—each worker making rapid-fire decisions as to an apple's size, its grade, and in which container to put it. The amount of incorrect sorting that resulted is shown in the following tabulation:

<i>Apples in carton</i>	<i>U.S. Utility-grade fruit in U.S. Extra Fancy-U.S. Fancy grade packs</i>	<i>Percent</i>
96	-----	16
120	-----	12
140	-----	13
160	-----	8
Weighted average-----		12

The quality of sorting is directly affected by the percentage of utility and cull fruit in the fruit received from the orchard. The more below-grade fruit there is, the more utility grade apples will get into the packed cartons. In this study, orchard-run fruit averaged 85 percent U.S. Fancy or better, and only 15 percent U.S. No. 1, U.S. Utility, or cull. After sorting, the apples in each packed carton were, on an average, 88 percent U.S. Fancy or better grade fruit and 12 percent U.S. No. 1's and U.S. Utilities, as shown in the tabulation. What sorting was done reduced the below-grade fruit only 3 percent. Some of this ineffectiveness of sorting was attributable to the

relatively high quality of the orchard-run fruit, but most of it was due to the sorting method used.

While packers did not remove many apples below U.S. Fancy grade from the orchard-run fruit, they still had to watch for such apples, and this requirement reduced the rate at which they were able to cell-pack.

Conclusions

Manual dumping, coupled with chain sizing and packers who are sorting for grade and checking for size in addition to packing, has a limited capacity. Many apples are bruised and poorly sized, and many off-grade apples end up as packed fruit.

While much of the bruising occurring on existing lines could undoubtedly be reduced or even eliminated, the characteristics of the equipment components of this packing line preclude reducing the bruise rate to that which could be achieved with the other packing lines. Nor could one worker, with the multiple responsibility for sorting, sizing, and packing, perform all these operations as well as a worker who had but one operation to perform.

Effect of Volume

As the volume of apples increased, the number of workers needed increased in almost a proportionate number. The fuller utilization of equipment that was possible at higher volumes reduced the unit cost for equipment, but had only a small effect on the unit cost for labor; the same equipment was able to handle 25,000 crates or 75,000 crates annually, but the same working force could not.

Labor and equipment costs for volumes of 25,000, 50,000, and 75,000 field crates per year are shown in table 3. It would be difficult to reduce the unit costs much below those shown because the line would be taxed to maintain such a volume, and any increase would require the addition of more equipment. Probably the only really effective way to increase the capacity of a line as described here would be to install still another complete line. Most packinghouses in the Northeast did not have the space for a second line, and this alone would place a ceiling on the volume that could be packed by operators using manual dumping, chain sizing, and sorting-packing from a return-flow belt.

MECHANICAL DUMPING, SORTING AT A ROLLER TABLE, WEIGHT SIZING, AND MANUAL PACKING FROM A RETURN-FLOW BELT

Only a small part of the apples in the New York-New England area were dumped mechanically, divided into grades at a sorting table, sized according to weight, and then packed manually from a return-flow belt. This was the newest

combination of packing equipment tested in this study, and it had been installed in only a few plants in the area. A layout for a packing line that incorporates this equipment is shown in figure 5, on page 11.

TABLE 3.—Labor and equipment required to sort, size, and pack apples by use of manual dumping and chain sizing, with sorting and packing from a return-flow belt, at three different annual volumes

Annual volume	Workers		Working days	Cost			Cost per packed container
	Number	Man-hours		Labor ¹	Equipment	Total	
25,000 field crates or 21,930 packed containers	² 6	3,054	<i>Number</i> 71	<i>Dollars</i> 3,817.50	<i>Dollars</i> ³ 1,998.00	<i>Dollars</i> 5,815.50	<i>Cents</i> 26.5
50,000 field crates or 43,860 packed containers	⁴ 11	6,217	71	7,771.25	⁵ 2,208.00	9,979.25	22.8
75,000 field crates or 65,790 packed containers	⁶ 15	8,786	75	10,982.50	⁷ 2,353.00	13,335.50	20.3

¹ Based on \$1.25 per hour per worker.

² One dumper, five sorter-packers.

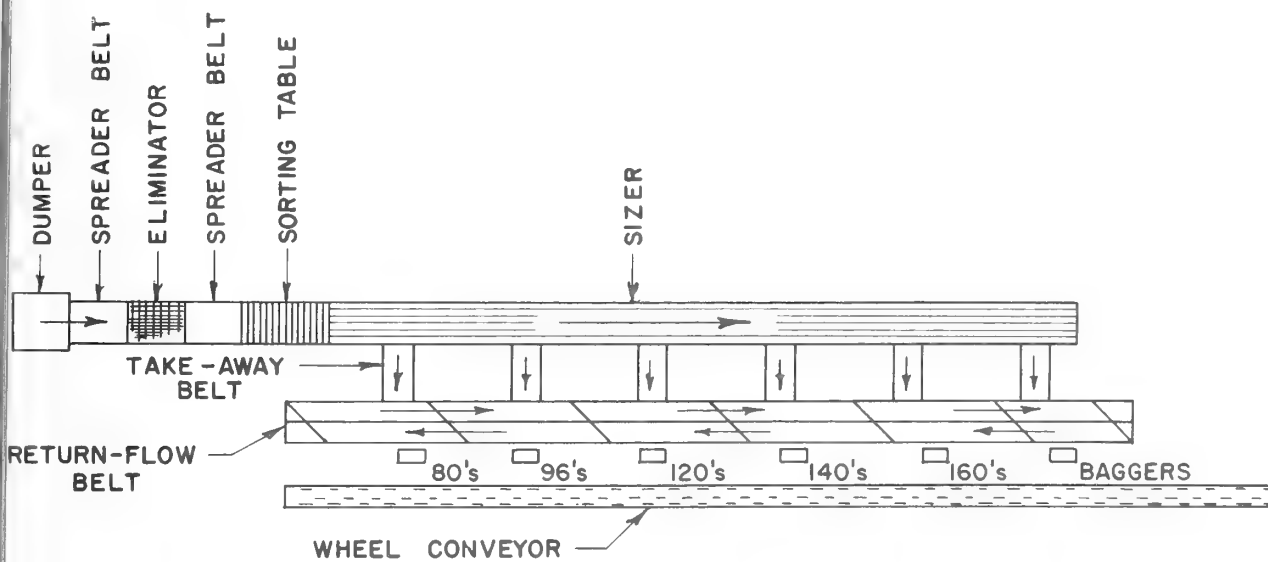
³ Basic equipment costs are developed in table 22, appendix.

⁴ Two dumpers, nine sorter-packers.

⁵ Basic equipment costs are developed in table 23, appendix.

⁶ Two dumpers, 13 sorter-packers.

⁷ Basic equipment costs are developed in table 24, appendix.



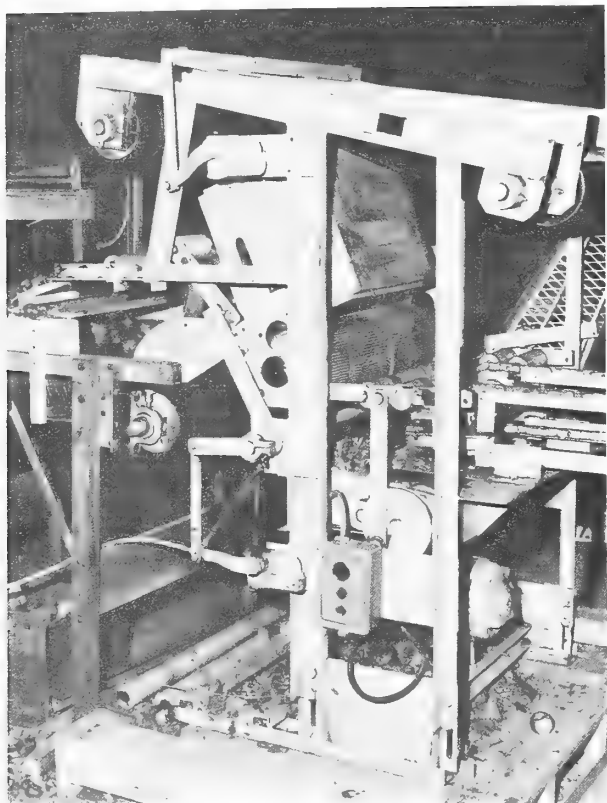
AUTOMATIC DUMPER
 ROLLER SORTING TABLE
 WEIGHT-TYPE SIZER
 PACKING FROM BELT

BN-14256-X

FIGURE 5.—Layout of an apple packing line incorporating mechanical dumping, sorting at a roller table, weight sizing, and manual packing from a return-flow belt.

Dumping

The mechanical dumper was a device for tipping apples out of crates. A full box moved automatically from the feeder conveyor into the dumper; a lid came down over the box, and the entire unit was tipped up and moved out over a spreader belt. As the box tipped, the lid moved back and apples dropped onto the spreader belt below. When empty, the box was removed from the dumper and either deposited on a conveyor, or else stacked manually near the dumping station (fig. 6).



BN-15132-X

FIGURE 6.—Mechanical dumper used with a weight-type sizer.

With mechanical dumping, labor was necessary only to supply full field boxes and to stack empty boxes after dumping. Boxes were brought to the dumper by forklift truck, conveyor, or handtruck. By whatever means full boxes were brought to the mechanical dumper, one worker had to manually place them on the conveyor which fed the dumper. He also stacked empty boxes that came from the dumper. These jobs together required only a small part of his total time, so that this worker was free to perform other duties as well.

A conveyor to supply full boxes to the mechanical dumper and another conveyor to accumulate

empty boxes after dumping made it possible for the worker to spend most of his time in other work. However, this man could not work outside the vicinity of the dumper, because he bore the responsibility for having full boxes always ready to dump, and for removing empty boxes.

Sorting

Apples were separated into grades by sorters alongside a roller sorting table (fig. 7). The rollers rotated in reverse directions and were covered with a thin rubber sleeve to protect the fruit. A sorter's sole function was to separate apples into different quality classifications. If only one grade (or one combination of grades) was packed, then apples of this grade were left on the sorting table and the lower grade apples were removed. Thus sorting became a process of picking out those apples not suitable for cell packing from among those that were. Apples removed from the sorting table were further divided; depending on the policy of the packinghouse, these apples were separated into culls, utilities, No. 1's or other grades, or grades were combined.

Much was expected of the sorters. Ideally, they would remove from the orchard-run fruit all those apples below the grade being packed, and then correctly subdivide these picked-out apples into grades. No crew of sorters could achieve this ideal; too many rapid-fire decisions were made for them all to be right (many apples were borderline between grades). Some lower-grade fruit was always left in, and some higher-grade fruit was always taken out.

Cull apples were either placed in a box beside the sorter or dropped down a chute to a conveyor which carried them to a common container. As they became full, the containers were removed and replaced.

U.S. No. 1's and utilities were also collected—if they did not occur in great numbers—in boxes beside the sorters. Otherwise, they were placed on over-the-table conveyors, and delivered to a place where they were either packed or jumble-filled into boxes.

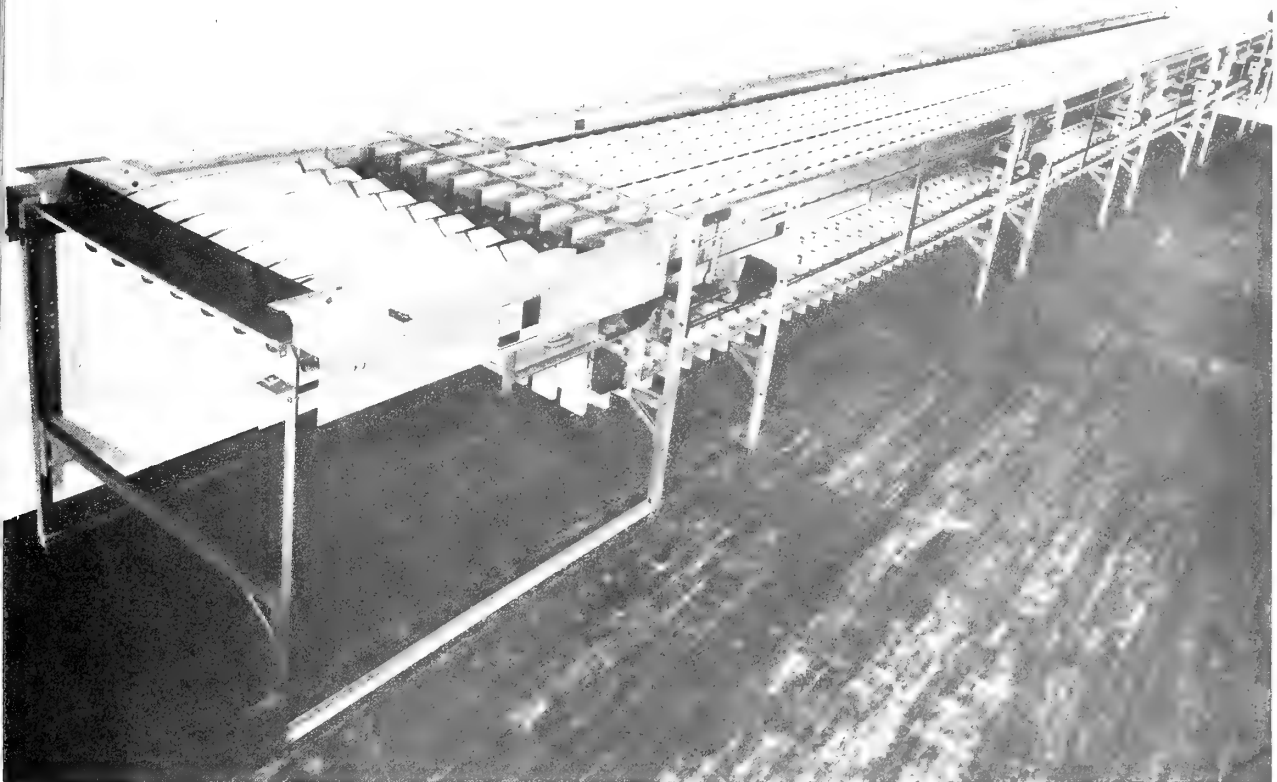
Sizing

Federal standards require that an apple's minimum size be stated as the greatest diameter along its stem-calyx axis. Nearly all apples are asymmetrical to some degree, making it difficult to measure their diameters directly. The sizer described here was designed to determine an apple's size by its weight (fig. 8). The weight principle of sizing has been used for many years, and depends entirely on a close correlation between an apple's weight and its largest diameter along the stem-calyx axis. It means also that all of the apples in a lot must have about the same specific



BN-15090

FIGURE 7.—Workers sorting fruit at a roller sorting table. Rubber-covered rollers rotate in reverse directions.



BN-15133-X

FIGURE 8.—Weight-type sizer. Each cup carries a single apple across a series of scales. At the scale which matches its weight the apple is released from the cup, and thus its size is determined.

gravity. Since this sizer is insensitive to an apple's shape, there is no way that it can identify and reject atypical specimens. Some varieties are more difficult to size than others, but this problem also occurs with other sizing methods.

Before apples entered the sizer, they first traveled over a sorting table, where substandard fruit was removed. Spilling off the sorting table, apples distributed themselves across a spreader belt, which delivered the fruit to a singulator. The singulator spaced apples so that only one would drop into each sizing cup. As an apple moved forward in a cup it passed over a series of scales. When it passed a scale that matched its weight, the apple dropped out. Falling onto a conveyor belt, the apple was delivered to a section of the return-flow belt set apart for that size of fruit.

Packing

A separate belt conveyor for each size of fruit would deliver apples from the sizer to sections of the return-flow belt. Shunts divided the belt into sections, one for each size of apple packed. An apple would travel back and forth—within its sec-

tion of the return-flow belt—until it was removed by a packer (fig. 9).

Two workers were usually assigned to those sections receiving apples of the most common sizes, whereas one worker could care for two sections receiving the less common sizes. It was sometimes necessary to shift packers as their workloads changed. This happened frequently, as changes in lots, varieties, owners, or orchards often changed the proportion of each size of apples in the field-run fruit. It was easy for a packer to change to another section; each packer had clear visibility to all sections of the return-flow belt, and at a glance could tell if her efforts were needed more elsewhere.

An Evaluation of the Method

This method had a relatively high capital outlay, compensated by reduced labor costs and more flexibility in the packing operations. Equipment in this packing line could be adjusted easily to higher or lower volumes, and brought to operate within narrow size and bruise tolerances.



FIGURE 9.—Worker cell-packing apples from a return-flow belt. The fruit has already been sorted and sized.

BN-15089

Labor and Equipment

Cost and labor requirements for dumping, sorting, sizing, and packing 1,000 apple containers with this packing line are in table 4. Labor and equipment cost per packed container was 18.0 cents. Despite the fact that this was one of the more highly mechanized lines, labor was still the major cost item. Although sorting had the highest labor cost of the four operations, it had the lowest equipment cost.

Of the total labor cost, 98 percent was in the two operations of sorting and packing. By contrast, only 40 percent of the equipment was in these two operations. When labor and equipment were considered together, the sorting and packing operations had about the same unit cost and together accounted for 76 percent of the total labor and equipment cost for the packing line operations.

Bruising

This packing line was not greatly different from the other lines with regard to apple bruising. It consisted of new types of equipment and incorporated new materials, but almost as many apples were bruised by this line as by the other, older packing lines. Why? Because the amount and degree of bruising inflicted on fruit was caused almost entirely by: (1) Softness of the fruit at time of packing, and (2) the lack of care taken to reduce or eliminate places within the packing line that could cause bruising. This was equally true for the other packing lines studied. The age of a line did not affect the amount and degree of bruising nearly so much as the two causes listed above.

On this packing line, dumping was done mechanically, sorting took place at a roller table, and size was determined by a weight-type sizer.

Damage was inflicted on 15.2 percent of the apples, when they had an average resistance of 14.2 pounds on a Magness-Taylor pressure gage. Of the bruised apples, 14.1 percent had only slight bruising, and 1.1 percent had bruising to a moderate degree. About 50 percent of the bruising that occurred came from the chain eliminator, and 40 percent from the singulator-sizer. The remaining 10 percent was divided between the dumping and sorting operations.

One item of equipment—the chain eliminator—was responsible for half of all the bruising that occurred on this line, and it was not even a major equipment item. The chain eliminator could have been removed completely, or replaced with one made of rubber. If the eliminator were removed, the small apples could be taken out by the sizer. Careful adjustment of the singulator and sizer would have reduced the bruising that occurred here. Even if this bruise reduction were small, it would be a net gain, since there would be no cost at all in achieving it.

Sorting

Where sorting is done at a sorting table, the quality of work is affected by a number of factors: (1) Dumping rate, (2) quality of orchard-run fruit, (3) experience of sorters, (4) number of sorters, and (5) number of grades the fruit is sorted into, and others. These factors become less important where packers do their own sorting. Where sorting was done at a sorting table the packing operation set the pace, and sorters had to keep up with it. Thus a change in any of the factors listed also changed the percentage of off-grade apples that were packed, unless some compensating change was also made. Such a change

TABLE 4.—Labor and equipment required to dump, sort, size, and pack 1,000 containers of apples daily by use of mechanical dumper, reverse-roll sorting table, weight sizer, and manual packing from a return-flow belt ¹

Operation	Labor Required		Cost		
	Workers	Man-hours	Labor ²	Equipment ³	Total
	Number		Dollars	Dollars	Dollars
Dumping.....	1	1.90	2.38	⁴ 10.83	13.21
Sorting.....	6	52.16	65.20	⁵ 3.78	68.98
Sizing.....				⁶ 30.61	30.61
Packing.....	⁷ 4	34.76	43.45	⁸ 23.82	67.27
Total.....	11	88.82	111.02	69.04	180.06

¹ 560 containers were cell-packed cartons, and 440 were jumble-filled crates. 1.14 field crates were dumped for each container packed.

² Based on \$1.25 per hour per worker.

³ Based on 50,000 crates dumped annually.

⁴ Includes one 20-foot friction chain conveyor, one mechanical dumper, one spreader belt, and one eliminator.

⁵ One reverse-roll sorting table.

⁶ Includes one 6-cup weight sizer with take-away belts, one spreader belt, and two 25-foot distributor belts.

⁷ Three tray packers, and one to jumble-fill utilities.

⁸ Includes one 60-foot return-flow belt, seven power shunts, three packing stands and one 90-foot wheel conveyor.

was usually in the dumping rate, or in the number of sorters used.

The sorting table in this packing line was the same type as that in the packing line using the drum dumper and dimension sizer, and it was as a part of that line that the sorting table was tested.

When more sorters were used, fewer below-grade apples were packed. Six sorters removed enough culls and utility-grade apples to reduce the amount of such fruit to only 6.7 percent of the packed apples. Where apples were sorted from lanes, the amount of offgrade fruit packed was reduced even further. This sorting record was accomplished at a dumping rate of 160 boxes per hour, or 1,280 boxes per 8-hour workday. Results of these tests are shown in table 5.

TABLE 5.—Utility grade fruit packed as U.S. Fancy by four and six sorters, when lanes were not used¹

Number of sorters	Dumping rate	Utilities and culls in orchard-run fruit	Utilities left in run-off fruit after sorting
	<i>Boxes per hour</i>	<i>Percent</i>	<i>Percent</i>
4-----	167	22.9	10.0
6-----	160	25.0	6.7

¹ Effectiveness of sorting was increased by 18 percent when lanes were used.

Sizing

The weight-type sizer discussed here separated apples within the middle-size groups (100-160 count), with a relatively high degree of accuracy, but with less accuracy in the extremely large or small (180 and 80 count). This is illustrated in table 6.

Since sizes 180 and 80 together seldom total 10 percent of the apples packed, the evaluation of this sizer must center on the more common sizes, 100 through 160 count. For apples within this middle-size range, 91 percent were sized to within $\frac{1}{8}$ inch of the correct diameters, and all of the apples were within $\frac{1}{4}$ inch of their true sizes; the "over" and "under" size apples were of approximately equal number. This was accuracy of a high order; in fact, it is questionable if more accurate sizing than this would serve any real purpose.

ALL-MANUAL SORTING, SIZING, AND PACKING

An all-manual method is a common way of sorting, sizing, and packing apples in New England. Probably this method is used by more packing-house operators than any other—either as the only method for packing apples, or to supplement an-

TABLE 6.—Accuracy of sizing by weight-type sizer

Apples packed in carton	Standard diameter	Sized apples whose diameters were—		
		Within $\frac{1}{8}$ inch of standard	Within $\frac{1}{4}$ inch of standard	More than $\frac{1}{4}$ inch from standard
<i>Size</i>	<i>Inches</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
180-----	$2\frac{1}{4}$	49	93	7
160-----	$2\frac{1}{2}$	89	100	-----
140-----	$2\frac{5}{8}$	94	100	-----
120-----	$2\frac{3}{4}$	82	100	-----
100-----	3	100	100	-----
80-----	$3\frac{1}{4}$	71	97	3

Conclusions

Mechanical dumping, sorting at a roller table, weight sizing, and manual packing from a return-flow belt, together make an efficient packing line operation. The mechanical dumper requires only a small part of one man's time; sorting is done more accurately at a sorting table than when it is done concurrently with other work; weight sizing is almost as precise as any other method of dividing apples into sizes; and packers achieve their greatest productivity when they can pack without also sorting and sizing the fruit.

Effect of Volume

The high initial cost of the equipment that accompanies this line places it at a cost disadvantage at low-volume levels. When only 25,000 crates are handled annually with this packing equipment, essentially the same items of equipment are needed as when a volume of 75,000 crates or more is handled annually. The number of workers increases as volume increases, but not in proportion to the increase in volume. Unit cost decreases as the scale of operation increases, with the greatest saving occurring in the equipment costs. Labor requirements and costs for annual volumes of 25,000, 50,000, and 75,000 crates are shown in table 7.

The capacity of this packing line was greater than 1,000 crates daily, and its inherent advantages are realized only as the volume of apples packed approaches the capacity of the equipment.

other method. Many operators feel that apples must be treated entirely by manual means after a period of storage—that they are too soft and too easily bruised at this point to be subjected to a mechanical packing line.

TABLE 7.—Labor and equipment required to dump, sort, size, and pack apples by use of mechanical dumper, reverse-roll sorting table, weight sizer, and return-flow belt at three different volumes

Annual volume	Workers		Working days	Cost			Cost per packed container
	Number	Man-hours		Labor ¹	Equip-ment	Total	
25,000 field crates, or 21,930 packed containers.....	² 5	2, 840	<i>Number</i> 71	<i>Dollars</i> 3, 550	<i>Dollars</i> ³ 3, 009	<i>Dollars</i> 6, 559	<i>Cents</i> 29. 9
50,000 field crates, or 43,860 packed containers.....	⁴ 8	4, 544	71	5, 680	⁵ 3, 452	9, 132	20. 8
75,000 field crates, or 65,790 packed containers.....	⁶ 11	6, 600	75	8, 250	⁷ 3, 769	12, 019	18. 3

¹ Based on \$1.25 per hour.

² One dumper, two sorters, two packers.

³ Basic equipment costs are developed in table 22, appendix.

⁴ One dumper, four sorters, three packers.

⁵ Basic equipment costs are developed in table 23, appendix.

⁶ One dumper, six sorters, four packers.

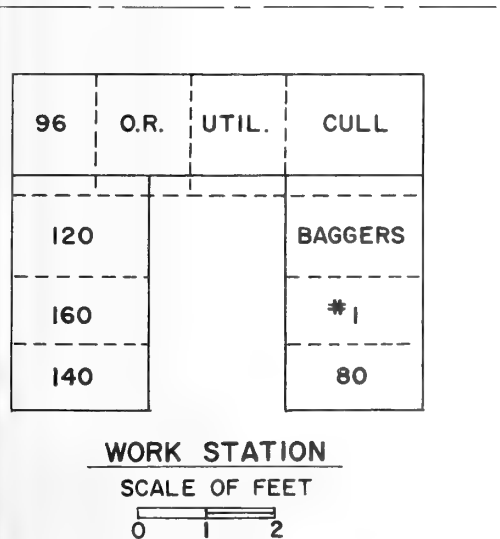
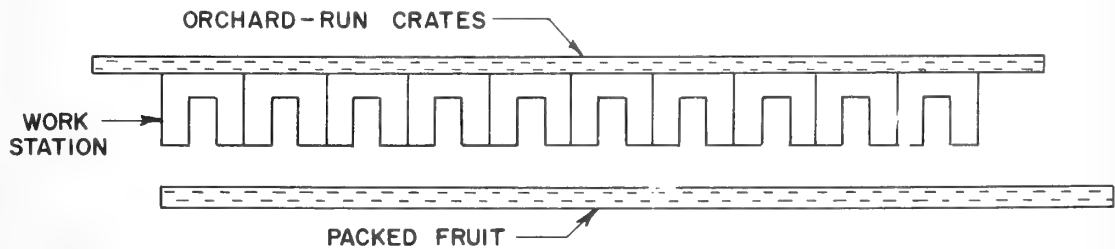
⁷ Basic equipment costs are developed in table 24, appendix.

Description of Operation

Sorting, sizing, and packing were done at the same time, at the same workplace, and by the same person. A worker pulled a crate of orchard-run apples from a conveyor onto her work station, and then picked apples out of the crate one by

one and placed them in different containers on the work station. A layout common for this operation is shown in figure 10. Packing supplies were usually kept in racks over the conveyor that delivered orchard-run fruit to the workers.

Manual packing stations were all made in the plant, and showed considerable variation in both



MANUAL SORTING
MANUAL SIZING
MANUAL PACKING

ALL OPERATIONS PERFORMED
BY SAME WORKER

SCALE OF FEET
0 5 10

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FIGURE 10.—Layout of work station where apples are sorted, sized, and packed by the same worker.

their construction and manner of use. Still, one requirement of them all was that each worker determine for each apple which of four quality classifications it belonged in (Combination U.S. Extra Fancy and U.S. Fancy, U.S. No. 1, U.S. Utility, and cull), and that she decide into which of six size groups (80, 96, 120, 140, 160, baggers) to put those she had judged to be U.S. Extra Fancy or U.S. Fancy grade. Having made these determinations, the worker had to remember which of the nine containers about her received each apple. All of these decisions had to be made for each apple in every crate.

All-manual packing stations observed during the course of this study lacked adequate planning for the purpose they were to serve. This was shown in different ways: Packing supplies for all grades and sizes were mixed together and separated from the cartons they were used with; working heights were identical for all the stations in a packing line and not adjustable for the varying heights of individual workers; and cartons were arranged randomly about the workers, without regard for the sizes and grades of apples occurring most frequently² (fig. 11).

To pack apples as described here, the worker was constantly in motion. She had to reach across a tabletop to pull a full crate from the supply conveyor; she had to twist around to place an apple in its proper carton; she had to pick up full cartons from their crowded positions about the work area (often after first moving other, partially full cartons out of the way); she had to carry full cartons to a removal conveyor; and she had to reach over (or under) the removal conveyor for empty cartons. Most of these movements entailed either stretching or lifting of heavy containers; this type of work was unusually fatiguing.

An Evaluation of the Method

The capital outlay required to establish this method of sorting, sizing, and packing apples was

² An improved manual work station based on work simplification principles was designed by Maine Agricultural Experiment Station and U.S.D.A. researchers. Miscellaneous Publication No. 641, "An Improved Work Station for the Manual Sorting, Sizing, and Packing of Apples," is available from the Maine Agricultural Experimental Station, University of Maine, Orono, Maine.



FIGURE 11.—Arrangement of typical manual sorting-sizing-packing station for apples. Note unorganized arrangement of packing supplies and containers.

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almost negligible (table 8). The only equipment necessary consisted of gravity conveyors, and wooden work stations, which could be made of unfinished lumber. Here labor replaced equipment, thus minimizing capital cost. Such complete and full reliance on a multiskilled labor force could well create its own problems: What if the labor supply suddenly changed? Or if the wage rate rose drastically? Or there was no room for additional work stations in case of increasing volumes? Or new regulations reduced tolerances on size and grade errors? These questions become paramount where reliance is placed entirely on each worker being skilled not only in the sorting, but also in the sizing and packing of fruit.

Labor and Equipment

With all of the packing lines studied, labor was a larger cost item than equipment. But with a manual sorting-sizing-packing line, labor accounted for 96 percent and equipment only 4 percent (table 8).

TABLE 8.—Labor and equipment required to sort, size, and pack 1,000 containers of apples¹ daily at manual work stations

Work element	Labor re-quired	Cost		
		Labor ²	Equip-ment ³	Total
	Man-hours	Dol-lars	Dol-lars	Dol-lars
Place pads and parti-tions and pack apples into cartons or crates	95.83	119.79	-----	-----
Remove filled con-tainers and replace with empties	6.33	7.91	-----	-----
Remove empty field-run crates and re-place with full crates	3.17	3.96	-----	-----
Total	105.33	131.66	4.96	136.62

¹ 560 containers were cell-packed cartons, and 440 were jumble-filled crates. 1.14 field crates were emptied for each container packed.

² Based on \$1.25 per hour.

³ 140 feet of gravity conveyor, and 8 work stations. Cost based on 50,000 crates per year.

To manually sort-size-pack 1,000 containers daily required 105.33 man-hours. This was equivalent to one packed container every 6.32 man-minutes, or 76 containers per worker per 8-hour workday. Containers refer to both tray-packed cartons and jumble-filled wood crates. Tray-packed cartons accounted for 56 percent, and jumble-filled crates 44 percent of the workers' production. From an average worker's daily production of 76 containers, 43 were tray-packed cartons, and 33 were crates jumble-filled with bagging

apples, ciders, culls, utility, or commercial grade apples.

The productive rate of those workers who sorted-sized-packed manually varied greatly; in fact, a worker packing twice as much as another worker on the same line was not unusual. Skill, dexterity, endurance, and self-confidence all helped determine the rate at which a packer worked, and were responsible for the wide differences found among workers. Also, there were wide differences in the number of grading and sizing errors occurring at different work stations.

Bruising

An all-manual operation for sorting-sizing-packing of McIntosh apples does not necessarily assure a high proportion of bruise-free apples in the packed containers, although that is the major reason for packing apples by an all-manual method. Comparisons of bruising between methods are always difficult because fruit samples are never identical. Nonetheless, some general conclusions are possible when the conditions of the tests are stated, and the test results have been carefully noted.

To test the bruising that occurred in packing with the manual method, nearly 1,000 bruise-free apples were selected and very carefully placed in field crates. These crates were delivered via a conveyor to a manual packing station much like the one in figure 11. A worker experienced in the manual method sorted and sized each apple, cell-packed the U.S. Extra Fancy and U.S. Fancy grades, and jumble-filled wood boxes with the other apples. As containers filled, he picked them up and carried them to a take-away conveyor. At the time these apples were packed under test conditions, they had a firmness of only 11.8 pounds; when they were inspected this firmness had dropped to only 10.3 pounds. The softness of the fruit could have been responsible for some part of the bruising that occurred (table 9).

Apples that were jumble-filled in wooden boxes were not handled as carefully as those that were cell-packed, and this undoubtedly accounted for their higher incidence of bruising. Bruising that did occur on cell-packed apples was probably caused by the forcing of apples into cells which were too small for them, and the constant pressure of a cell's walls against an apple's surface. Throughout the Northeast area, cartons were deliberately packed this way so that apples would be held snugly in their cells with no chance of rolling around while in transit. It is likely that a looser pack would cause some bruising from apples striking and rubbing against the cell walls, but many of the pressure bruises now occurring would be eliminated. Most of the bruising that was caused by cell-packing would have to be added to that recorded for the other packing lines, because cell-packing was not included in their bruise tests.

TABLE 9.—Amount and degree of bruising from a manual sorting-sizing-packing operation¹

Type of pack	Apples tested	Degree of bruising							
		None		Slight		Moderate		Severe	
	<i>Number</i>	<i>Number</i>	<i>Percent</i>	<i>Number</i>	<i>Percent</i>	<i>Number</i>	<i>Percent</i>	<i>Number</i>	<i>Percent</i>
Cell-pack:									
Size 96.....	43	23	53.5	10	23.2	6	14.0	4	9.3
Size 120.....	240	212	88.3	25	10.4	3	1.3		
Size 140.....	210	180	85.7	22	10.5	8	3.8		
Size 160.....	240	220	91.7	19	7.9	1	.4		
Total.....	733	635	86.6	76	10.4	18	2.5	4	0.5
Jumble-fill:									
Baggers.....	100	80	80.0	11	11.0	7	7.0	2	2.0
Utilities.....	40	36	90.0	3	7.5	1	2.5		
No. 1's.....	100	74	74.0	15	15.0	10	10.0	1	1.0
Total.....	240	190	79.2	29	12.1	18	7.5	3	1.2
Grand total.....	973	825		105		36		7	
Weighted average.....			84.8		10.8		3.7		0.7

¹ Firmness of fruit was 11.8 pounds when packed, and 10.3 pounds when inspected (measured by a Magness-Taylor pressure gage).

Sorting and Sizing

The degree to which apples are incorrectly sorted and sized in a completely manual operation depends almost solely on the abilities of individual workers. A packing line employing the manual method is no more than a battery of individual, independent work stations, and the sorting and sizing errors that occur at any given station are solely the responsibility of the individual working there. Thus, packed cartons were observed which held large numbers of incorrectly sorted and sized apples; others were virtually free of such fruit. These cartons were all a product of the same packing line, but the wide variation from packer to packer made a sampling of the off-grade and off-size apples impractical.

For the packing line as a whole, a comparatively wide range existed in the number of incorrectly sorted and sized apples in packed cartons. This range was greater than that which occurred with those packing lines on which sizing was done mechanically and sorting took place at a sorting table.

Conclusions

The all-manual method of packing apples has been popular in the New York-New England area for a long time. It is likely to be used for a long time to come. Low capital requirements plus low maintenance and operating costs have made it attractive to smaller packers, particularly those who operate farm sheds with family or local labor. Where the volume packed is comparatively small, and the packing rate is fairly constant, this can be an economical method of packing apples. Prob-

ably the greatest single requirement of this method is that the workers be skilled in determining grades and sizes, and that all the workers use the same benchmarks in making their grade and size determinations.

Research shows that the all-manual method does not produce a better-graded, closer-sized pack than other mechanized methods. Therefore, this most commonly given reason for manual sorting-sizing-packing is no longer valid, and it is expected that the demands of increasing volumes will more and more be met with installations of mechanized apple packing equipment.

Effect of Volume

Whether the volume packed grows greater or becomes smaller, the change has little effect on the unit cost of packing apples. This is true because, with this packing system, there is virtually no equipment cost, and the workers are free and independent of one another. Each worker sets her own production rate, and does not influence the rate of the other workers; nor is her own rate affected by the rate at which the others work. As long as there are full field crates of orchard-run apples on one of the conveyors, and room to place packed containers on the other conveyor, each worker can proceed independently of all other workers in the packinghouse.

When the volume of apples packed does change, workers can be either added or removed, or else those already available can work more or fewer hours. Changes in labor and equipment costs resulting from changes in the volume handled are shown in table 10.

TABLE 10.—Labor and equipment required to sort, size, and pack apples at manual work stations at three different annual volumes

Annual volume	Workers		Work- ing days	Cost			Cost per packed con- tainer
	Num- ber	Man- hours		Labor ¹	Equip- ment	Total	
<i>Number</i>			<i>Number</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Dollars</i>	<i>Cents</i>
25,000 field crates, or 21,930 packed containers	4	2,370	71	2,962.50	² 145.00	3,107.50	14.2
50,000 field crates, or 43,860 packed containers	8	4,620	71	5,775.00	³ 227.00	6,002.00	13.7
75,000 field crates, or 65,790 packed containers	12	6,930	75	8,662.50	⁴ 324.00	8,986.50	13.7

¹ Based on \$1.25 per hour.

² Basic equipment costs are developed in table 22, appendix.

³ Basic equipment costs are developed in table 23, appendix.

⁴ Basic equipment costs are developed in table 24, appendix.

It is not surprising that the unit cost remained practically unchanged through a volume range of 25,000 to 75,000 field crates annually, even though for all the other packing lines studied the cost per container decreased as the volume increased over this range. This characteristic is particularly significant for those operators who pack small volumes, and who would be the victims of high unit-equipment costs were they to use the more mechanized packing lines.

The major disadvantage of a manual line lies in this fixed-unit-cost characteristic: There is no way to increase the capacity of a packing line made up of individual manual packing stations except by adding more stations. Adding on work stations can create layout, materials flow, and space utilization problems capable of overcoming by a wide margin the advantage of low equipment cost that is a feature of the manual method of sorting-sizing-packing apples.

DRUM DUMPER AND REVERSE-ROLL SORTING TABLE, WITH DIMENSION SIZING AND PACKING FROM A RETURN-FLOW BELT

In 1958, this type of packing line was installed for the first time in an apple packinghouse in the New York-New England area. It was an experimental line, consisting of equipment items yet untested with McIntosh apples. The installation was designed to determine in what ways packing equipment developed elsewhere, and for other apple varieties, could be used successfully with McIntosh apples. Thousands of apples were passed over the line, and then carefully examined to determine if they had been affected. Each component and each equipment item was tested and evaluated. The results of these tests have been published.³ Because this packing line was analyzed so thoroughly in the previous report, only its most distinctive aspects will be discussed here. Figure 12 is a layout of this line.

Dumping

A drum dumper tipped apples out of field crates onto a spreader belt (fig. 13). With this equipment, very little labor was required in the dumping

operation. A worker had only to load the friction-chain conveyor with some 20 field crates, and he was then free to work elsewhere in the plant until it was time to fill the conveyor again. Both the feeding of crates containing field-run apples into the dumper and their removal as they became empty were done mechanically. Only a small portion of one man's time was necessary in this operation.

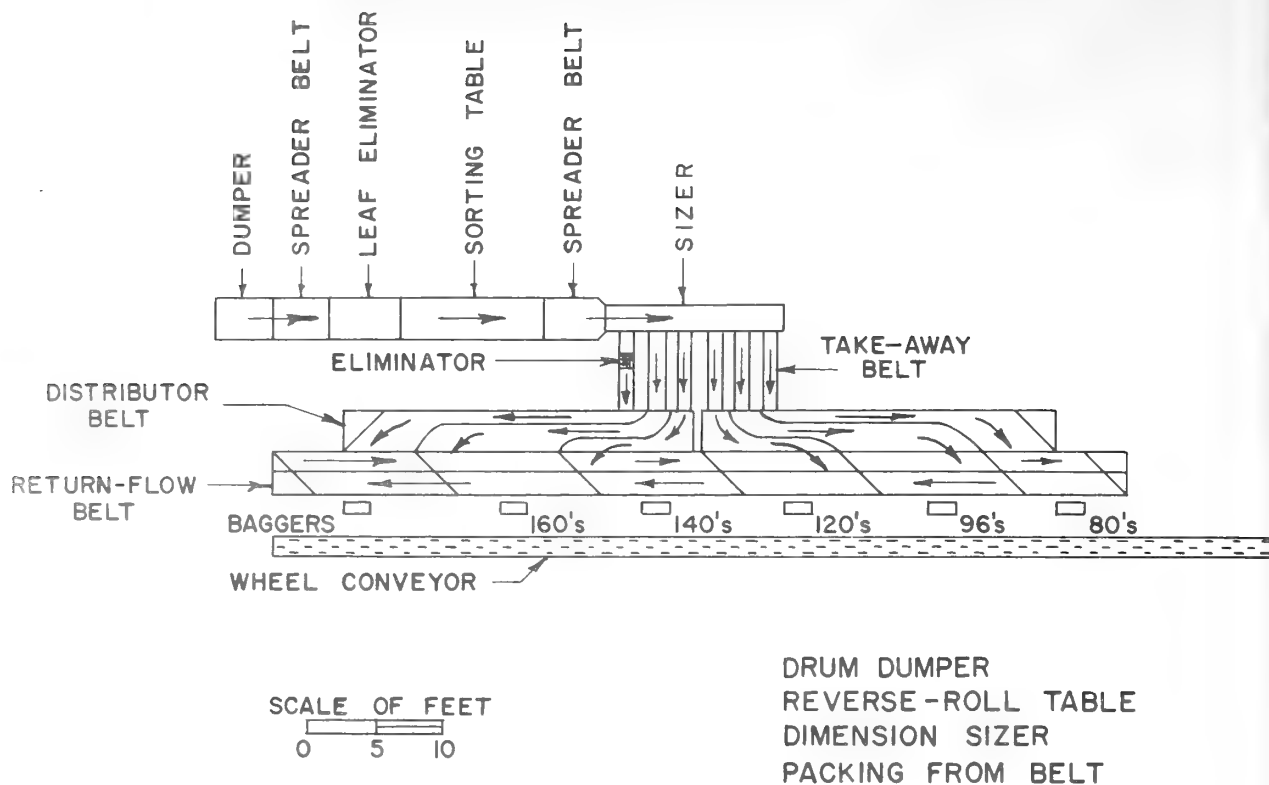
Empty crates dropped a few inches from the dumper onto a gravity conveyor. When a number of crates had accumulated on this conveyor they were removed (usually by the worker supplying apples to the dumper), nested, and stacked out of the way.

The dumping rate was adjustable up to 600 crates an hour. Once set, the dumper did not deviate, but operated at a steady, constant rate. The capacity of the dumper was much greater than that of other components of the line.

Sorting

Sorting of the fruit took place at a table the surface of which consisted of 2 $\frac{3}{8}$ -inch rubber-covered aluminum rollers spaced 3 inches on

³ Burt, S. W. An Experimental Packing Line for McIntosh Apples. U.S. Dept. Agr. AMS No. 330, 28 pp., illus. 1959.



BN-14257-X

FIGURE 12.—Layout of apple packing line, including drum dumper, reverse-roll sorting table, and dimension sizer, with packing stand placed at a return-flow belt.



BN-10014

FIGURE 13.—Drum dumper for tipping apples out of field crates onto a spreader belt.

center. The movement of these rollers could be adjusted to change both the rate at which apples were carried past the sorters, and the rate at which they were made to rotate as they moved forward. Thus, it was possible to achieve any desired combination of translation and rotation rates.

The table surface was well lighted by fluorescent lamps, and cull chutes were placed along its side—one for each sorter (fig. 14). Conveyors over the table carried away those apples picked out by sorters. They were usually the utility or No. 1 grade apples and were jumble-filled into crates by an automatic box filler.

This sorting table was divided into lanes by plastic-covered clotheslines 4 inches apart and running the length of the sorting table. Each sorter was assigned one lane, and it was her responsibility to sort all the apples in that lane. In this way each apple was seen by only one sorter, but there was greater assurance that every individual apple would be inspected. Where lanes were not used, some apples would be inspected several times, and others would be passed over with hardly a glance. In addition to distributing the workload evenly, sorting lanes (1) increased the number of apples that could be sorted, (2) eliminated duplication of work, (3) made each sorter directly responsible for her work, and (4) made it possible to check the work of each sorter. Tests conducted on this table, and others elsewhere, proved conclusively the value of sorting from individual lanes.⁴

⁴ Hunter, D. L., Kafer, F., and Meyer, C. H. Apple Sorting Methods and Equipment. U.S. Dept. Agr. Mktg. Res. Rpt. No. 230, 23 pp., illus. 1958.



BN-15286

FIGURE 14.—Reverse-roll sorting table for apples. Note cull chutes and lane dividers.

When apples left the sorting table they were carried under a brusher, and spilled off the rollers onto a spreader belt. This belt delivered the fruit to the sizer.

Sizing

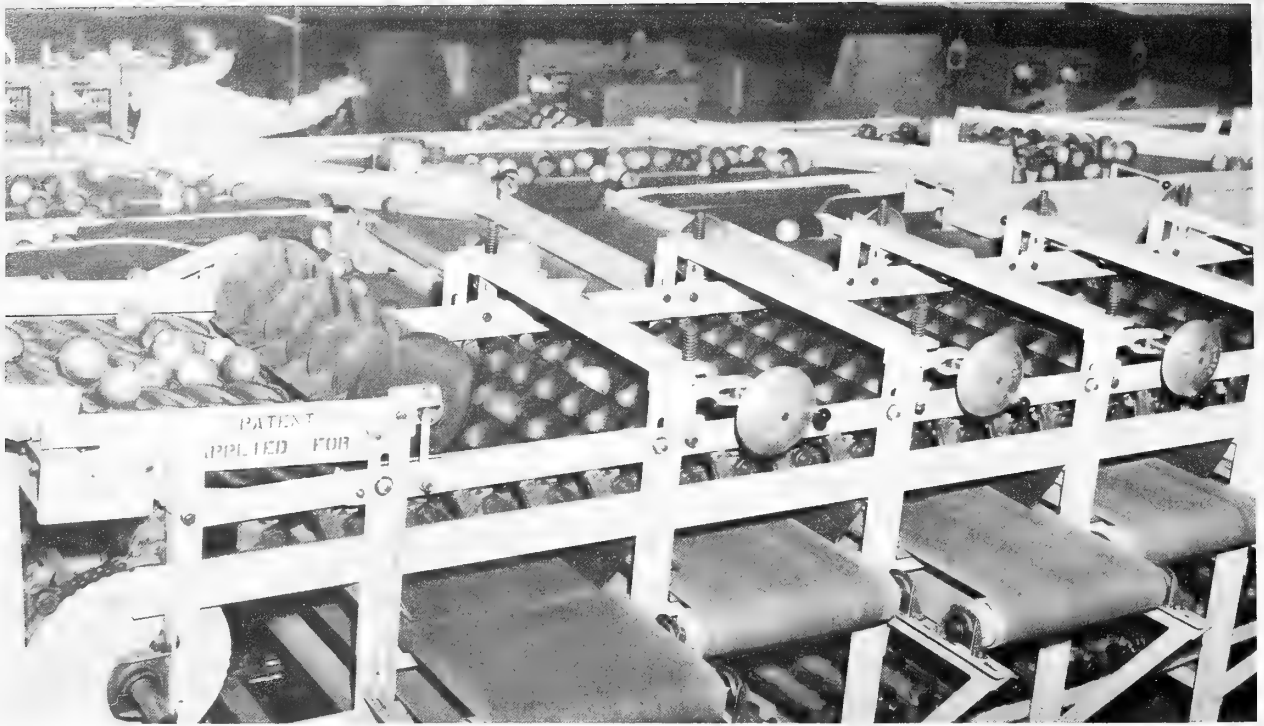
The dimension sizer did not always measure an apple's maximum diameter along the stem-calyx axis, as required by official standards. More often than not, an apple would be measured along some other axis, depending on the position of the apple when it came to rest in a sizing cup. This was a failing which applied to other mechanical sizers as well.

Included as part of the sizer were a singulator and six take-away belts, one belt for each size packed (fig. 15). The singulator was adjusted to deposit only one apple in each cup. As the sizing cups moved forward their hemispheres gradually spread apart until at some point the apple fell through; that point determined its size classification. Falling through the cup, an apple dropped onto one of the six take-away belts. Each take-away belt delivered its apples to a particular section of the return-flow belt, from which the fruit was packed.

Packing

Apples came to the packers already sorted and sized, so that the packers had only to put the fruit into containers. They did this without reinspecting or resizing individual apples, as was the more common practice in the New York-New England area. Packers did, however, remove any "wrong" apples they happened to see, but they were not on the lookout for them. This packing policy represented a considerable deviation from that generally in force, which was based on the premise that apples needed one last inspection to assure that only the minimum of below-grade and off-size apples was packed.

Because packers were not charged with the final inspection of the fruit, they were able to pick up and pack apples with both hands, and in this way more than double their output. Standing in front of a carton on a packing stand alongside the return-flow belt, a packer reached out with both hands and grabbed two or three apples in each; she then pivoted around, and deposited the apples in cells. When one layer was filled, she placed a pad and partition on top of the filled cells and continued packing. For the top layer in the car-



BN-7510

FIGURE 15.—Dimension-type sizer. Singulator places apples in sizer cups, and take-away belts remove them to their proper packing stations.

ton, a little additional time was spent arranging fruit so that most attractive sides of the apples were visible. The packer then lifted the full carton from its stand and placed it on a conveyor, which carried it to a lidding station. Having done this, she placed an empty carton on the packing stand, and repeated the operation.

An Evaluation of the Method

The method of using the equipment in this packing line was as important as the equipment itself in determining the unit cost of packing apples. This statement would apply in different degrees to all the packing lines studied, but it was particularly pertinent to the more mechanized lines. These are the packing lines that require higher capital investments, and which can be justified only if they result in increased productivity of the workers. Modern equipment is capable of high productivity, but increased worker productivity cannot be achieved by bringing old methods to new equipment.

Labor and Equipment

At an annual volume of 50,000 crates the cost for labor totaled \$100.15 and equipment \$72.67 per 1,000 packed containers (table 11). This is equivalent to a combined cost of 17.3 cents per container.

TABLE 11.—Labor and equipment costs to dump, sort, size, and pack 1,000 containers of apples daily by use of a drum dumper, reverse-roll sorting table, and dimension sizer with packing from a return-flow belt¹

Operation	Labor required		Cost ²		
	Workers	Man-hours	Labor ³	Equipment	Total
	Number		Dollars	Dollars	Dollars
Dumping-----	1	1.90	2.38	⁴ 10.05	12.43
Sorting-----	6	52.16	65.17	⁵ 3.78	68.95
Sizing-----				⁶ 27.54	27.54
Packing-----	3	26.08	32.60	⁷ 31.30	63.90
Total----	10	80.14	100.15	72.67	172.82

¹ 560 containers were cell-packed cartons, and 440 were jumble-filled crates. 1.14 field crates were dumped for each container packed.

² Based on 50,000 crates dumped annually.

³ Based on \$1.25 per hour per worker.

⁴ Includes one 20-foot friction chain conveyor, one drum dumper, one spreader belt, and one leaf eliminator.

⁵ One reverse-roll sorting table.

⁶ Includes one spreader belt, one dimension sizer, one eliminator, and two 25-foot distributor belts.

⁷ Includes one 60-foot return-flow belt, seven power shunts, three packing stands, one 90-foot wheel conveyor, and two semiautomatic box fillers.

Ten workers made up the crew: one dumped, six sorted, and three packed. The dumper also performed other jobs, such as stacking empty crates, bringing up full field crates to the dumper, and servicing automatic box fillers. The crew was capable of packing 1,000 containers (560 cell-packed cartons, and 440 crates jumble-filled by semiautomatic box fillers) in 8.7 hours; apples for 1,000 packed containers came from 1,140 field crates. By adding workers and increasing the speed of the components within the line, this rate of packing could have been increased considerably.

Sorting had the highest labor cost of any of the four packing line operations; it also had the greatest combined labor and equipment cost. Packing had the greatest equipment cost, and dumping cost the least. Together, sorting and packing accounted for 77 percent of the total packing line cost, but took 90 percent of the labor that was used. Consequently, these are the operations that should be examined first for ways to reduce costs and increase packinghouse efficiency.

Bruising

Bruising tests conducted on this packing line pointed out the striking importance of (1) careful synchronization of the components, and (2) careful padding of all places where apples may strike or rub against a hard surface. These two considerations were carefully checked in this packing line before any testing was done.

Each item of equipment was adjusted to carry apples away at a faster rate than the equipment received them. This prevented apples jamming up and pushing against other apples or the sides of the equipment, thus eliminating an important cause of bruising. Also, special care was taken to adjust the singulator so that it deposited apples properly in the plastic sizing cups. If this had not been done, considerable bruising would have occurred when the apples transferred from the singulator to the sizer. All potential contact points were covered with ¼-inch sponge rubber, and the distances that the apples dropped were minimized. Not until all these things had been done was the packing line tested to determine the amount and degree of bruising that would occur.

Bruising tests conducted here, and their results, are described in detail in a previous report.⁵ In general, there was very little bruising with this packing line. Two different lots of bruise-free apples (testing 17.0 and 14.5 pounds on a Magness-Taylor pressure tester) were set into the line at the dumper. After passing over the complete line, the apples were removed from the return-flow belt, held for 24 hours, and then inspected. The first lot, testing 17.0 pounds, showed only 1.4 percent of the apples to be bruised; the second lot,

testing 14.5 pounds, showed 2.3 percent of the apples to be bruised. With both lots the degree of bruising that did occur was slight.

The bruise testing so far described did not include that caused by cell-packing the fruit. Adding the bruises that occurred from cell-packing to those resulting from apples traveling over the line raised the bruise count considerably. In fact, 15.2 percent of a group of apples testing 11.8 pounds were bruised. (See discussion of manual sorting-sizing-packing line.) Of these, 4.4 percent were bruised to a moderate or severe degree.

Because of the difference in firmness of apples used in tests on the line and in cell-packing, there is no way to combine these bruise data and arrive at a total figure for this equipment and this method of packing apples. But all-in-all, sorting, sizing, and packing apples as it was done here was no more damaging to fruit than the other methods studied.

Sorting

In testing the accuracy of the sorting operation, samples were taken from a test lot of orchard-run fruit, and examined to determine the percentage of the apples that were below the grade being packed. This represented the percentage that should have been removed by the sorters. The test lot was then dumped onto the spreader belt by the drum dumper in the normal manner. During the test-run, samples were drawn from fruit removed by the sorters as being below packing grade, and other samples were taken from fruit that was passed by the sorters.

Four sorters removed only 56 percent of the apples that should have been removed; six sorters removed 73 percent. When four workers sorted, packed fruit contained 10 percent utility grade fruit; with six sorters, packed fruit contained 6.7 percent utility grade. When the table was divided into lanes, with each worker sorting from one assigned lane, sorting errors decreased 18 percent.

Many apples that were actually Fancy grade were classified by sorters as utilities. In fact, this happened frequently and consistently enough to warrant some corrective action by the management to reduce loss of revenue caused by misclassification.

Sizing

With each size group a range in diameter of ½ inch occurred, but four out of five apples fell within a ¼-inch range (table 12). In some cases this may be sufficiently accurate; in others it may not be. It is possible that closer adjustment of the sizer would have narrowed the range; but as long as apples continue to be sized along diameters selected purely by chance—as happened here—the amount of possible improvement is narrowly limited.

⁵ See footnote 3, page 21.

TABLE 12.—Accuracy of sizing by dimension-type sizer

Apples packed in carton	Standard diameter	Sized apples whose diameters were—		
		Within 1/8 inch of standard	Within 1/4 inch of standard	More than 1/4 inch from standard
Size	Inches	Percent	Percent	Percent
180-----	2 1/2	60	99	1
160-----	2 5/8	89	100	-----
140-----	2 3/4	81	100	-----
120-----	2 7/8	71	100	-----
100-----	3	83	100	-----
80-----	3 1/8	78	100	-----

Conclusions

The equipment in this packing line freed some workers for assignment elsewhere in the plant, and increased the productivity of workers who remained at the job. The worker who formerly dumped all apples manually was freed for other, more productive work; packers more than doubled their output of cell-packed cartons when they no longer had to reinspect the fruit. This packing line raised the productivity of the labor force over that associated with older, less efficient lines. This fact was perhaps its greatest single asset. Another was that it permitted an easy adjustment for changes in volumes dumped or packed. The packing line as constituted here had a capacity of about 2,000 crates dumped per day, and this rate could be achieved by simply speeding up

the equipment, and adding workers where they were needed. The packinghouse operator knew that his daily volume could fluctuate, within a wide volume range, without increasing the equipment required and without decreasing the efficiency of the workers. This gave him a degree of flexibility in operations that most other packinghouse operators did not have.

Effect of Volume

Labor and equipment costs for annual volumes of 25,000, 50,000, and 75,000 crates are in table 13. Twenty-five thousand crates per year is at the lower end of the volume scale, and here equipment represents 54 percent of the combined labor and equipment cost. As volume increased, equipment cost became a smaller portion of the combined cost. At 50,000 crates annually, equipment costs were 42 percent, and at 75,000 crates, equipment costs were only 35 percent. This packing line had a capacity of about 200,000 crates annually, and an increase in the volume of apples handled up to this capacity would decrease proportionately the unit cost as well as the percentage of the combined labor and equipment cost chargeable to equipment.

To increase the volume of apples packed it was necessary to add workers in numbers nearly proportional to the amount of increase. Thus, the unit cost for packing labor declined only slightly as volume increased, while the unit cost for equipment declined substantially. Any packing line as mechanized as this one must operate at a high volume if the advantages inherent in mechanization are to be realized.

SUPPLEMENTARY PACKING LINE OPERATIONS

A packing line incorporates four basic operations (dumping, sorting, sizing, and cell-packing). While these operations are responsible for the great majority of labor and equipment costs, in a total packing line there are other jobs that must be done before apples can leave the plant as a graded, sized, and packaged product. These jobs include: carton closing, tallying the pack, making cartons, boxing culls, and bagging apples.

Carton Closing

Cartons were closed at the end of the gravity conveyor, usually by hand-stapling or taping the lids. When a number of cartons had accumulated on the gravity conveyor (usually three to six) a worker pulled up the lid on each carton to form a cover over the apples. If the lid was to be stapled closed, this was done by using a hand stapler and setting two staples. If the box was not stapled, a strip of 4-inch sealing tape was

placed across the top flaps to seal the carton. Having closed the container, the worker stamped the grade, size, variety, and other pertinent information on the carton. Then he removed the carton from the conveyor and placed it in its proper stack for later removal.

Table 14 shows the labor and equipment costs for each method of closing cartons. Hand stapling required less time, and the stapler and staples cost less than the gummed tape. Both methods appeared to hold the lids securely.

Tallying

A record of each day's input and pack-out was essential. This was not a difficult record to keep, but it had to be kept accurately. This is why the "packed container" tally was assigned to someone in a position to see each container as it came from the packing line, and the "dumped crates" tally was kept by the worker who supplied crates to the

TABLE 13.—Labor and equipment required to sort, size, and pack apples by use of a drum dumper, reverse-roll sorting table, dimension sizer, and return-flow belt

Annual volume	Workers		Working days	Cost			Cost per packed container
	Number	Man-hours		Labor ¹	Equipment	Total	
25,000 field crates, or 21,930 packed containers.....	² 4	2, 272	<i>Number</i> 71	<i>Dollars</i> 2, 840	³ 3, 369	<i>Dollars</i> 6, 209	<i>Cents</i> 28. 3
50,000 field crates, or 43,860 packed containers.....	⁴ 7	3, 976	71	4, 970	⁵ 3, 634	8, 604	19. 6
75,000 field crates, or 65,790 packed containers.....	⁶ 10	6, 000	75	7, 500	⁷ 3, 959	11, 459	17. 4

¹ Based on \$1.25 per hour.

² One dumper, two sorters, one packer.

³ Basic equipment costs are developed in table 22, appendix.

⁴ One dumper, four sorters, two packers.

⁵ Basic equipment costs are developed in table 23, appendix.

⁶ One dumper, six sorters, three packers.

⁷ Basic equipment costs are developed in table 24, appendix.

TABLE 14.—Labor and equipment costs for closing 1,000 packed cartons of apples by two different methods

Method of closing	Labor required		Cost		
	Workers	Man-hours	Labor ¹	Equipment	Total
Push packed carton to closing station, hand-staple lids closed, stamp information on ends of cartons, and remove and stack cartons nearby.....	<i>Number</i> 1	9. 00	<i>Dollars</i> 11. 25	² <i>Dollars</i> 3. 13	<i>Dollars</i> 14. 38
Push packed cartons to closing station, tape-seal lids closed, stamp information on ends of cartons, and remove and stack cartons nearby.....	1	10. 81	13. 51	³ 4. 00	17. 51

¹ Based on \$1.25 per hour per worker.

² Includes one hand stapler plus \$2.90 for preformed staples.

³ 1,000 yards of gummed sealer tape.

packing line. The tally sheet itself was only a piece of paper with a column for each grade and size of apple packed. The tally-keeper placed a mark in the appropriate column for each carton packed and at the end of the day each column was totaled.

Some packinghouse operators preferred to wait until the day's work was over to take an inventory of packed cartons. This system was satisfactory as long as a careful count was kept of cartons that left the plant during the day.

Carton Making

In most packinghouses, size 80 apples were put into a carton specially designed for this size. Another carton served for sizes 100 and 120 and a third for sizes 140 and 160. Cartons were received and stored in bundles, and assembled by a worker using a motorized stitcher. Cartons were formed by stapling the bottom flaps together with 12 staples.

Table 15 shows the labor requirements and costs for forming and stapling 1,000 cartons. Two

workers reduced the elapsed time required, but increased the labor cost by 47 percent.

One worker needed to spend only a small part of his time making cartons to supply the day's needs. The rest of his time was free for bringing up apples, obtaining packing supplies, and helping to sort or pack apples. This man could move about the plant and apply his efforts where they were most needed, because it was possible for him to make up a large supply of cartons in advance.

Boxing Culls

The manner in which cull apples were boxed depended largely on how the fruit was sorted. Where sorting, sizing, and packing were done simultaneously the culls were usually collected in a box under the work table. When a box was filled the worker pulled it out from under the table and lifted the box up onto the gravity conveyor, which carried away the packed cartons. Then an empty box was placed under the table, and the process repeated.

TABLE 15.—*Labor and equipment costs for forming and stapling 1,000 fiberboard cartons on motorized stitcher by one and two workers*

Work method	Crew size	Elapsed time	Labor required	Cost		
				Labor ¹	Equip-ment	Total
	Number	Hours	Man-hours	Dollars	Dollars	Dollars
One worker performed all work elements.....	1	4.38	4.38	5.48	² 4.24	9.72
One worker removed flat carton from bundle, formed it into carton, and handed it to second worker who stitched bottom flaps and removed carton.....	2	3.22	6.43	8.04	² 4.24	12.28

¹ Based on a cost of \$1.25 per hour.

² Includes \$2.16 for wire staples (12 per carton).

When culls were removed by sorters, they were either placed in boxes beside the sorters, or set on a belt conveyor which carried them to a box. This box could be on a bench at the end of the conveyor, with apples dropping into it, or the box could be contained in an automatic box filler. In the former case a worker had to remove the box as soon as it filled (or apples would spill onto the floor) and set an empty box in its place. With an automatic box filler a supply of empty boxes was set in position at the beginning of the day, and two or three times during the day. The full boxes were removed and stacked at the same time that the empty boxes were restocked, and again at the end of the day. Beyond this, the box filler needed no attending.

Out of 700 field crates dumped in a day, an average of 30 boxes of culls may be expected. These could be handled easily by one of the regular workers assigned to that area, since it normally takes no more than 1 minute to replace a full box with an empty one. This is not a large part of a worker's time; however, this job must be done at frequent intervals, which could easily interfere with his other work.

Bagging

Apple packers in the Northeast bagged their apples in one of two ways. The operation could be performed manually with a worker placing apples in a bag by hand until the proper weight had been attained, or bags could be filled mechanically. The method used usually depended upon the volume of apples handled by the packing-house, and the relative importance of bags as a container for packed apples. When a significant part of the volume was bagged, it was customary to use bagging machines, which saved considerable time and labor. Studies showed that manually filling one bag with apples required 0.512 man-minute while with a bagging machine, only 0.318 man-minute was needed. This represents a saving of 38 percent in labor over the manual method of bagging apples. The cost of a bagging machine would reduce this saving; but by spreading this equipment cost over a number of bags the unit cost could be reduced sufficiently so that the mechanical method of bagging apples would still have the least total cost.

COMPARISON OF THE DIFFERENT PACKING LINES

The four principal types of packing lines used to pack apples in the Northeast have been discussed separately, and results of tests have been given. Tests conducted on each line measured (1) labor and equipment costs, (2) amount and severity of bruising to fruit, (3) accuracy of sorting, and (4) accuracy of sizing. These data are all necessary for accurate and complete comparisons of the different packing lines.

Such wide differences exist between packing-houses that direct comparisons between packing lines in existing packinghouses would have little meaning. Volumes handled, wage rates paid, and

quality of fruit packed were highly variable; to permit comparisons it was necessary to adjust all data to a standard set of conditions. Assumed operating conditions are described in the appendix. The wage rate was assumed to be \$1.25 per hour.

Labor and Equipment

Labor and equipment costs for four different types of apple packing lines were analyzed in this study. Their costs are presented in table 16.

Considering labor alone, the line employing the drum dumper and dimension sizer had the lowest unit cost (10.0 cents per packed container); the line with the mechanical dumper and weight sizer was next (11.1 cents per packed container); the all-manual method cost 13.2 cents per packed container; and the line using manual dumping and chain sizing had the highest labor cost of all (16.5 cents per packed container).

Should the wage rate increase, the difference in labor cost between the mechanized and the all-manual packing lines would become even greater. The one advantage a manual sorting-sizing-packing line has over the mechanized lines is its very low equipment cost, and this is a considerable advantage. If labor becomes difficult to hire or more costly, the advantage would then shift to the mechanical packing lines.

TABLE 16.—Labor and equipment required to dump, sort, size, and pack 1,000 containers of apples daily by use of four different packing lines. Annual volume, 50,000 crates

Packing line	Workers		Cost			Cost per packed container
	Number	Man-hours	Labor ¹	Equipment	Total	
Manual dumping and chain sizing with sorting and packing from a return-flow belt.....	16	132.00	Dollars 165.00	Dollars 44.16	Dollars 209.16	Cents 20.9
Mechanical dumping, sorting at a roller table, weight sizing, and manual packing from a return-flow belt.....	11	88.82	111.02	69.04	180.06	18.0
Sorting, sizing, and packing done by the same worker.....	13	105.33	131.66	4.96	136.62	13.7
Drum dumper and reverse-roll sorting table, with dimension sizing and packing from a return-flow belt.....	10	80.14	100.18	72.67	172.85	17.3

¹ Based on \$1.25 per hour.

Bruising

The packing of apples into cells was not included in the bruise studies, for the three mechanical packing lines. Cell-packing was included in studies of the manual line because it was done simultaneously with sorting and sizing. Therefore, bruising that occurred from cell-packing must be added to that caused by other components in the three mechanical packing lines.

A different lot of apples was used for each test, and it was impossible to keep the lots uniform. In one test the fruit registered only 11.8 pounds pressure on a Magness-Taylor pressure tester; in another the apples tested 16.0 pounds. These

readings can be equated to "soft" and "firm" fruit. Such differences in the fruit itself must temper any judgments as to the comparative merits of the packing lines. Table 17 presents the results of tests that were conducted. Probably the major conclusion to be drawn from these data is that the greatest single safeguard against bruising is close attention to elimination of bruise points on the packing line. Such attention was given to the line utilizing a drum dumper, reverse-roll sorting table, and dimension sizer; the result was that 98.2 percent of the apples tested over this line suffered no bruising at all. No special care was taken with the other lines, and the bruising was considerably greater.

TABLE 17.—Amount and degree of bruising from components of four different apple packing lines

Apple packing line, and operations tested	Firmness of fruit	Degree of bruising			
		None	Slight	Moderate	Severe
	<i>Pounds</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Manual dumping and chain sizing (packing not included).....	16.0	84.2	14.2	1.6	-----
Mechanical dumping, sorting at a roller table, and weight sizing (packing not included).....	14.2	84.8	14.1	1.1	-----
Sorting, sizing, and packing done by the same worker.....	11.8	84.8	10.8	3.7	0.7
Drum dumper and reverse-roll sorting table with dimension sizing (packing not included).....	15.8	98.2	1.8	-----	-----

Sorting

Sorting was done most efficiently where workers were assigned solely to this operation, and where they worked at a sorting table. Where sorting was combined with one or more other operations, the quality of workmanship was reduced for each operation. A worker could not concentrate on several tasks, and perform as well as a worker who had but one responsibility. This is illustrated in table 18.

Workers who both sorted and packed removed only 20 percent of the apples that should have been taken out; where workers sorted only, four sorters removed 56 percent and six sorters removed 73 percent of the culls and utilities from the orchard-run apples. Where workers sorted, sized, and packed, the effect was even greater. In fact, there were such extreme differences in the abilities of individual workers that this as a method of sorting could not really be evaluated; the evaluation was of the individual worker, rather than of a method of sorting.

TABLE 18.—*Utility and cull grade apples that were removed from field-run fruit by different sorting methods*

Sorting method	Utility and cull grade apples in mix—	
	Before sorting	After sorting
	Percent	Percent
Workers both sort and pack apples from return-flow belt.....	15.0	12.0
Workers sort apples at reverse-roll sorting table:		
Four workers.....	22.9	10.0
Six workers.....	25.0	6.7

Probably the most significant conclusion to be drawn from the testing that was done is that the best sorting was by workers who specialized in this job, and the worst by those who performed other operations as well.

Sizing

Chain sizers are not adjustable, nor do they get out of adjustment. The weight- and dimension-type sizers are adjustable, and their accuracy was in part dependent on how well they were adjusted, and whether the correct adjustment was maintained. Where sizing was done manually in conjunction with other operations the accuracy of sizing depended on the capability of the worker.

There was no way to control or adjust sizing when it was done manually, and any attempt to measure it became a measurement of an individual's performance. From observation it appeared that there was a wider variation in sizing with the manual method than when some mechanical means were used.

Table 19 presents the degree of sizing accuracy found with the three mechanical sizers in this study. The differences among these sizers are not great enough to declare one clearly superior to the others for the accuracy with which it sizes apples. It is probable that the extent to which the weight- and dimension-type sizers are kept in adjustment will determine their degree of accuracy in sizing apples, but there is no way to either increase or lessen the accuracy of chain sizers.

TABLE 19.—*Accuracy of sizing by different types of apple sizers*

Type of sizer	Sized apples whose diameters were—		
	Within $\frac{1}{8}$ inch of standard	Within $\frac{1}{4}$ inch of standard	More than $\frac{1}{4}$ inch from standard
	Percent	Percent	Percent
Chain.....	73	98	2
Weight.....	81	98	2
Dimension.....	79	100	-----

Effect of Changes in Volumes and Wage Rates

It makes little difference with the all-manual packing line what volume of apples is packed—the unit cost remains virtually unchanged. A manual station for sorting, sizing, and packing apples costs very little, and has an almost insignificant effect on the total cost of packing apples (table 20). As volume packed increases additional packing stations are placed in the line, and more workers are hired to man them. This tends to hold the unit cost nearly constant. At \$1.25 per hour the unit cost is 12.4 cents when the volume is 25,000 crates annually. When this volume is tripled the unit cost is reduced only 0.4 cent to 12.0 cents per crate. Even at different wage rates, the scale of operation has little effect on the unit cost of sorting, sizing, and packing apples by an all-manual method. For example, at \$3 per hour for labor, it cost 29 cents per crate when 25,000 crates were dumped annually and 28.1 cents when the annual volume was 75,000 crates. Table 21 shows how the unit cost is affected by both changing volumes and changing wage rates for each of the packing lines discussed.

TABLE 20.—Cost of dumping, sorting, sizing, and packing apples by use of four different packing lines at different annual volumes

Packing line	25,000 crates annual volume				50,000 crates annual volume				75,000 crates annual volume			
	Work-ers	Cost		Total	Work-ers	Cost		Total	Work-ers	Cost		Total
		Labor ¹	Equip-ment ²			Labor ¹	Equip-ment ³			Labor ¹	Equip-ment ⁴	
Manual dumping and chain sizing with sorting and packing from a return-flow belt-----	Number 6	Dollars 3, 817. 50	Dollars 1, 998. 00	Dollars 5, 815. 50	Number 11	Dollars 7, 771. 25	Dollars 2, 208. 00	Dollars 9, 979. 25	Number 15	Dollars 10, 982. 50	Dollars 2, 353. 00	Dollars 13, 335. 50
Mechanical dumping, sorting at a roller table, weight sizing, and packing from a return-flow belt-----	5	3, 550. 00	3, 009. 00	6, 559. 00	8	5, 680. 00	3, 452. 00	9, 132. 00	11	8, 250. 00	3, 769. 00	12, 019. 00
Sorting, sizing, and packing all done by the same worker-----	4	2, 962. 50	145. 00	3, 107. 50	8	5, 775. 00	227. 00	6, 002. 00	12	8, 662. 50	324. 00	8, 986. 50
Drum dumper and reverse-roll sorting table with dimension sizing and packing from a return-flow belt-----	4	2, 840. 00	3, 369. 00	6, 209. 00	7	4, 970. 00	3, 634. 00	8, 604. 00	10	7, 500. 00	3, 959. 00	11, 459. 00

¹ Based on \$1.25 per hour.

² Table 22, appendix.

³ Table 23, appendix.

⁴ Table 24, appendix.

TABLE 21.—*Cost per crate for labor and equipment to dump, sort, size, and pack apples at different volumes and different wage rates*

Packing line	Hourly wage rate	Cost per crate when annual volume is—		
		25, 000 crates	50, 000 crates	75, 000 crates
Manual dumping and chain sizing with sorting and packing from a return-flow belt.....	<i>Dol-</i>			
	<i>lars</i>	<i>Cents</i>	<i>Cents</i>	<i>Cents</i>
	0. 75	17. 2	13. 8	11. 9
	1. 00	20. 2	16. 8	14. 8
	1. 25	23. 3	20. 0	17. 8
Mechanical dumping, sorting at a roller table, weight sizing, and packing from a return-flow belt.....	1. 50	25. 7	23. 1	20. 7
	3. 00	44. 6	41. 7	38. 3
	0. 75	20. 6	13. 7	11. 6
	1. 00	23. 4	16. 0	13. 8
	1. 25	26. 2	18. 3	16. 0
Sorting, sizing, and packing all done by the same worker.....	1. 50	29. 1	20. 5	18. 2
	3. 00	46. 1	34. 1	31. 4
	0. 75	7. 7	7. 4	7. 4
	1. 00	10. 1	9. 7	9. 7
	1. 25	12. 4	12. 0	12. 0
Drum dumper and reverse-roll sorting table, with dimension sizing and packing from a return-flow belt.....	1. 50	14. 8	14. 3	14. 3
	3. 00	29. 0	28. 2	28. 1
	0. 75	20. 3	13. 2	11. 3
	1. 00	23. 0	15. 2	13. 3
	1. 25	24. 8	17. 2	15. 3
	1. 50	27. 1	19. 0	17. 3
	3. 00	40. 7	31. 1	29. 3

The all-manual packing line does have a major disadvantage: Volume packed can be increased only by setting up additional work stations, and by hiring new help. This characteristic of the method can create at the same time space utilization problems within the packinghouse, and problems of finding and supervising the workers. Not many packinghouses in the Northeast have the room for additional packing stations, to say nothing of room for the other packinghouse operations that would have to be enlarged with an expanding volume. New workers often have con-

cepts of apple grades and sizes that differ from those of management's, and changing these concepts can be a slow and difficult process. When a packinghouse outgrows the all-manual method of packing apples, the operator must go to a mechanized packing line.

Manual dumping and chain sizing with sorting and packing from a return-flow belt has more disadvantages than the other two mechanized lines: The labor cost is high, chain sizers are damaging to the fruit, sorting is not performed well, and rising wage rates tend to place it at an even greater disadvantage. Also, the capacity of this packing line is less than that of the other two mechanized lines. However, it does have a lower equipment cost which could be an important advantage, particularly when small volumes are packed; but at all volume levels a larger crew was required than for any other method studied.

There was no significant difference in the combined labor and equipment cost between: (1) The packing line employing mechanical dumping, sorting at a roller table, weight sizing, and packing from a return-flow belt, and (2) the packing line employing a drum dumper and reverse-roll sorting table with dimension sizing and packing from a return-flow belt. The former had a higher labor cost at each volume level because an extra worker was assigned to jumble-fill utility and cull grade apples; the latter line had a higher equipment cost at each volume level because semi-automatic box fillers were used for utility and cull grade apples. Each of these two packing lines had a relatively high capacity—as much as 2,000 boxes per day. This is considerably more than could be expected with either the all-manual or chain-sizer method.

The advantages of mechanized packing lines increase with increasing wage rates and greater volumes packed. If the rate for labor and the volume packed become great enough, the saving in labor from mechanized packing will overcome the cost of owning and operating the necessary equipment. This combination occurs at an annual volume of about 100,000 crates and a wage rate of \$3 per hour. However, it is almost inevitable that limitations of the all-manual method will force a conversion to mechanization long before this combination of volume and wage rate is reached.

APPENDIX

Methodology

Each type of packing line was observed over a sufficient period to permit an accurate recording of the different packing costs involved. Studies were made of crew size; work assignments; volumes dumped, packed, and sorted into each grade; transportation distances; plant layout; and other pertinent considerations. Time studies were made of operations in the packing line, and the productivity of each worker was determined. Productivity rates of individual workers were adjusted, where necessary, to bring them into line with the productivity of average workers. This was necessary so that comparisons between lines would be based on methods and equipment only, and would not reflect the levels of productivity of individual workers. These levels varied considerably between packing lines.

To compare efficiencies of the lines studied it was necessary to assume certain operating conditions. These were:

1. Annual volume was 50,000 field crates.
2. 700 crates daily.
3. 70 percent of the fruit was cell-packed, 10 percent was bagged, and 20 percent was collected in field crates.
4. All U.S. Extra Fancy and U.S. Fancy grade apples were cell-packed.
5. All U.S. Utility grade and cider apples were jumble-filled into crates.
6. 12 percent "line loss" (for example, for each crate only 0.88 packed container was received from the line).

Adjusting all the operating costs to a set of standardized conditions makes it possible to present costs and efficiencies of the lines on a comparable basis.

Criteria for Evaluating Bruise Damage

Bruises were classified as slight, moderate, or severe. This permitted the extent of each bruise as well as the number of bruises to be tabulated. A definition of each bruise classification as used in this study appears below:

Slight Bruising—(applies to U.S. Extra Fancy Grade)

- a. Bruises of slight depth (not over $\frac{1}{8}$ "') with a single bruise exceeding $\frac{1}{2}$ "' in diameter or an aggregate area of bruises exceeding $\frac{3}{4}$ "' in diameter.
- b. Bruises of lesser area but more than slight depth or soft.

Moderate Bruising—(applies to U.S. Fancy and U.S. No. 1 Grades)

- a. Bruises of moderate depth (not over $\frac{1}{4}$ "') with a single bruise exceeding $\frac{3}{4}$ "' in diameter or an aggregate area of bruises exceeding 1" in diameter.
- b. Bruises of lesser area but more than moderate depth or soft.

Serious Bruising—(applies to U.S. Utility Grade)

- a. Bruises that are of more than moderate depth (over $\frac{1}{4}$ "') with a single bruise exceeding 1" in diameter or an aggregate area of bruising exceeding $1\frac{1}{4}$ "' in diameter.
- b. Bruises of lesser area that are deep or soft enough to affect the quality of the apple.

NOTE.—The terms are applied to individual specimens and based on medium-size apples (125 to 160 count or $2\frac{5}{8}$ "' to 3" in diameter); greater or lesser amounts are allowed according to the sizes of the apples.

Computing Labor and Equipment Costs

A wage rate of \$1.25 per hour was assumed for all workers included in the study. These workers were: Dumpers, sorters, packers, baggers, carton makers, and carton sealers. The cost of management personnel, foremen, storage workers, and others not directly assigned to a packing line operation is excluded.

Equipment costs presented in tables 22, 23, and 24 are those that a packinghouse operator could expect to pay for the equipment delivered to and installed in his facility. The purchase price of a piece of equipment can be expected to vary over time and between customers. To that extent the costs shown here should be considered approximations.

TABLE 22.—Cost of apple packing equipment in the New York-New England area—1961,¹ 25,000 bushels per year

Equipment	Initial cost per unit	Ex-pected life	Ownership cost				Operating costs			Total annual cost
			Depre-ciation	Interest ²	Insur-ance and taxes at 4%	Total	Power ³	Main-tenance	Total	
	Dollars	Years	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Sizer chain.....	200	14	14.28	5.00	8.00	27.28	19.15	3.00	22.15	49.43
Spreader belt.....	350	14	25.00	8.75	14.00	47.75	12.70	10.00	22.70	70.45
60' return-flow belt.....	3,000	14	214.28	75.00	120.00	409.28	16.60	30.00	46.60	455.88
Packing stand.....	50	18	2.78	1.25	2.00	6.03				6.03
Gravity conveyor (10' section).....	100	18	5.56	2.50	4.00	12.06		1.00	1.00	13.06
Drum dumper.....	1,700	14	121.43	42.50	68.00	231.93	12.70	25.00	37.70	269.63
Wooden roller sorting table.....	1,000	14	71.43	25.00	40.00	136.43	20.90	15.00	35.90	172.33
6-cup weight sizer.....	6,400	14	457.14	160.00	256.00	873.14	24.90	80.00	124.90	953.14
Manual packing station.....	20	17	1.18	.50	.80	2.48		1.00	1.00	3.48
Box filler.....	1,100	14	78.57	27.50	44.00	150.07	6.80	10.00	16.80	166.87
Reverse-roll sorting table.....	1,600	14	114.28	40.00	64.00	218.28	20.90	15.00	35.90	254.18
Dimension sizer.....	4,800	14	342.86	120.00	192.00	654.86	24.90	80.00	104.90	759.76
25' distributor belt.....	1,050	14	75.00	26.25	42.00	143.25	12.65	10.00	22.65	165.90
Power shunt.....	250	14	17.86	6.25	10.00	34.11	36.85	2.00	38.85	72.96
Friction chain conveyor.....	180	14	12.86	4.50	7.20	24.56	5.35	2.00	7.35	31.91
Leaf eliminator.....	550	14	39.28	13.75	22.00	75.03	2.70	3.00	5.70	80.73
Chain eliminator.....	475	14	33.93	11.88	19.00	64.81	8.20	3.00	11.20	76.01
Manual stapler.....	65	14	4.64	1.62	2.60	8.86		3.00	3.00	11.86
Mechanical dumper.....	2,000	14	142.86	50.00	80.00	272.86	12.70	25.00	37.70	310.56

¹ Based on 568 hours of annual use.
² Computed at 5 percent of average investment.
³ Based on 2.7 cents per kilowatt hour.

TABLE 23.—Cost of apple packing equipment in the New York-New England area—1961,¹ 50,000 bushels per year

Equipment	Initial cost per unit	Ex-pected life	Ownership cost				Operating costs			Total annual cost
			Depre-ciation	Interest ²	Insur-ance and taxes at 4%	Total	Power ³	Main-tenance	Total	
	Dollars	Years	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Sizer chain.....	200	12	16.67	5.00	8.00	29.67	19.15	5.00	24.15	53.82
Spreader belt.....	350	12	29.17	8.75	14.00	51.92	12.70	15.00	27.70	79.62
60' return-flow belt.....	3,000	12	250.00	75.00	120.00	445.00	16.60	50.00	66.66	511.66
Packing stand.....	50	17	2.94	1.25	2.00	6.19				6.19
Gravity conveyor (10' section).....	100	18	5.56	2.50	4.00	12.06		1.50	1.50	13.56
Drum dumper.....	1,700	12	141.67	42.50	68.00	252.17	12.70	35.00	47.70	299.87
Wooden roller sorting table.....	1,000	12	83.33	25.00	40.00	148.33	20.90	20.00	40.90	189.23
6-cup weight sizer.....	6,400	12	533.33	160.00	256.00	949.33	24.90	110.00	134.90	1,084.23
Manual packing station.....	20	15	1.33	.50	.80	2.63		2.00	2.00	4.63
Box filler.....	1,100	12	91.67	27.50	44.00	163.17	6.80	17.00	23.80	186.97
Reverse-roll sorting table.....	1,600	12	133.33	40.00	64.00	237.33	20.90	20.00	40.90	278.23
Dimension sizer.....	4,800	12	400.00	120.00	192.00	712.00	24.90	110.00	134.90	846.90
25' distributor belt.....	1,050	12	87.50	26.25	42.00	155.75	12.65	15.00	27.65	183.40
Power shunt.....	250	12	20.83	6.25	10.00	37.08	36.85	3.50	39.85	76.93
Leaf eliminator.....	550	12	45.83	13.75	22.00	81.58	2.70	5.00	7.70	89.28
Friction chain conveyor.....	180	12	15.00	4.50	7.20	26.70	5.35	2.00	7.35	34.05
Chain eliminator.....	475	12	39.58	11.88	19.00	70.46	8.20	5.00	13.20	83.66
Manual stapler.....	65	12	5.42	1.62	2.60	9.64		2.00	2.00	11.64
Mechanical dumper.....	2,000	12	166.66	50.00	80.00	296.66	12.70	35.00	47.70	344.36

¹ Based on 568 hours of annual use.
² Computed at 5 percent of average investment.
³ Based on 2.7 cents per kilowatt hour.

TABLE 24.—Cost of apple packing equipment in the New York-New England area—1961,¹ 75,000 bushels per year

Equipment	Initial cost per unit	Expected life	Ownership cost				Operating costs			Total annual cost
			Depreciation	Interest ²	Insurance and taxes at 4%	Total	Power ³	Maintenance	Total	
	Dollars	Years	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Sizer chain.....	200	11	18. 18	5. 00	8. 00	31. 18	20. 20	7. 00	27. 20	58. 38
Spreader belt.....	350	11	31. 82	8. 75	14. 00	54. 57	13. 40	18. 00	31. 40	85. 97
60' return-flow belt.....	3, 000	11	272. 73	75. 00	120. 00	467. 73	17. 50	60. 00	77. 50	545. 23
Packing stand.....	50	15	3. 33	1. 25	2. 00	6. 58				6. 58
Gravity conveyor (10' section).....	100	15	6. 67	2. 50	4. 00	13. 17		2. 00	2. 00	15. 17
Drum dumper.....	1, 700	11	154. 54	42. 50	68. 00	265. 04	13. 40	40. 00	53. 40	318. 44
Wooden roller sorting table.....	1, 000	11	90. 91	25. 00	40. 00	155. 91	22. 00	22. 00	44. 00	199. 91
6-cup weight sizer.....	6, 400	11	581. 82	160. 00	256. 00	997. 82	26. 30	120. 00	146. 30	1, 144. 12
Manual packing station.....	20	13	1. 54	. 50	. 80	2. 84		2. 50	2. 50	5. 34
Box filler.....	1, 100	11	100. 00	27. 50	44. 00	171. 50	7. 20	20. 00	27. 20	198. 70
Reverse-roll sorting table.....	1, 600	11	145. 45	40. 00	64. 00	249. 45	22. 00	22. 00	44. 00	293. 45
Dimension sizer.....	4, 800	11	436. 36	120. 00	192. 00	748. 36	26. 30	120. 00	146. 30	894. 66
25' distributor belt.....	1, 050	11	95. 45	26. 25	42. 00	163. 70	13. 35	17. 00	30. 35	194. 05
Power shunt.....	250	11	22. 73	6. 25	10. 00	38. 98	38. 90	4. 00	42. 90	81. 88
Friction chain conveyor.....	180	11	16. 36	4. 50	7. 20	28. 06	5. 60	3. 00	8. 60	36. 66
Leaf eliminator.....	550	11	50. 00	13. 75	22. 00	85. 75	2. 90	6. 00	8. 90	94. 65
Chain eliminator.....	475	11	43. 18	11. 88	19. 00	74. 06	8. 60	6. 00	14. 60	88. 66
Manual stapler.....	65	11	5. 91	1. 62	2. 60	10. 13		2. 50	2. 50	11. 63
Mechanical dumper.....	2, 000	11	181. 82	50. 00	80. 00	311. 82	13. 40	40. 00	53. 40	365. 22

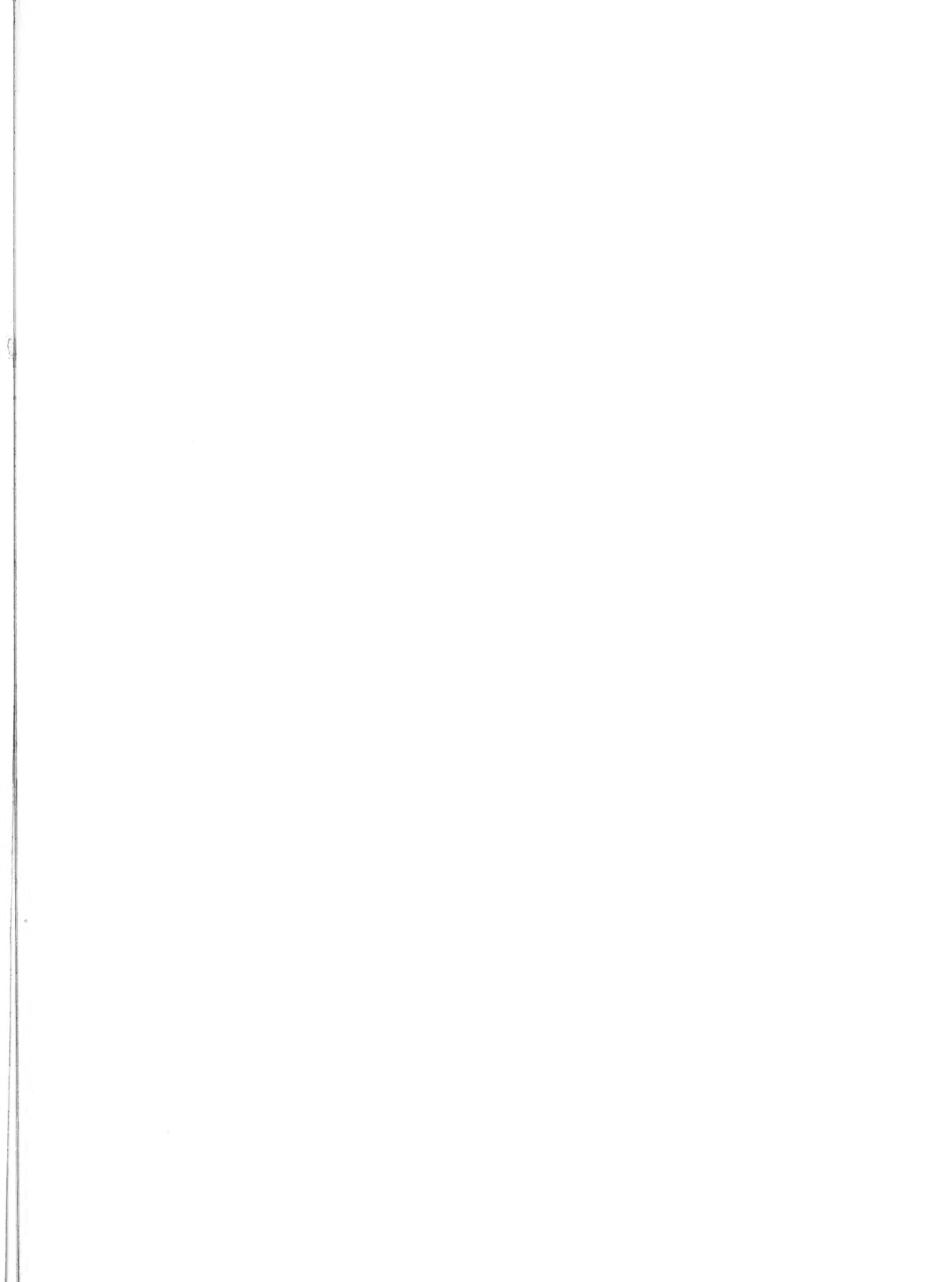
¹ Based on 600 hours of annual use.

² Computed at 5 percent of average investment.

³ Based on 2.7 cents per kilowatt hour.



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