RELATIONSHIPS BETWEEN PLANT SIZE AND COST OF PROCESSING FLUID MILK IN OREGON

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Introduction

Recent Changes in the Fluid Milk Processing Industry

The number and size of Oregon fluid milk processing plants has changed considerably during recent years. Many processors have quit or been absorbed by their competitors. Other dealers have expanded both in volume of business and in area served. The number of milk processors in Oregon in 1940 was 666. On January 1, 1957, the number was 151. Average size in pounds of butterfat processed for fluid purposes has increased from an average of 85,972 pounds per year in 1951 to 117,291 pounds per year for 1956.

Many reasons may be cited as influencing changes in the fluid milk processing industry. They may be classified either as influences that actively create internal pressures for expansion of a processing plant or as external developments that passively facilitate the growth of a dealer's operation.

The internal pressures created by rising fixed costs require greater plant output to reduce or maintain average unit costs. The size of investment required to operate a licensed plant has been increased by compulsory pasteurization laws and by health department specifications for sanitary equipment and plant facilities. Further increases in investment necessary to meet competition have accompanied the introduction of new products and containers. For instance, homogenized milk required additional machinery. Larger containers such as the gallon jug required an additional bottle washer and filler. The use of paper bottles required more costly bottle fillers. The development of more and better automatic equipment such as the HTST pasteurizer as well as rising labor costs and higher fixed costs from larger investment has increased the optimum size for a fluid milk processing plant. Larger container sizes also require an increased volume of milk to fully utilize the plant and crew designed to handle a given number of units.

Other food industry operators have reduced their costs through mechanization. These foods now compete more favorably with dairy products.

Dealers could not respond to the internal pressures to expand without commanding a larger share of their existing market area or pushing into outlying areas.

Expansion into outlying areas has been facilitated by a number of recent developments. The development of transportation facilities has been one of the foundations for dairy plant growth. Improved roads make regularly scheduled routes over long distances possible the year around. Mechanical perfections have produced more reliable and economical trucks, more dependable refrigeration equipment, and more effective insulation.

The introduction and acceptance of the paper carton has increased the optimum truck load and the optimum area that may be served by a plant. Milk in paper cartons weighs a third less and requires less space per case than milk in glass, stays cold longer, and does not require haulback of empty bottles (34, p.31).

Distribution patterns also have changed. General population growth and increasing urbanization of the country side surrounding work centers have produced larger concentrated market areas. The shift from home delivery to store sales has concentrated even more the distribution outlets for a plant.

Consumers have demanded higher and more uniform quality both in their selection at the market place and in their insistence upon more stringent health regulations and inspections. Quality improvements, in turn, have made longer hauls practical.

Decreasing numbers and increasing average size of producers has permitted the introduction and growing acceptance of bulk handling methods of procuring raw milk. Farm bulk pickup has allowed enlargement of a processing operation at but a fraction of the investment formerly required for a system of outlying can receiving and milk consolidation stations.

Finally, court action has tended to break rather than uphold trade barriers restricting free movement of milk.

The Need for Information

Processing plant operators have not fully responded to changing conditions in spite of the presence of internal pressures to grow and the development of external facilities for expansion. Vertical and horizontal integration in the industry, restrictive trade regulations, and elements of spacial monopoly have lessened the effectiveness of competitive forces in many market areas. Individual dealers often have hesitated to adjust because of the uncertainty associated with the long time nature of investment. In other cases, reaction to change by both producers and processors have impeded progress. Often decisions have been based on non-economic or personal preferences rather than on available economic information.

Prior studies have indicated plant unit processing costs decline as the size of operation increases. Transportation unit costs, on the other hand, increase with the expansion of the area served. A basic unanswered question in the fluid milk industry is at what point do economies of scale in plant processing costs begin to be neutralized by increased transportation costs in the procurement and distribution of milk.

An over-all regional project was initiated to study the relationship between decreasing plant unit processing costs and increasing transportation costs. The study was divided into three phases: procurement, distribution, and plant costs. Phase one covers the effect of plant expansion on costs of procuring raw milk; phase two compares costs of distributing milk in local and outlying areas; and phase three is a study of the relationship of plant processing costs to size of operation.

The Purpose of This Study

The main purpose of this study was to determine the relationship between unit processing costs and size of fluid milk processing plants operating under Oregon conditions. This study was a part of phase three of the regional project, but was concerned primarily with larger than average milk plants. A preliminary study of smaller plants in Idaho by Monroe and Walker has already been completed (27).

A Review of Theory Related to the Problem

The Scale Line Concept

For every given fluid milk processing plant, there are certain fixed costs such as depreciation and interest on investment, that continue regardless of plant output (OA in Figure 1). In addition, there are variable costs such as labor, utilities, and supplies, that may increase at first at a decreasing rate and later at an increasing rate as volume of output is increased (AB in Figure 1). Every total cost, OC, divided by its corresponding output, OD, will give a series of unit costs (AE in Figure 2). As plant output increases, unit costs decrease up to the point called the optimum or least cost point. Increases in output beyond this point bring rising unit costs.

Fluid milk processing plants may differ either in combination of processing technique, in volume handled, or both. If the average cost curves for a group of plants of the same type but varying sizes are plotted together on the same chart, a line will be formed by their least cost points. Some of the terms used for this line are expansion path, long run average cost curve, and planning curve. The heavy line in Figure 3 drawn through the low point in each of the individual curves is such a long run average cost curve. Average cost curves might show constant returns to scale as in Figure 4, decreasing costs, hence, increasing returns to scale as in Figure 5, or vice versa as in Figure 6. The average cost curves in Figures 4, 5, and 6 show

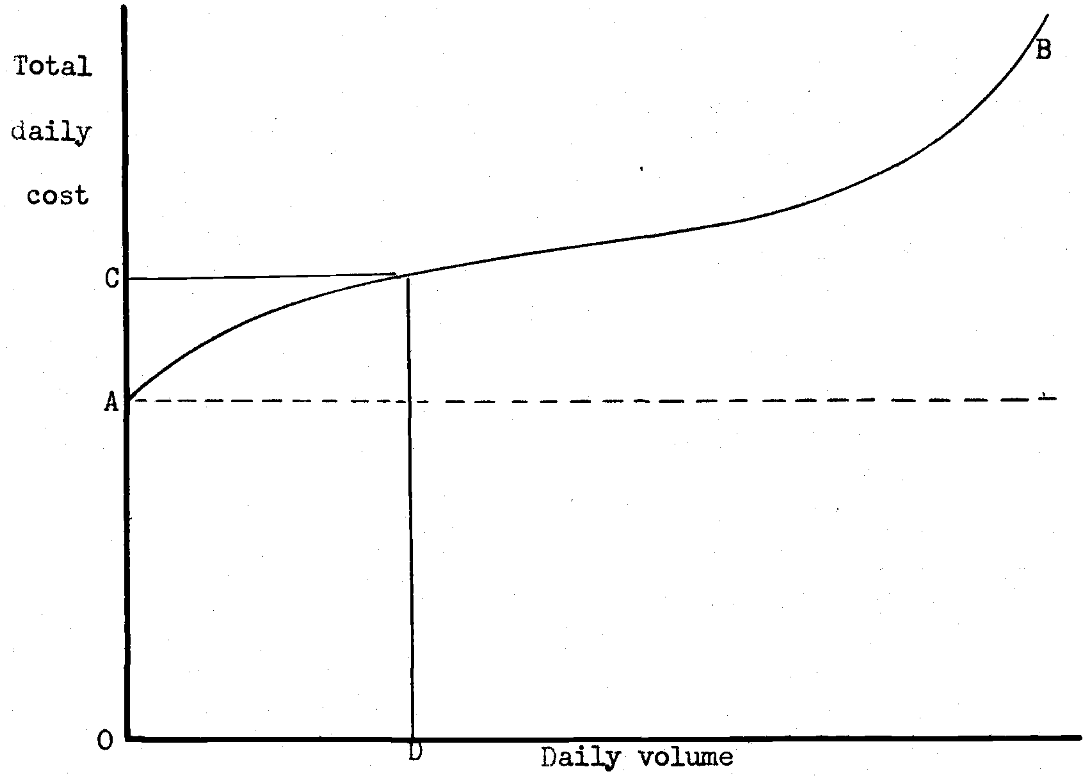

Figure 1. The relationship between total, fixed, and variable costs.

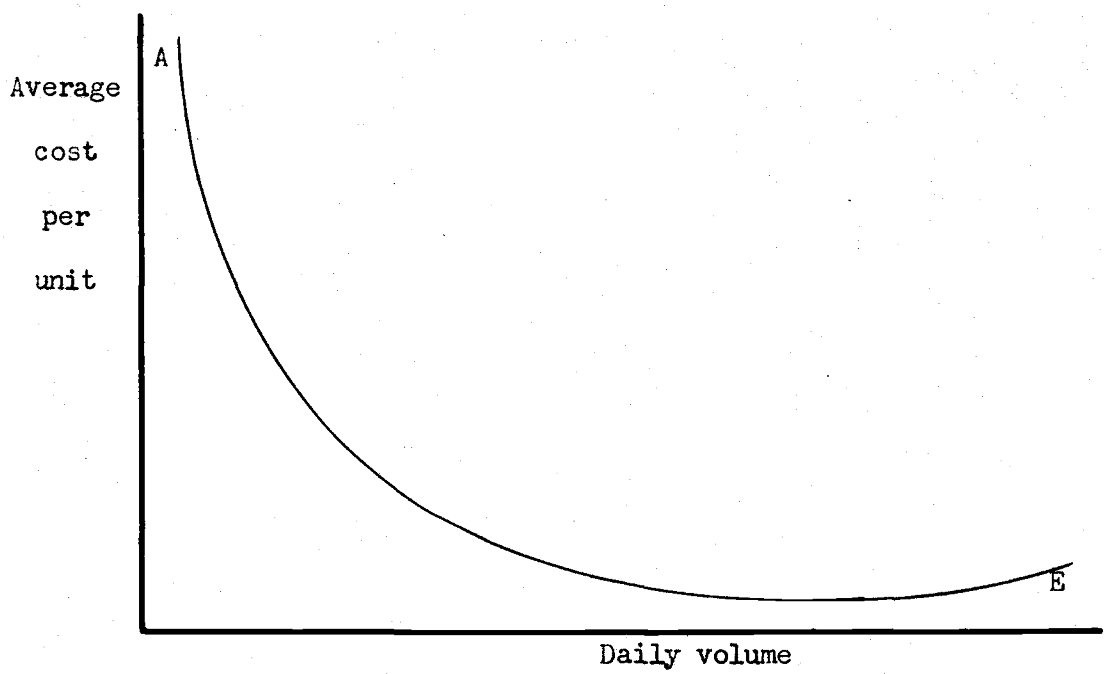

Figure 2. The average unit cost curve for a hypothetical plant.

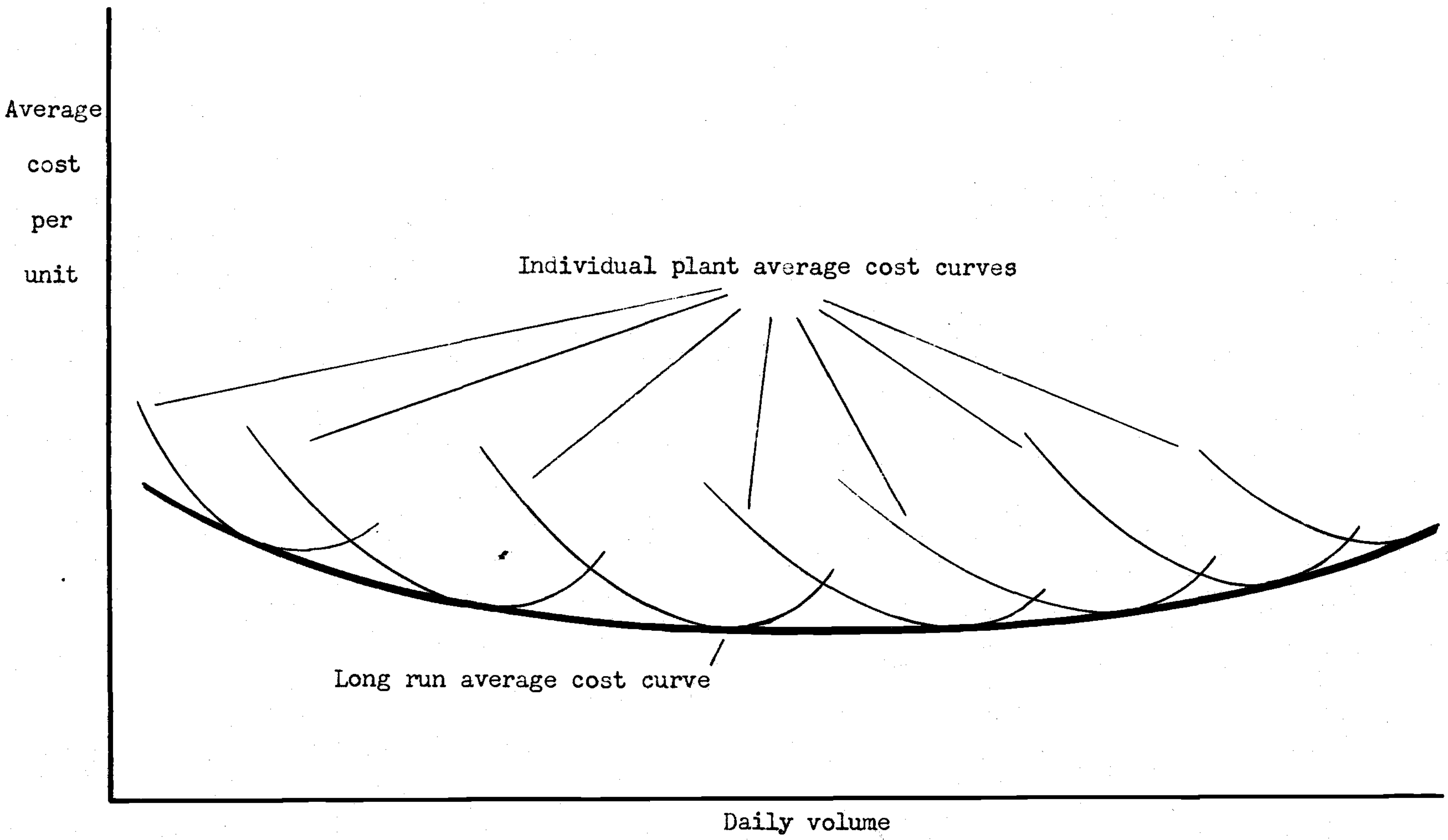

Figure 3. The relationship between long run and short run average cost curves.

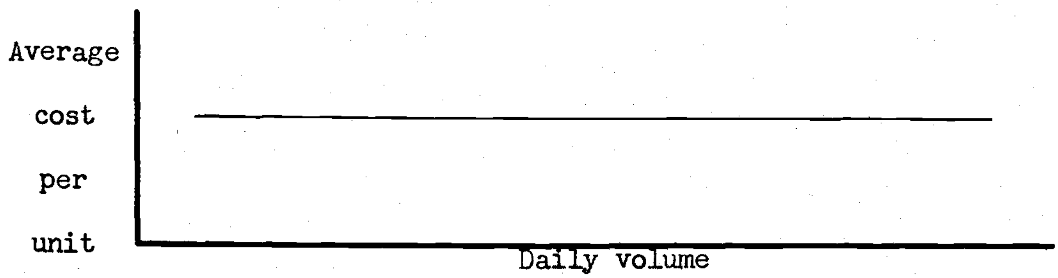

Figure 4. Long run average cost curve with constant average costs per unit.

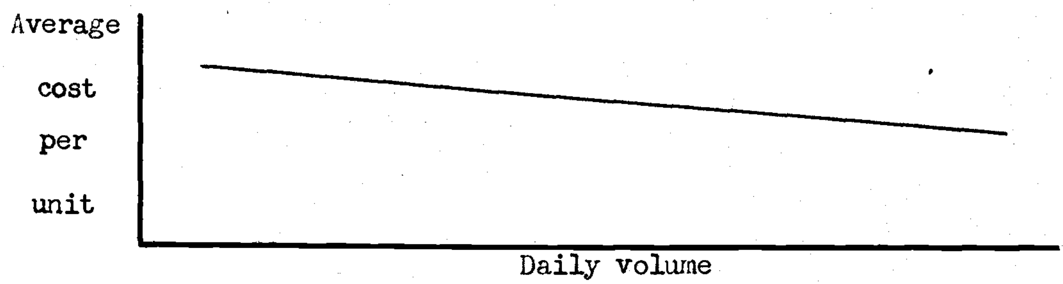

Figure 5. Long run average cost curve with average costs per unit decreasing at a constant rate.

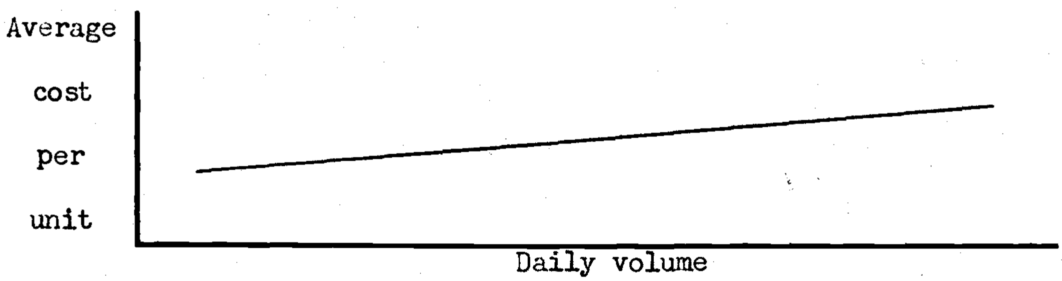

Figure 6. Long run average cost curve with average costs per unit increasing at a constant rate.

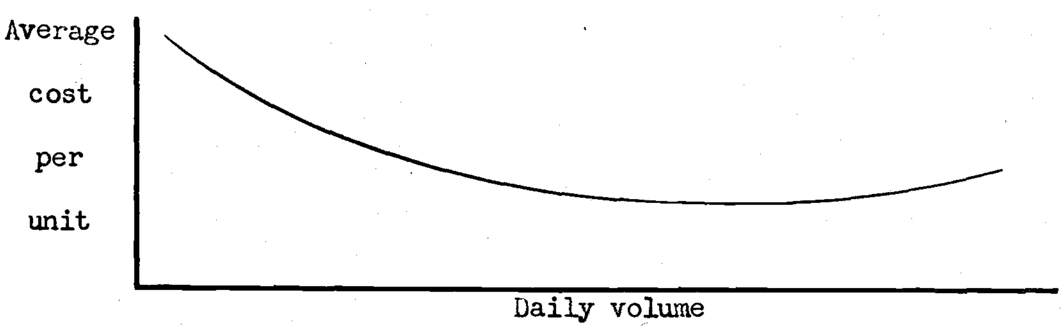

Figure 7. Long run average cost curve with average costs per unit first decreasing and then increasing.

a straight line expansion path. The ratio of costs to volume of output is a constant.

Prior studies of fluid milk processing plants have found not a straight line relationship, but, rather, a curved expansion path as shown in Figures 3 and 7. The ratio of unit costs to volume changes as the level of output increases. This indicates there is a size of plant that will have lower costs than similar plants either smaller or larger.

Every other combination of plant processing methods also will have a long run average cost curve. These curves may or may not show the same costs.

The Discontinuous Curve Refinement

Dairy plant cost curves are not continuous. In a given plant some so called variable inputs can be added only in lumps. Labor is usually such an input. A given plant may be able to vary output considerably until it reaches the capacity of some factor. To produce beyond this point, another unit of input must be added. In the transition from the utilization of a small fraction of a plant's capacity to full capacity, a cost curve similar to Figure 8 will likely appear. In the illustrated case, operation at a low capacity with a partial or two man crew will give lower unit costs than the use of a larger crew. At some point, however, output can not be increased without the addition of more labor either in the form of overtime pay or in the form of a new crew member.

This same phenomenon exists in dairy plant long run average cost

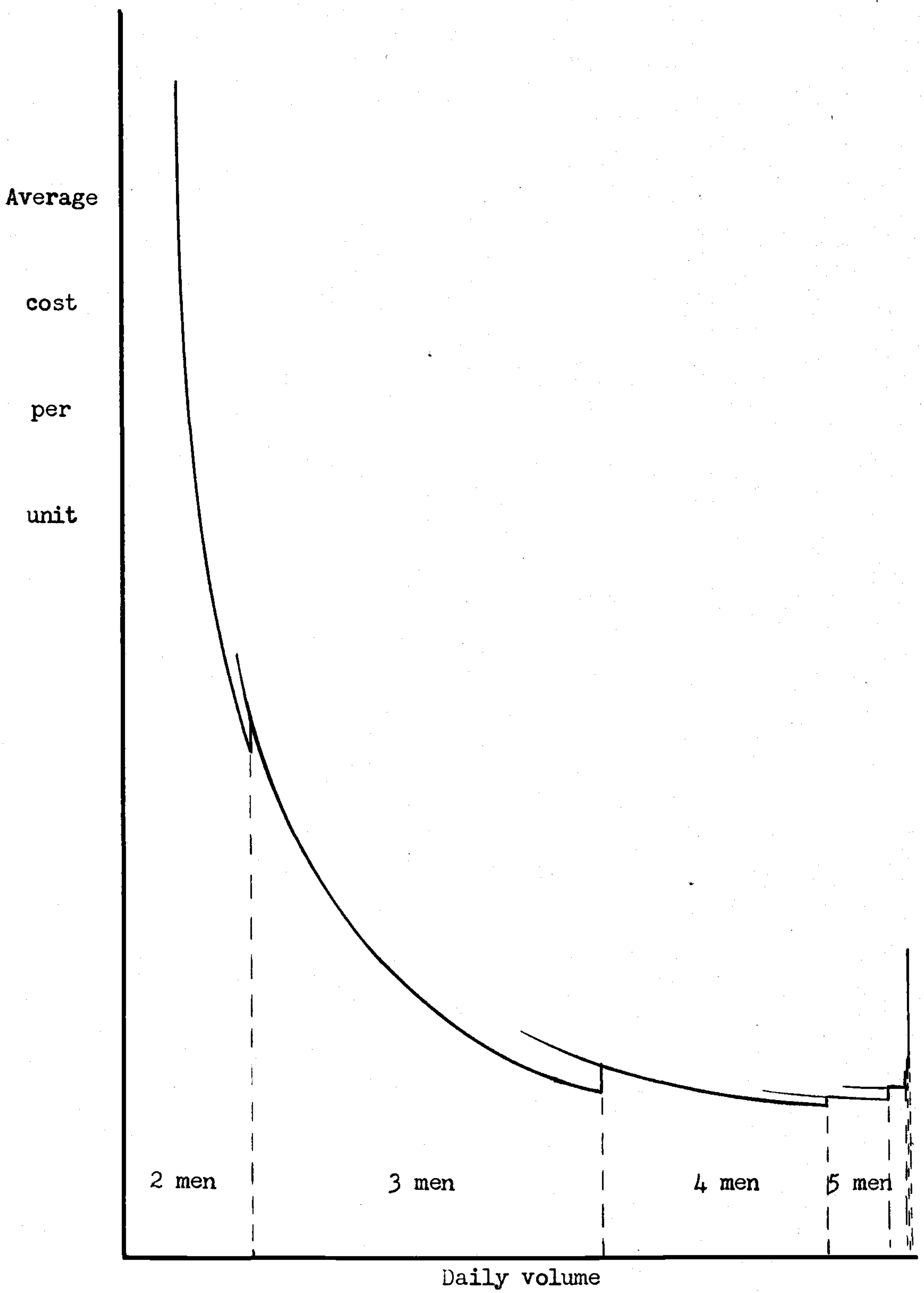

Figure 8. A discontinuous average cost curve for labor in a hypothetical dairy plant.

curves (Figure 9). Bottle fillers are made in but a limited number of sizes. The same is true of boilers, refrigeration equipment and vats and tanks. Hence, there may not be a feasible processing plant for every point along the theoretical expansion line. Small plants are particularly limited as to possible graduations in size. Larger operations, however, may choose not only larger capacity processing units, but also multiple units of smaller equipment.

The primary purpose of this study, restated in terms of the above theory, was to locate points on the long run average cost curve for varying sizes of plants typical of those found in Oregon. It was not concerned with defining individual plant cost curves. Nor was it concerned with the refinement of locating the kinks in the expansion path.

Choices in Method of Analysis

There are two possible approaches for locating a long run average cost curve. One approach is the analysis of actual plants. The other is synthetic model or budgetary analysis.

Field survey of actual plants has one very important advantage. The results are subject to verification by statistical analysis.

Analysis of actual plant records appears to give a practical concept of the long run average cost curve. However, the least cost long run curve probably will lie somewhat below the observed curve since there is little chance all plants studied will be operating at the least cost point on their individual cost curve.

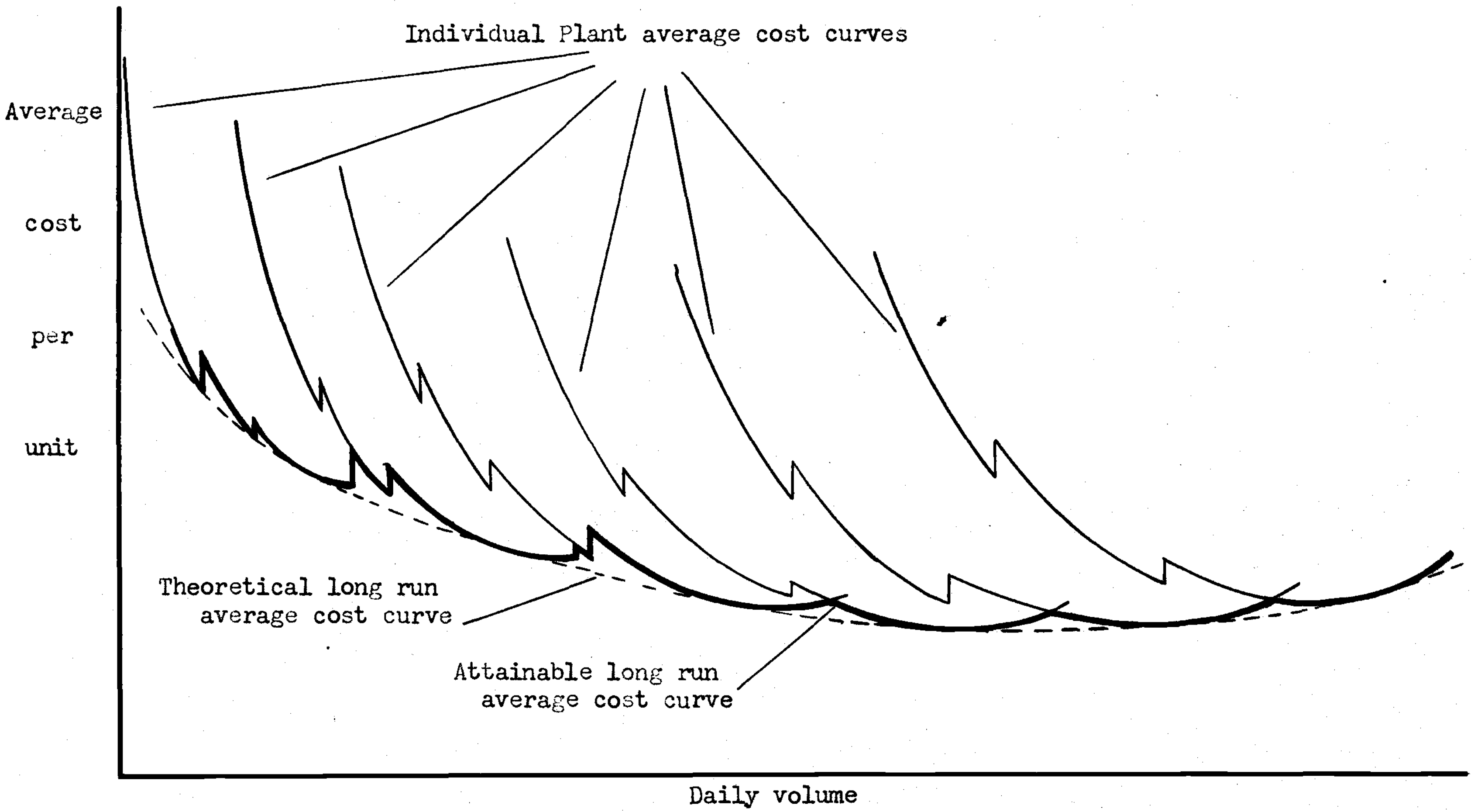

Figure 9. A family of hypothetical average cost curves with a discontinuous long run average cost curve.

Unfortunately, the usefulness of statistical analysis is limited by the availability of the data. If, in what would otherwise be a sufficient number of plants, there are too many interrelated variables, the method requires a larger and more complex experimental sample design. If there are too few plants available for the design, meaningful statistical analysis is impossible. In some cases, costs of collecting data from a sufficient sample may be too high for available funds. Usually, however, this method is less expensive than a full scale synthetic study.

Synthetic or budgetary analysis, on the other hand, is not subject to the limitations of statistical analysis. It allows study of problems where price changes or new techniques have destroyed the usefulness of available historical records. It may be used where there are too few plants for statistical analysis. It is valuable where a sample of plants operating under comparable condition at any one time cannot be found. In addition, a new or untried variable may be postulated and studied by the synthetic method.

As implied earlier, the costs developed in a synthetic model cannot be statistically verified. At best, only rough comparisons can be made with base data. A second objection to the method is the work and, hence, the expense involved in a synthetic study. The labor required in the first phase of gathering and preparing base data for most synthetic studies would complete similar studies using the statistical method of analysis.

A final objection of the method is the qualifications required of the researcher. The analyst not only must be familiar with methods of economic evaluation, he must also have the technical knowledge and skill to prepare a reliable budget.

Initial survey of Oregon plants showed too many interrelated variables and too few plants to allow determination of the long run average cost curve by statistical methods. General non-uniformity in dairy plants has long plagued both researchers and plant operators searching for relative cost information. With many interrelated variables, the factors affecting costs are difficult to separate and study. This undoubtedly explains why most studies of dairy plants made prior to the development of the synthetic method have reported costs only as an average for the group of plants in their respective studies. The limitations of the statistical method made it an improper tool for studying an industry with relatively few plants and many variables.

Therefore, this study was an analysis of synthetic models that used as a guide data obtained from actual Oregon plants. By relying heavily on base data from actual plants, the costs developed in the synthetic models likely approximated closely those of the actual plants studied. Therefore, the long run average cost curve obtained in this manner probably, as mentioned earlier, was not the least cost curve. However, a long run average cost curve approximating actual experience should be a more practical guide for planning than one showing only theoretical least costs.

Also, models synthesised to closely resemble actual plants should have less opportunity for error than those whose synthesis is guided only by theoretical relationships.[1]

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[1]Black (7), Rudd (38), and Bressler (10) each present further discussion on the development of costs by the budgetary method.

Review of Previous Work

Early Economic Studies of Dairy Plant Operations

History of dairy plant research reveals a rather marked evolution in the type of work done. Some of the first studies of dairy plant operation were efficiency studies concerned primarily with the economies of a specific technological development. For instance, in 1913, Bowen published a USDA circular on the utilization of exhaust steam for heating wash water and boiler feed water (8). Another example was Farrall's study of power requirements for electrically driven dairy equipment published in 1927 (19). From this beginning has evolved a long series of studies, including this one, concerned with processing costs and plant efficiency.

Another approach to dairy plant costs has been the study of marketing margins. Some of the publications have been little more than reports of the margin taken by plant operators. These reports bore little resemblance to cost and efficiency research. However, particularly in later years, margin analysis was refined to allow comparison of costs between plants and between methods of operation. Hence, studies of marketing margin also are classified as studies of processing costs and efficiency.

Most early work was conducted on the plant survey basis. Findings were published as averages for the group of plants studied. Researchers were concerned with comparative costs between plants of different size and method of operation. However, dairy plants were so few in number and had such wide variations in size, product output, and method of operation that meaningful comparison by statistical analysis was difficult. Consequently, some of the most valuable information of this era was statistically unverifiable observations and opinions based on a few case studies. An early example of this type of study was published in 1924 by Black and Guthrie (7). These researchers, one a dairy technician and the other an accountant, teamed up to study the factors related to plant volume and technique.

To make the survey method more useful, several refinements were introduced. For instance, costs were presented on a per unit basis to facilitate comparison between plants and plant operations. This concept was used successfully in the late 1920's by a number of researchers studying cost-volume relationships in country receiving stations. Schoenfeld (47) in 1927, Bartlett and Gregg (4) in 1928, Camburn (14) and Tucker (48) in 1929 each published a receiving station study. Tucker's study not only presented total unit costs per hundred weight, but also introduced the use of cost elements such as labor, supplies, and utilities. Hence, some of the sources of variation in costs could be shown.

Subsequent studies of dairy plant costs also began to include Tucker's method of analyzing cost elements as well as total costs. However, researchers did not establish satisfactorily cost-volume relationships for processing plants.

Advancement in research technique probably was arrested by the rapid development of milk marketing regulatory agencies in the middle

1930's. These agencies requested considerable information, not on cost-volume or cost-technique relationships, but, rather, on average margins and average unit costs for plants in the market. Consequently, most of the research published during these years was conducted at the request of or for the benefit of these agencies. For instance, in 1934, Spencer reported costs and profits for New York City Milk Dealers (42). Later, he made a study of upstate milk dealers. Also, in 1934, Mortensen published an analysis of milk marketing policies (28). It included a historical array of dealer margins and a breakdown of the margin into elementary costs as a percent of the total margin. The next year, Stelzer published average processing costs for 22 plants in West Virginia.

Probably the most significant study of processing costs to come out of this era was prepared in 1936 for the Massachusetts Milk Control Board by the Charles F. Rittenhouse firm of accountants. The usual survey of processing plant records was supplemented with an engineering time study for allocating costs to departments. This procedure not only allowed determination of average unit costs by cost element, it also allowed determination of costs for individual products.

There were many California Department of Agriculture reports on costs of processing fluid milk in that state (eg.,12). These, also, were based on audits of handler records and engineering time studies for allocating costs to individual products.

The technique demonstrated in these reports later became an essential analytical tool for gathering base data for synthetic studies.

In 1939, Dow broke away from the conventional survey method of comparing unit processing costs (17). He developed a quart equivalent standard for each product. His base unit was the cost of processing and distributing a quart of regular milk. Spencer followed this same procedure in a study of the costs of processing and distributing milk in northern New Jersey (43). The procedure allowed comparison of costs between plants with varying product mix. Thus, these studies were an attempt to overcome one of the uncontrollable variables in actual plants.

The Development of the Synthetic Method of Analysis

The synthetic approach to cost analysis was developed to overcome the many elements of non-comparability found in actual plants. The dairy industry had too few plants and too many sources of variation for meaningful statistical analysis of plant records. Refinements of the survey technique had helped. To make surveys more useful, researchers broke total costs into cost elements such as labor, supplies, and equipment costs. Later, they allocated these costs to individual products or processing functions. With these developments, cost variations between plants were studied. Costs of alternative processing methods were compared. However, the development of a long run average cost curve required a series of plants varying only in size. Such a group of plants are seldom to be found. The appearance of the synthetic method at this point in the evolution of dairy plant research was probably natural.

One of the first examples of this type of study was an analysis of receiving stations by Bressler (9). It was published only 15 years ago. The study was based on an analysis of eight actual receiving stations.

Bressler's work was followed by a series of twelve University of Connecticut bulletins generally titled Efficiency of Milk Marketing in Connecticut. One of these by Henry, Bressler, and Frick, 1948, was a synthetic determination of costs for smaller processing plants (22). It was the earliest and almost the only publication to date that attempted to define and locate the long run average cost or planning curve for dairy plants.

Four other examples of dairy industry cost-volume determination by the synthetic method may be cited. In 1952, Frazier, Nielson, and Nord, dairy technician, industrial engineer, and agricultural economist teamed up to develop input-output data for six butter plants (20). As an interesting addition, the synthetic models were compared with the original plants.

The next year, Walker, Preston, and Nelson published a study of butter-nonfat dry milk plants (50). Twelve actual plants were used as a basis for synthesizing five roller and seven spray process plants.

In 1954, Baum, Riley, and Weeks published a synthetic analysis of both can and bulk receiving operations (5). The study presented costs resulting both from variations in volume for a given operation and from variations in size of operation. Hence, both the average cost curve for the individual plants and the long run average cost curve were established.

In 1956, Monroe and Walker published a study of small fluid milk plants in Idaho (27). The publication presented problems found while analyzing six small processing operations and used the synthetic approach to study means of solving these difficulties. It was originated as a pilot study for this project. Consequently, the methodology used in this study follows rather closely that of Monroe and Walker.

The synthetic method has been explored for uses other than cost-volume analysis. In 1951, Carter, Brundage, and Bradfield published physical specifications for a milk receiving station (13). This study differed from other publications reviewed in that its main purpose was not to determine unit costs, but, rather, to present guides and physical specifications needed in planning or altering a receiving station.

A similar synthesis of a 15,000 quart a day milk bottling plant was published in 1953 by Conner, Spencer, and Pierce (15). However, in this case, costs were also presented. It was a pilot study to test and illustrate the potentialities of the budgetary method for analyzing cost relationships within a plant. The input-output data used in the study was developed largely by a firm of management engineers studying dairy plant costs for the New York State Temporary Commission on Agriculture.

A second study of this same type was published in 1956 by

Webster (51 and 52). He used an adaptation of the method developed by Conner, Spencer, and Pierce to develop specifications and costs for a plant processing 6,400 quarts per day.

A discussion of the development of synthetic analysis is not complete without mentioning use of the method in other fields. Probably one of the most comprehensive studies using the synthetic method was Brewster's study of cotton seed oil mills (11). He synthesized 67 types and sizes of mills for five geographic areas. He also examined the effect of universal use of the least cost method upon returns to cotton seed producers and processors and upon the prices to users of cotton seed products.

Another use of synthetic analysis was published in 1955 by Hall (21). He used a method similar to that developed by Conner, Spencer, and Pierce in developing specifications and costs for four sizes of country elevators.

These studies show some of the possibilities of the synthetic method for analyzing problems in other fields of research.

Summary of Postwar Publications Based on the Survey Method of Analysis

In 1946, Howe published a general summary of prior research in the dairy industry (24). In his summary of work on country milk receiving stations, he presented a group of studies showing cost-volume relationships for this operation. It is interesting to note that he did not do this for plant processing costs. His summary of research on dairy plant costs included only average unit processing costs. This may be further evidence that the dairy industry with relatively few plants and many interrelated variables is not suitable for cost-volume analysis by the survey method.

By this time, the budgetary method of analysis had been introduced. However, the method required considerable physical input-output data that were not readily available or easily developed. Futhermore, it required the researcher to have considerable technical skill. Partly for this reason and partly because detailed costs were not always sought, much of the post-war research completely ignored the synthetic method of analysis. Other studies might be called transitory research. In these cases, at least, some of the physical input-output relationships needed in synthetic studies was developed, but no synthesis was made.

Probably the most extensive average cost and marketing margin analyses of recent years were the series published 1948 to 1951 by the New York State Temporary Commission on Agriculture (29,30,31,32 and 33). A firm of management engineers conducted extensive time studies for all route and plant operations. Unit costs were determined in minute detail to allow comparison between milk dealers and within a given dealer's operation. No synthesis was made to show cost possibilities in the reorganization of a given plant, or to compare costs between plants with the same organization but of different size. However, the data that were compiled has since found use in the synthetic studies by Conner, Spencer and Pierce and by Webster.

In 1952 Bartlett and Gothard published a study on measuring the efficiency of processing plants (3). Both physical inputs and monetary costs were developed and presented. Twelve plants were arrayed to show gallons of milk processed per day and the corresponding man minutes, square feet, horse power hours, and BTU's required per hundred gallons of milk processed. Then two plants were examined in detail. Some of the analytical tools and physical data of this study could be adapted for use in a synthetic analysis.

The next year Scott published an analysis of labor requirements in small milk processing plants (39). This publication was based on a time study of four plants handling 2,500 to 3,500 quarts per day. The purpose of the study was to compare labor costs of different methods of operation. The physical data developed was suitable for use in a synthetic analysis of labor costs for similar plants.

One of the most unusual transitory studies reviewed compared costs for a plant with a glass filling operation with costs for the same plant after it switched to an all paper operation (36). Research workers from business, education, science, and industry teamed up to determine the cost of packaging milk in paper as compared with glass, and to determine which type of container was preferred by the customers who bought home delivered milk. The analysis of plant and delivery operations included both monetary and physical costs.

Applicability of Previous Work to the Given Problem

To date no results have been published that are completely applicable to the determination of processing costs for the Oregon plants. In the first place, very few investigators have studied cost-volume relationships in fluid milk processing plants. Of all the studies reviewed, only those by Henry, Bressler, and Frick (22), and by Monroe and Walker (27), included detailed cost information for each of several specified sizes of plants. However, both of these studies were for smaller plants.

Equally unsuitable was a second alternative of combining various studies into one composite source of information. For one thing, a vast majority of the work reviewed presented average costs for a group of plants that differed both in volume handled and in processing methods used. Obviously, such data could not be adapted for a study of cost-volume relationships.

Some of the studies were not all inclusive. For example, Carter, Brundage, and Bradfield studied only receiving operations. Scott, on the other hand, studied a complete processing operation, but he presented only the labor requirements.

A few studies presented detailed costs, but they appeared all or in part only in monetary terms. Most of the cost items could be adjusted using available index series providing the physical relationships on which they were based were known to approximate those for Oregon plants. Processing relationships may vary over time or between different areas of the country. Thus, unless adequate information about the accompanying relationships is available, the use of historical data can be misleading.

In addition to these difficulties, the range of plant sizes studied does not include plants as large as those found in Oregon. Hence, even if data from prior studies were usable, supplementary information would need be obtained to complete the analysis of Oregon plants.

Thus, in summary, most prior research either was reported in monetary terms only, or was conducted on plants smaller than most found in Oregon. However, methodology and some of the findings of other researchers have been used in this study. The application of prior research to the specific problems in this study will be discussed as it occurs in the later sections.

Preliminaries

Selection of the Base Plants[2]

As an introduction to the number and size of processors in the state, a list of Oregon fluid milk plants and their approximate volume of output was obtained from the now defunct milk marketing administration. There were sixteen plants on the list that were of suitable size for the study. These plants were surveyed by a personal visit to determine method of operation, number and type of non-fluid milk products processed in the plant, and willingness of the operator to be included in the study.

The plants were divided, roughly, into six size groups. One plant from each group was selected to supply the base data. The criteria for selecting the plants were plant size, product output, and processing technique used. The plants chosen were representative of the medium to large operations found in the state. To the extent possible, plants were selected that did not process non-fluid products.

Description of the Area and the Plants Studied

Most of the data obtained from the processors were strictly confidential. Consequently, detailed information about the individual base plants are not presented. However, a few general

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[2]Throughout this study, the term "base plants" has reference to the actual plants whose records were used as a guide in developing the synthetic models presented in this study.

observations about the area and the plants serving this part of the Northwest should increase the usefulness of the study. Without this description, the suitability of the findings for other markets and situations may be difficult to determine.

Oregon plants ranged in size from less than 14,000 pounds per processing day to an average exceeding 200,000 pounds per day.

Most plants had unionized employees and operated five days a week.

Many of the plants in this area received part or all of their milk on daily order from a producers' cooperative. Consequently, in these cases, the problems of seasonality of receipts and of utilizing excess milk had been transferred to the cooperative. Also, in these cases, five-day-a-week operation was possible with less raw milk storage than would otherwise have been required.

Most products were short time pasteurized. However, several plants vat processed cream. A few plants, both large and small, vat pasteurized chocolate milk. Some plants vat pasteurized skim for buttermilk.

Base Plants

The base plants were all located in the Willamette Valley of Oregon. All but the smallest and the largest were operating near practical capacity.[3] All sold their product both retail and wholesale. All processed primarily for an urban market and faced considerable competition.

Most of the plants processed 32 and 20 percent cream, half and half, homogenized, regular, skim, and chocolate milk, orange drink, buttermilk, and from one to four other types of milk. The other milks included 4 percent milk, 5 percent milk, multivitamin milk, multivitamin skim, breed milks, premium or herd milks, and fluid drinks with skim milk solids added. Generally, the plants carried only one or two of these other milks.

Most plants packaged milk in both paper and glass bottles. Except for half gallons, more plants used the preformed paper bottle than the type formed at the time of filling. In this part of the Northwest, the size of plant apparently has not influenced the choice between these two types of bottles. Smaller plants also filled half gallons in preformed nested cartons. Some milk was distributed in half gallon glass bottles. The gallon jug also was in limited use.

At the time of the survey, practically all plants distributed homogenized milk in bulk cans, and in half gallon, quart and half pint containers. Skim and regular milk often were distributed both in quart bottles and in bulk cans. All other types of milk and fluid drinks were generally distributed only in quart containers.

[3] At practical or normal capacity, the preparation of equipment and the processing and bottling of milk was completed in an eight and a half hour period of time (one eight hour shift with a half hour for lunch). Washup and servicing of equipment required additional time. The smallest base plant was operating at less than practical capacity. The largest was operating somewhat over practical capacity.

Half and half was packaged in quart and pint bottles. Creams were distributed in pint and half pint containers. Since the survey, an increasing number of products have appeared also in half gallon paper cartons.

For all plants, the division of total plant output between milks, creams and specialty products was about the same. They ranged from 80 to 85 percent in fluid milk, around 5 percent in half and half, and .53 to 1.13 percent in cream, and 8 to 13.4 percent in the chocolate, skim, buttermilk, and orange products. Only the proportions between homogenized and regular milk varied extensively between plants. Homogenized milk ranged from 55 to 83 percent of the total plant output for the several plants studied.

Some variation was found among the plants in the proportion of plant output packaged in various sizes of containers. Plants ranged from 12 to 30 percent of output in half gallon bottles, 63 to 83 percent in quart bottles, 1.4 to 2.4 percent in pint bottles and 4.5 to 13.8 percent in half pint bottles.

The greatest variation occurred among the base plants in the percentages of total product put up in paper and glass containers and in bulk cans. Except for one plant, the proportion in glass ranged from 36 to 68 percent of the plant output; the proportion in paper ranged from 18.5 to 61.5 percent; and the proportion in bulk cans ranged from 2.4 to 24.6 percent.

No marked seasonal changes occurred in the product proportions. Except for homogenized half pint bottles, the proportion in different sizes of containers also did not change. For all plants, the number of half pint containers did not change during the school year, but declined during the summer.

The Base Data

Each of the selected plants was requested to supply data for the year, 1955. The product flow, the plant crew, and the duties of each member were obtained by interview with the plant manager. Building costs and equipment inventories were taken from plant inventory records where possible. Otherwise, equipment was listed while inspecting the plant. The layout for plant and equipment was sketched to scale. Milk received and product output were obtained from plant records. Quantities of utilities and their unit and total costs were obtained from plant files. When possible, physical quantities of supplies purchased and their unit prices also were obtained from the plant files. Machinery repairs, building repairs, property taxes, interest rates and payments, insurance costs, and total expenditures for supplies were obtained from records kept for income tax purposes.

Equipment and supply houses also were visited. Where possible, 1956 prices for equipment and supplies were obtained from three separate suppliers. Price changes for larger quantities were noted where applicable.

Current labor costs were obtained from the 1956 union contract.

The Use of the Data

The above information obtained from the base plants was used as a guide for selecting the model plant product mix, establishing the operational assumptions, and synthesizing the physical relationships and budgets of the model plants.

Five models were budgeted to represent the medium to large sizes of plants in Oregon. The smallest, designated plant X, processed an average of 14,000 pounds of raw milk a day, five days a week. The subsequent models processed twice the amount of milk as the preceding size of plant. They were designated 2X, 4X, 8X, and 16X.

When the physical specifications for the model plants were completed, they were checked by plant owners and dairy equipment sales engineers for reasonableness. Corrections were made and the 1956 prices were applied to the physical budgets. Finally, total and unit costs for the models were calculated.

Selection of the Model Plant Product Mix

The product mix used throughout this study is shown in Table 1. It is the arithmetic average of the proportions found in the base plants. The share of total output assigned in this manner to each product is fairly representative of all the base plants. However, as noted earlier, the base plants varied considerably in proportion of output in different sizes of containers and particularly in the proportion in glass and paper.

Table 1. Product mix for all model plants with glass and paper output with number and kinds of containers for plant X only.*

Fluid product	Number of containers by size					Percent of total output
	5 gal.	½ gal.	quarts	pts.	½ pts.	
Glass bottles						
homogenized			353,715		67,787	22.00%
regular			88,415			5.25
special			33,682			2.00
cream 32%				1,564	2,936	.09
cream 20%				2,804	4,496	.15
cream 10%			15,950	9,192		1.22
skim			47,828			2.84
Glass total			539,590	13,560	74,580	33.55%
Percent of glass output			95.5%	1.2%	3.3%	
Paper bottles						
homogenized		118,670	411,835		255,240	42.36%
regular			41,430			2.46
special			21,893			1.30
cream 32%				8,368	14,248	.46
cream 20%				3,400	6,672	.20
cream 10%			58,625	35,712		4.52
skim			25,598			1.52
chocolate			22,178		9,640	1.46
buttermilk			34,861			2.07
Paper total		118,670	616,060	47,480	285,800	56.35%
Percent of paper output		25.0%	65.0%	2.5%	7.5%	
Bulk cans						
homogenized	4,210					5.0%
regular	3,032					3.6
skim	1,263					1.5
	8,505					10.1%
Total containers	8,505	118,670	1,155,650	61,040	360,380	
Percent of total output	10.10%	14.08%	68.67%	1.81%	5.34%	100.00%

*The product mix for plants 2X, 4X, 8X, and 16X was the same as X except that the respective quantities of each of the products in each subsequent size of plant were double those for the preceding size.

Thus, the proportion of product in different kinds and sizes of containers was not necessarily typical of all the base plants.

With the selected product mix and product tests, only a minimum amount of excess skim milk resulted. Hence, no provisions were made for the disposition of surplus skim or cream. Plant X had an average surplus of ten pounds of skim a day, and 16X an average of one hundred and sixty pounds.

Since more of the plants visited used preformed paper cartons than the type formed at the time of filling, the preformed bottles were adopted as standard in the development of the models.

Operational Assumptions

Ideally, all models should be as near the same as possible to eliminate cost variations due to factors other than those being studied. On the other hand, to be realistic, the standards for a model for any given plant size should approximate those found in typical industry counterparts. For most of the standards selected for the synthetic models, no conflict existed between these two concepts. Procedures followed in a small plant were usually equally suited to a large operation. However, some of the procedures used in small plants were not found in a large plant except in a modified form. In these instances, the model plant standards used in this study also were modified slightly to represent practices followed in the actual plants.

Below are listed the assumptions adopted as standard for all of the model plants.

1. Plant operation began with the receiving of the milk and ended when the milk was loaded onto the trucks or loadout platform.
2. Part or all of the milk was received from a producers' cooperative. Thus, problems of seasonality and surplus milk were not of immediate concern for these models.
3. The raw milk average test was 4 percent butterfat.
4. The standard product flow is shown in Figure 10. All products were short time pasteurized.
5. Plant labor was unionized.
6. The plants operated on a five day week.
7. The milk processing and bottling operation occupied six and a half hours with the HTST pasteurizer operating at the specified capacity and bottle filling equipment operating at 80 percent of its rated capacity. This assumption had to be relaxed in the case of the largest model plant because a glass bottle filler large enough to meet this schedule was not available at the time the data were gathered.
8. Truck load out was for early morning delivery.

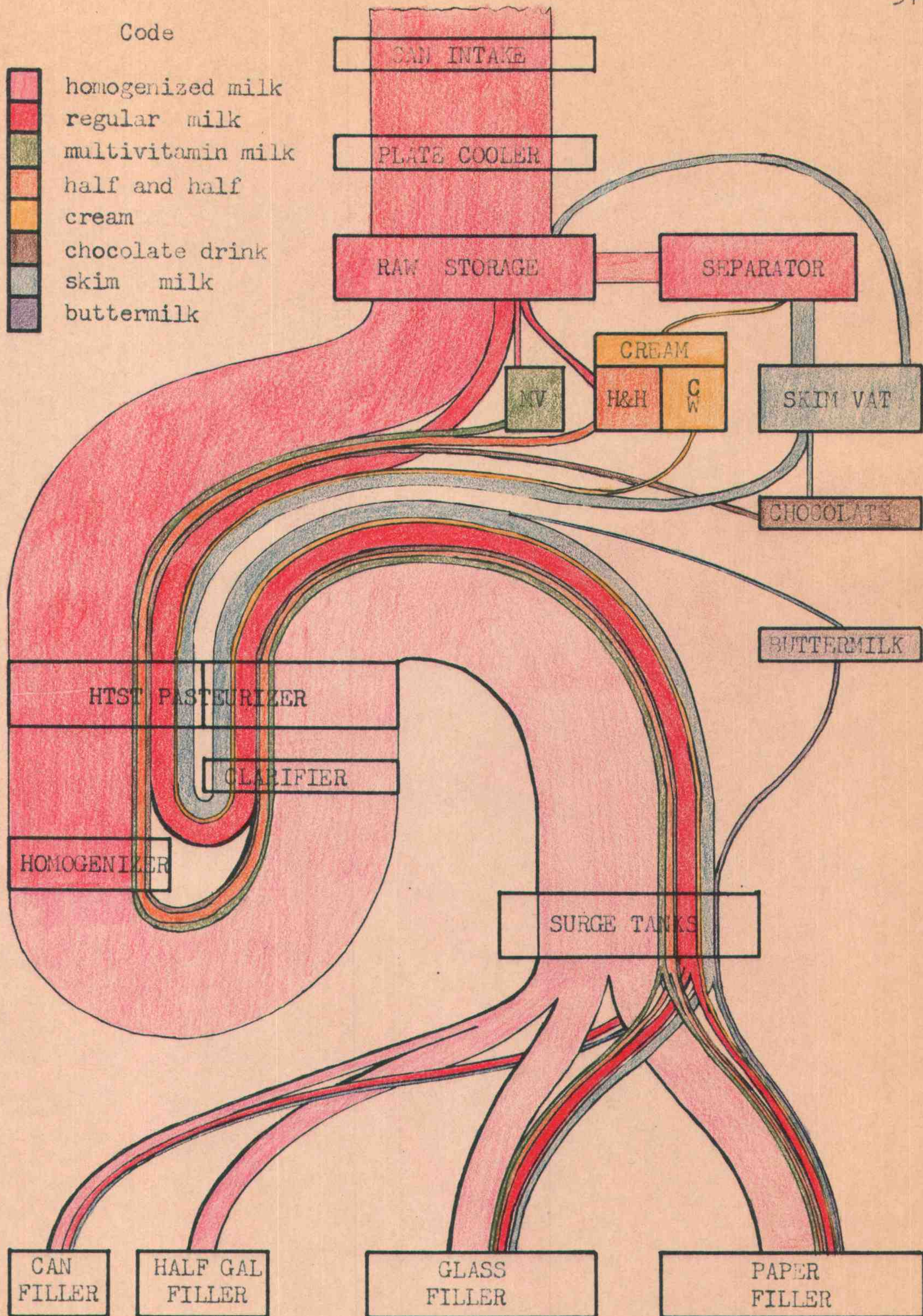


Figure 10. Product flow for five model plants with can intake and glass and paper output based on an analysis of Oregon plants, 1956.

Physical Specifications and Inputs for Five Model Plants

Building Facilities and Plant Layout

Considerable variation existed in the building facilities and plant layouts of the base plants. Some of the buildings were new, others were old. Some had long spans of floor space; others were cut up into relatively small rooms and cubicals by structural bearing-walls. Some of the plant arrangements were easy to alter and expand. More often, expansion in the plants could not come about without either completely rearranging the plant equipment or expanding the existing layout in a haphazard, illogical, inefficient manner.

Variations in types of buildings and plant layout were reflected in plant efficiency and, thus, in plant unit processing costs in the base plants. Therefore, standard buildings and layouts were developed and used in all model plants to keep random variations in these plant features at a minimum.

Building System and Materials

One-level buildings with tunnels for service lines and surge tanks and paper bottle storage over the cooler were used throughout this study.

The building system used for all model plants was the long span skeleton frame type. Roof trusses were supported only by structural columns in the outside walls. This type of construction greatly increased the cost of the roof frame. However, it was ideal for flexibility. Walls of a less expensive construction could be added and removed during remodeling without affecting the stability of the structure. Equipment could be placed and rearranged without interference from pillars or inside supporting walls. Thus, this more expensive structural system was chosen to allow greater flexibility in layout and to allow savings during future remodeling.

In general, construction materials were of concrete, concrete block, and wood. All floors except the cooler and processing room floors were four-inch concrete with surface hardener. The cooler and processing room were four-inch concrete floor with a quarry tile overlay. All walls were eight-inch concrete block. The office walls were furred and plastered. The cooler and processing room walls were covered with face tile.

The roof frames were wood bowstring trusses with half inch plywood decking. Roofing was corrugated aluminum.

Both glass block and steel frame windows were used as a source of outside light. Doors were wood. The cooler was insulated with eight to ten inches of cork. The roof was insulated with a one inch ridgid insulation. All ceilings and walls without face tile were covered with three coats of paint.

A contractors form for estimating materials and construction costs for the five model plants will be shown in a later section (Table 24).

Model Plant Layout and Distribution of Floor Space

As in the case of building specifications, a standard plant layout or building and equipment arrangement was developed for all model plants. The quantity of floor space allocated to each processing function was determined from analysis of the distribution of floor space in the base plants.

On the basis of total plant volume some of the base plants appeared to have a disproportionate quantity of floor space allocated to certain processing centers such as bulk can filling, glass bottle filling, and paper bottle filling. This was due to variations in the proportion of the total plant product handled in these centers. Therefore, the volume of output attributed to each area of floor space was only that portion of the total plant output processed in the given area. Table 2 lists the processing centers and the daily volume correlated with each area. For instance, the volume of milk attributed to the glass bottle filler area was only that portion of total plant output bottled in glass. Using this procedure, variations between base plants in the proportion of the total plant output bottled in glass did not affect the volume-floor space relationship. In this manner, a uniform relationship between volume and quantity of floor space was developed for all the floor space subdivisions of the model plants (Table 3).

Prior to selecting a standard model plant building and equipment arrangement, layout objectives were established. The objectives selected for the model plants were as follows:

Table 2. Method of allocating average daily volume to floor space subdivisions.

Subdivision of floor space	Volume allocated	Annual volume divided by
Receiving areas		days
truck shed	Total raw milk receipts	365
bulk intake	*	
can intake	Pounds of milk received in cans	365
raw storage	Total raw milk receipts	365
Processing areas		
HTST	*	
surge tanks	Total raw milk receipts	260
Dock, linear feet	Total pounds of product	260
Bottle handling areas		
bottle and case dock	Total pounds of product	260
bottle washer	pounds of product bottled in glass	260
glass filler	pounds of product bottled in glass	260
half gallon filler	pounds of product bottled in half gallons	260
paper filler	pounds of product bottled in paper	260
Specialty areas		
bulk can wash and fill	pounds of product in bulk cans	260
processing vats	*	
Cooler area	total pounds of product	260
General plant areas		
separator	*	
test lab	*	
washup	*	
paper storage	total pounds of product in paper	260
other storage	total pounds of product in glass and cans	260
all other areas	total pounds of product	260

*Floor space was constant for all sizes of plants.

Table 3. Distribution of Floor Space to Cost Centers for Five Model Plants Based on Analysis of Oregon Plants, 1956.

Cost Center	Floor space by size of plant				
	X (14,000 lbs. per day)	2X (28,000 lbs. per day)	4X (56,000 lbs. per day)	8X (112,000 lbs. per day)	16X (224,000 lbs. per day)
	Square feet				
Receiving					
Receiving room	288	288	288	832	832
Raw storage	216	312	384	720	1,440
Processing					
HTST	240	240	240	336	336
Surge tanks	48	64	120	192	320
Bottle handling					
Dock and storage	640	956	2,052	2,616	5,136
Bottle washing	180	200	288	336	572
Glass filling	160	224	256	260	480
Paper filling	72	96	156	288	420
Half-gallon filling	116	140	336	288	480
Specialties					
Bulk can storage	172	228	260	540	916
Can filling	16	16	96	100	112
Vats	180	180	180	312	400
Product storage					
Cold room	504	968	1,544	2,592	3,168
General plant					
Separator	48	48	48	48	96
Boiler	224	264	384	544	544
Refrigeration	224	276	328	480	1,088
Ice builder	56	84	112	288	384
Paper storage	776	1,104	1,424	2,400	2,848
General storage	1,004	1,356	1,680	2,128	2,852
Babcock lab	72	72	72	72	72
Workshop	192	224	320	528	832
Washup	96	96	96	120	144
Rest room	80	112	112	160	160
Truck shed	1,668	1,740	3,384	5,484	7,896
Offices	528	752	976	2,080	3,292
Locker room	248	280	488	768	1,196
Route room	224	248	320	480	752
Total plant	8,048	10,568	15,944	24,992	36,768

1. To provide as short a milk line as possible into and through the plants.
2. To provide a short, compact line of travel into and out of the plants for bottles and cases.
3. To provide for short service lines (refrigeration, steam, air, and water).
4. To provide for a minimum difference in plant and building arrangement between all sizes of model plants.
5. To accomplish the above objectives without obstructing the expansion of the plant in the future.

This study was not directly concerned with the costs of expansion for a given plant. However, a plant arrangement that did not provide for plant expansion was considered unsound. Therefore, objective five was included.

With the specific roof system used in these buildings, lengthwise expansion was the simplest and easiest. Another type of system allowing expansion in both length and width would have required a somewhat different initial plant arrangement. However, the layout principles demonstrated in this section were suitable for use with all types of buildings.

A floor plan for plant X was drawn according to the distribution of floor space listed in Table 3 and arranged with the above layout objectives in mind. Then, to minimize layout variations between the model plants (objective four), the floor plan for plant 2X and 4X was drawn as an expansion of the preceding size (Figure 11). Likewise,

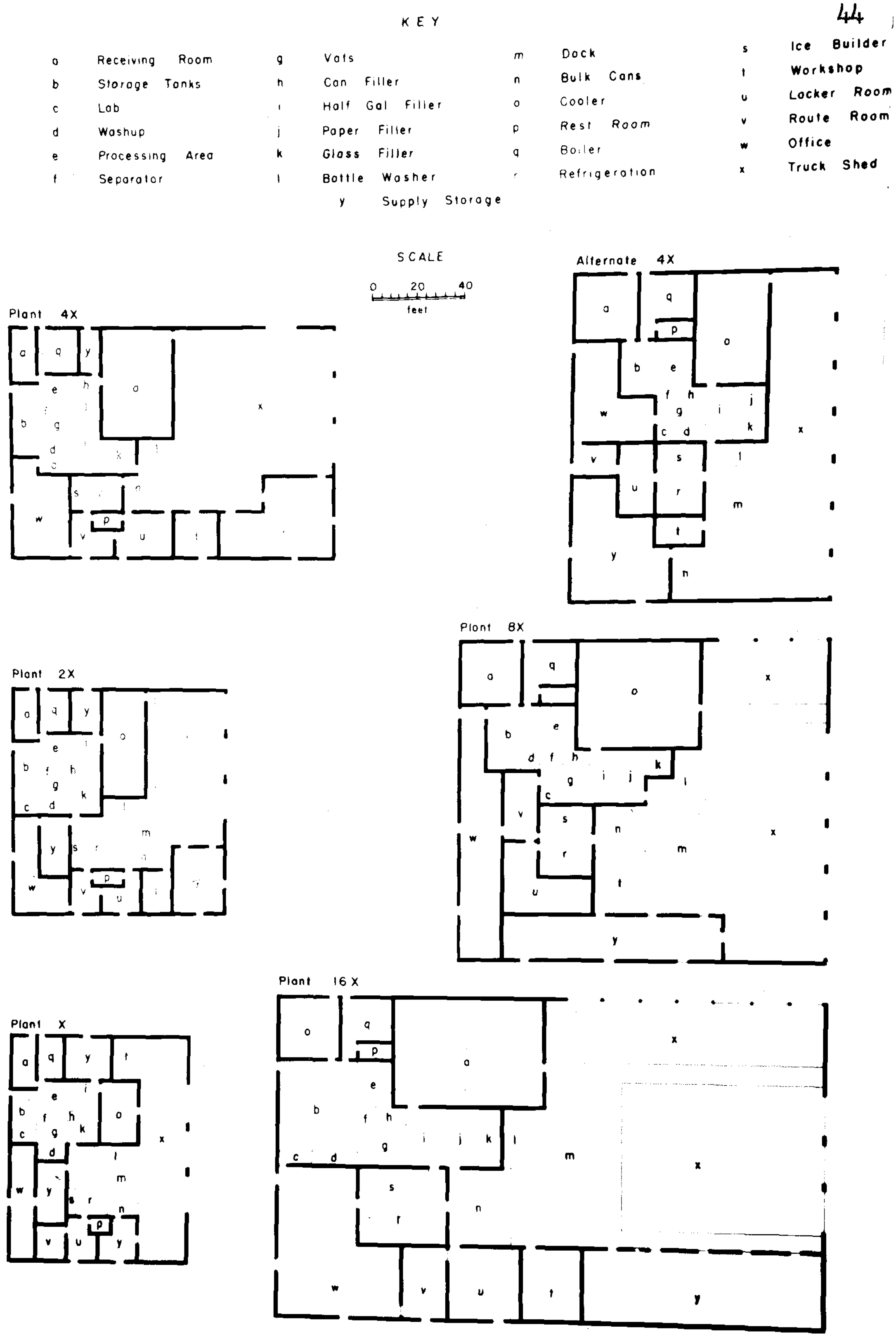


Figure 11. Plant layouts for five model plants.

an alternate plan was drawn for 4X and expanded for plant 8X and 16X. This procedure practically eliminated unnecessary variations in building and equipment arrangement between the different sizes of plants. Incidently, it also showed how plants could be arranged to allow for expansion with a minimum of remodeling and equipment relocation expense.

As shown in Table 3, all sizes of plants required about the same quantity of floor space for certain of the processing centers. These were the centers that included the HTST pasteurizer, homogenizer, separator and clarifier, babcock tester, bulk receiving pump and hose, and washup equipment. Only small increases in size occurred in the areas allowed for specialty vats, ice builders, bottle and case washers, and boiler rooms. For each subsequent size of plant, more definite increases appeared in the raw storage, bottle filler, bulk can, refrigeration, and route room areas. The greatest increase in floor space allotments occurred in the offices, locker rooms, truck sheds, docks, bottle and case sorting areas, coolers, and paper bottle and general storage rooms.

The areas that expanded may be observed readily in Figure 11.

Plant Equipment Standards

The base plants varied considerably in their plant equipment. Equipment combinations varied in size and type. The speed and capacity of various pieces of equipment were not matched in the same manner for all sizes of plants. The quality of the equipment was not the same and the amount of stainless steel and other deluxe exteriors also varied between plants.

These variations affected unit processing costs. Variations in equipment purchase price and length of life affected depreciation costs. Variations in the matching of equipment altered unit costs through effects on plant efficiency. Thus, for meaningful cost comparisons between the model plants, uniform equipment standards had to be adopted.

The standards followed in sizing each piece of equipment are described below. As near as possible, all standards used in selecting size and combination of equipment were consistant with the general practices of the base plant (Table 4).

Can Receiving Equipment

All can receiving equipment was sized to allow intake of the average daily receipts in two and a half hours time. The milk was assumed to arrive in forty-quart cans containing an average of 70 pounds of milk or 80 percent of capacity.

The pump was sized at one and one half times the receiving rate.

Storage Tanks

Raw milk storage tanks were sized to hold up to 80 percent of the average daily receipts over night. In addition, one empty tank was provided for receiving early morning milk.

In the larger base plants, the number of tanks increased even though more economical storage capacity could have been obtained

Table 4. List of equipment for five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item	Capacity or type by size of plant*				
	X (14,000 lbs per day)	2X (28,000 lbs per day)	4X (56,000 lbs per day)	8X (112,000 lbs per day)	16X (224,000 lbs per day)
Receiving					
can conveyor	gravity	gravity	power	power	power
can dump	bar	bar	cradle	cradle	reel
scales	1,000 lbs	1,000 lbs	1,000 lbs	1,000 lbs	1,000 lbs
weigh tank	500 lbs	750 lbs	1,000 lbs	1,000 lbs	1,000 lbs
receiving tank	800 lbs	1,000 lbs	1,200 lbs	1,500 lbs	2,000 lbs
sampler	hand	hand	hand	hand	vacuum
can washer	2½ CPM	3 CPM	4 CPM	8 CPM	16 CPM
plate cooler	4,000#/hr	8,000#/hr	16,000#/hr	32,000#/hr	64,000#/hr
pump	¼ HP	½ HP	1 HP	1 HP	5 HP
storage tank	1,000 gal	1,500 gal	1,500 gal	3,000 gal	5,000 gal
storage tank	1,000 gal	1,000 gal	1,500 gal	3,000 gal	5,000 gal
storage tank	-	1,000 gal	1,500 gal	3,000 gal	5,000 gal
storage tank	-	-	1,500 gal	1,500 gal	3,000 gal
storage tank	-	-	-	-	3,000 gal
Processing					
HTST	3,000#/hr	5,400#/hr	9,600#/hr	18,000#/hr	35,000#/hr
timing pump	3,000#/hr	5,400#/hr	9,600#/hr	18,000#/hr	35,000#/hr
homogenizer	3,000#/hr	5,400#/hr	9,600#/hr	18,000#/hr	35,000#/hr
clarifier	5,000#/hr	6,000#/hr	12,000#/hr	22,000#/hr	22,000#/hr
clarifier	-	-	-	-	22,000#/hr
surge tanks	100 gal	150 gal	300 gal	600 gal	1,000 gal
surge tank	150 gal	300 gal	300 gal	600 gal	1,000 gal
surge tank	-	-	300 gal	600 gal	1,000 gal
surge tank	-	-	-	-	25,000 gal

Table 4. (continued)

Item	Capacity or type by size of plant*				
	X (14,000 lbs per day)	2X (28,000 lbs per day)	4X (56,000 lbs per day)	8X (112,000 lbs per day)	16X (224,000 lbs per day)
Bottle handling					
case conveyor	gravity	power	power	power	power
case washer	5 CPM	10 CPM	5 CPM	5 CPM	10 CPM
case washer	-	-	10 CPM	15 CPM	20 CPM
bottle washer	20 BPM	28 BPM	54 BPM	110 BPM	160 BPM
bottle conveyor	power	power	power	power	power
glass filler	20 BPM	30 BPM	50 BPM	110 BPM	140 BPM
paper filler	35 BPM	45 BPM	60 BPM	50 BPM	110 BPM
paper filler	-	-	-	75 BPM	120 BPM
½ gal filler	10 BPM	10 BPM	16 BPM	16 BPM	33 BPM
Specialties					
can washer	-	-	-	4 CPM	6 CPM
can filler	hand	hand	hand	mechanical	mechanical
cream vat	50 gal	100 gal	200 gal	300 gal	600 gal
buttermilk vat	75 gal	150 gal	300 gal	600 gal	600 gal
mixing vat	-	-	-	400 gal	800 gal
skim vat	200 gal	400 gal	800 gal	1,500 gal	3,000 gal
pumps	2 ½ HP	2 3/4 HP	2 3/4 HP	3 3/4 HP	3 2 HP
incubator	jar	jar	jar	can	can
Cooler blowers	15,000 BTU's	25,000 BTU's	35,000 BTU's	50,000 BTU's	70,000 BTU's
General plant					
separator	1,400#/hr	2,000#/hr	4,000#/hr	6,000#/hr	2 6,000#/hr
timing pump	1,400#/hr	2,000#/hr	4,000#/hr	6,000#/hr	2 6,000#/hr
boiler	25 HP	30 HP	50 HP	85 HP	205 HP
compressor	2 7½ HP	2 7½ HP	2 15 HP	2 25 HP	2 40 HP
compressor	-	15 HP	25 HP	40 HP	2 40 HP
condenser	8.8 T	17.5T	33.2 T	67.8 T	149 T

Table 4. (continued)

Item	Capacity or type by size of plant*: X (14,000 lbs per day)	2X (28,000 lbs per day)	4X (56,000 lbs per day)	8X (112,000 lbs per day)	16X (224,000 lbs per day)
ice builder	4,600 lbs	9,000 lbs	19,200 lbs	36,000 lbs	71,000 lbs
pumps	2 1 HP	2 2 HP	2 3 HP	2 5 HP	3 10 HP
air compressor	9.3 CFM	9.3 CFM	24.3 CFM	37.0 CFM	43.3 CFM
air compressor	-	4.9 CFM	9.3 CFM	16.4 CFM	43.3 CFM
acid sink	S.S.	S.S.	S.S.	S.S.	S.S.
acid dispenser	sulfuric	sulfuric	sulfuric	sulfuric	sulfuric
bottle shaker	12 bottle	24 bottle	24 bottle	36 bottle	36 bottle
centrifuge	12 bottle	24 bottle	24 bottle	36 bottle	36 bottle
water bath	24 bottle	24 bottle	24 bottle	36 bottle	36 bottle
bottle washer	12 bottle	24 bottle	24 bottle	36 bottle	36 bottle
acidity tester	milk	milk	milk	milk	milk
pipe wash tank	10 ft	10 ft	12 ft	12 ft	12 ft
disc washer	painted	painted	painted	painted	painted
CIP unit	3/4 HP	1 HP	2 HP	3 HP	5 HP
floor scrubber					
wash sink					
well pump	2 HP	3 HP	7½ HP	15 HP	25 HP
water tank	220 gal	315 gal	750 gal	1,500 gal	3,000 gal
chlorinator					

*Symbols and abbreviations are used as follows: lbs for pounds, CPM for either cans per minute or cases per minute, #/hr for pounds per hour, HP for horsepower, gal for gallons, HTST for high temperature short time pasteurizer, BPM for bottles per minute, BTU's for British thermal units, T for tons of refrigeration, CFM for cubic feet of air per minute, S.S. for stainless steel, ft for feet, and CIP unit for clean-in-place unit.

with a fewer number of larger tanks. However, larger numbers of tanks allowed greater flexibility of operation. Less time elapsed during filling and standardizing a smaller tank. A greater variety of products could be mixed and standardised in the holding tanks at the same time.

The number of raw milk holding tanks in the model plants was determined from the trend established in an analysis of the numbers in the base plants.

Processing and Bottling Equipment

This equipment was sized to allow processing of the average daily output between 8:00 A.M. and 2:30 P.M. with the HTST pasteurizer operating at the stated capacity and the bottle washing and filling equipment operating at 80 percent of maximum capacity. This allowed the preparation of the equipment and the processing and packaging of the product in an eight and a half hour work shift.

Plants X and 16X did not meet this standard. For plant X, gaps in available sizes of bottle fillers resulted in a choice of a filler capable of filling the day's output in less than six hours. In other words, plant X had excess filler capacity. For 16X, the available glass bottle fillers were not large enough to permit processing in a six and a half hour period. These deviations from the adopted standard also existed in the corresponding base plants.

Minor adjustments were made in the choice of processing equipment to match more closely the capacities of the various individual pieces. For instance, the capacity of the pasteurizing equipment in plant X was increased to match more closely the capacities of the bottle filling equipment.

Surge Tanks

These tanks were sized so the smallest tank would hold the contents of the largest specialty product vat. In the model plants, the contents of the largest specialty vat was buttermilk when processed every other day. The total capacity was selected to allow constant operation of the HTST pasteurizer. The number of tanks in each size of model plant was determined by the trend established by analysis of the numbers in the base plants.

Specialty Vats

These vats were sized to permit processing creams, buttermilk, and chocolate drink every other day, and half-and-half daily. Cream was accumulated and standardized in a vat also used in the preparation of multivitamin milk. Chocolate drink and half and half were mixed in one of the raw milk holding tanks. Skim milk was accumulated in a vat in the smaller plants and in one of the raw milk holding tanks in the two larger plants. All products were short time pasteurized.

Separator

This item was sized to handle necessary separation in about a three to four hour period. Thus, separation was completed and the product standardized in time for pasteurization the same day in the product sequence selected for use in the model plants.

Boiler

The plant boiler was sized to meet the maximum anticipated load. The maximum load was figured as the combined loads of all plant equipment requiring steam. Using this standard, the boiler had considerable reserve capacity for most operations.

Refrigeration Equipment

The total refrigeration load consisted of the combined needs of the cooler and the ice builder. The load of the ice builder was the cooling necessary for the pasteurizer and the cooling required for the raw milk plate cooler. Raw milk was received in cans at 60 degrees and cooled to 40 degrees. Pasteurized milk left the regeneration section at 70 degrees and was cooled to 38 degrees. Thus, the daily load of the ice builder was calculated as 32 BTU's per pound of milk pasteurized and 20 BTU's per pound of milk received.

The average daily load of the cooler depends a lot upon the way workers keep the doors closed. For the models, the heat leak through the walls, ceilings, and floors with an average of 30 degrees temperature differential was estimated from information in Farrall (18,p. 118). This estimate was then increased 25 percent for a uniform estimate of the extra loss through open doors.

The compressors were sized to handle the total load in 12 hours of operation out of every 24 hours. Plants paying for electricity on a demand basis might prefer equipment to operate 15 to 18 hours a day to even out electricity consumption. However, the longer operating day gave less reserve capacity for future expansion or emergency situations.

The condenser was sized to match the total capacities of the compressors.

Ice Builder

The ice builder was sized to store enough ice for a complete day's operation. Since compressors normally run during the operating day, this gave about a 24 hour ice reserve.

Labor and Equipment Utilization Schedules

Labor and equipment utilization schedules were prepared for each model plant (Figures 12, 13, 14, 15, and 16). They were developed to check the suitability of the equipment selected for the model plants and to assist in the planning of plant processing crews and their assignments.

Equipment Operation and Utilization Schedules

Plant processing operations could not be scheduled until additional plant procedures and processing assumptions were defined.

Receiving of raw milk was assumed to commence by 7:30 A.M. About 80 percent of the average receipts were received daily, seven days a week. Thus, less overnight raw milk storage capacity was required. The rest of the average daily receipts was ordered as needed and processed the same day it was delivered.

Receiving was not scheduled at maximum capacity because of anticipated irregularities in the arrival of the milk trucks. On

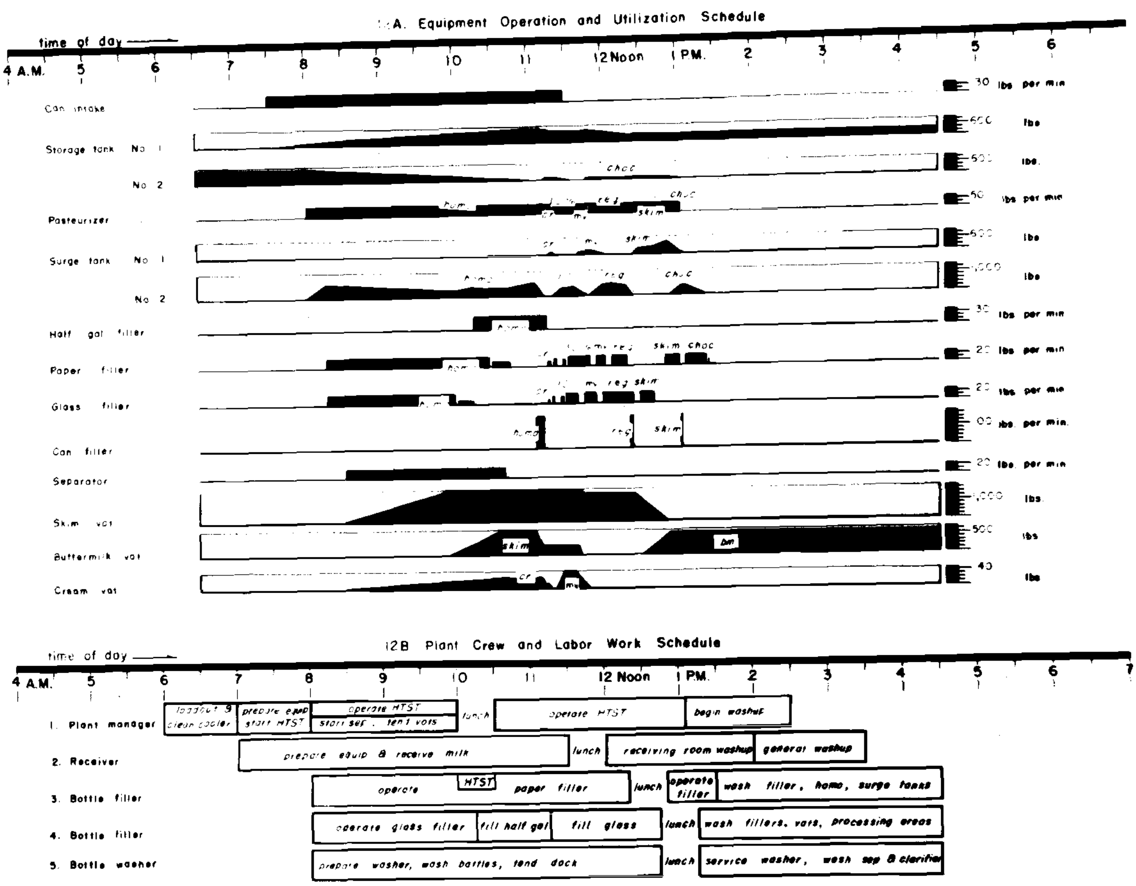


Figure 12. Labor and equipment operation and utilization schedules for plant X with can intake and glass and paper output.

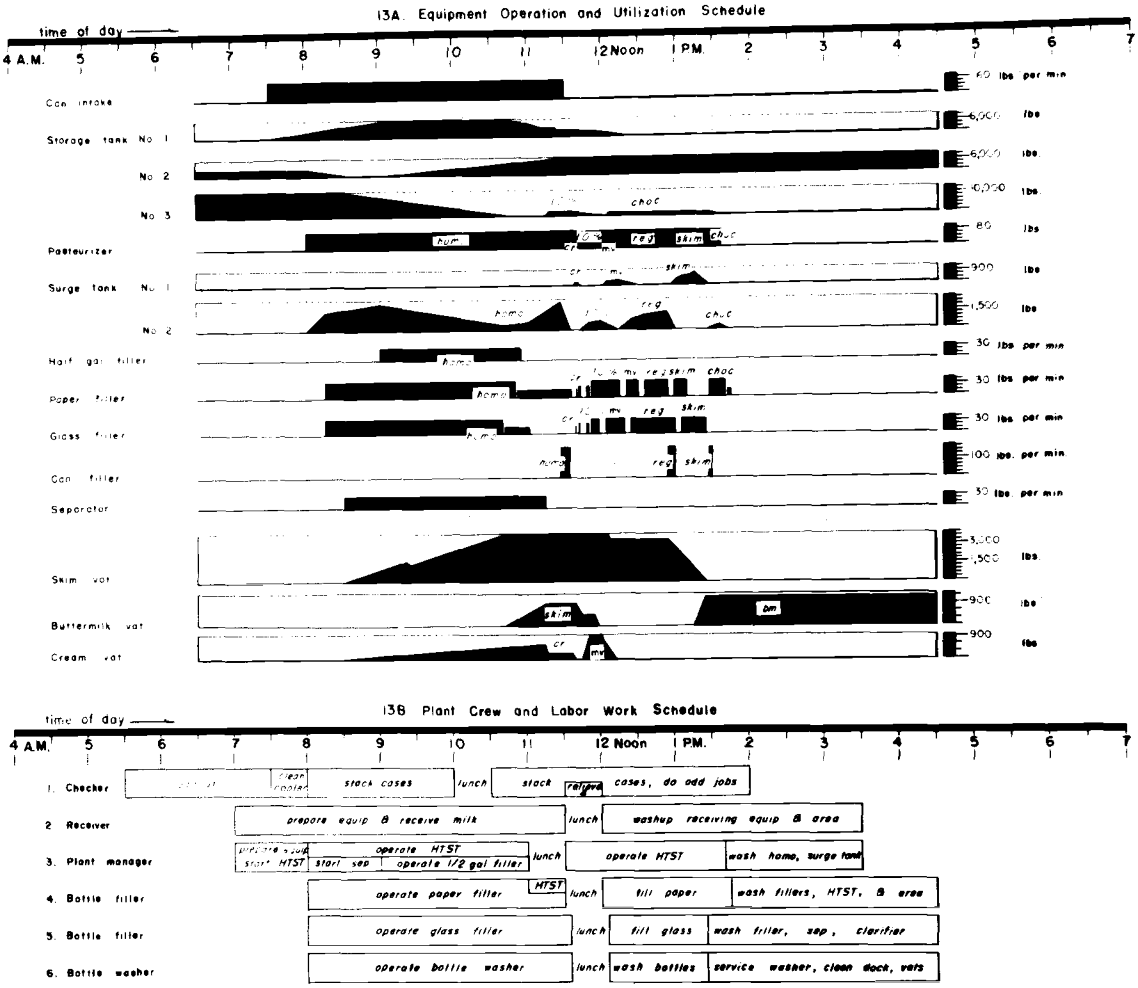


Figure 13. Lobor ond equipment operation and utilization schedules for plant 12X with can intake and glass and paper output.

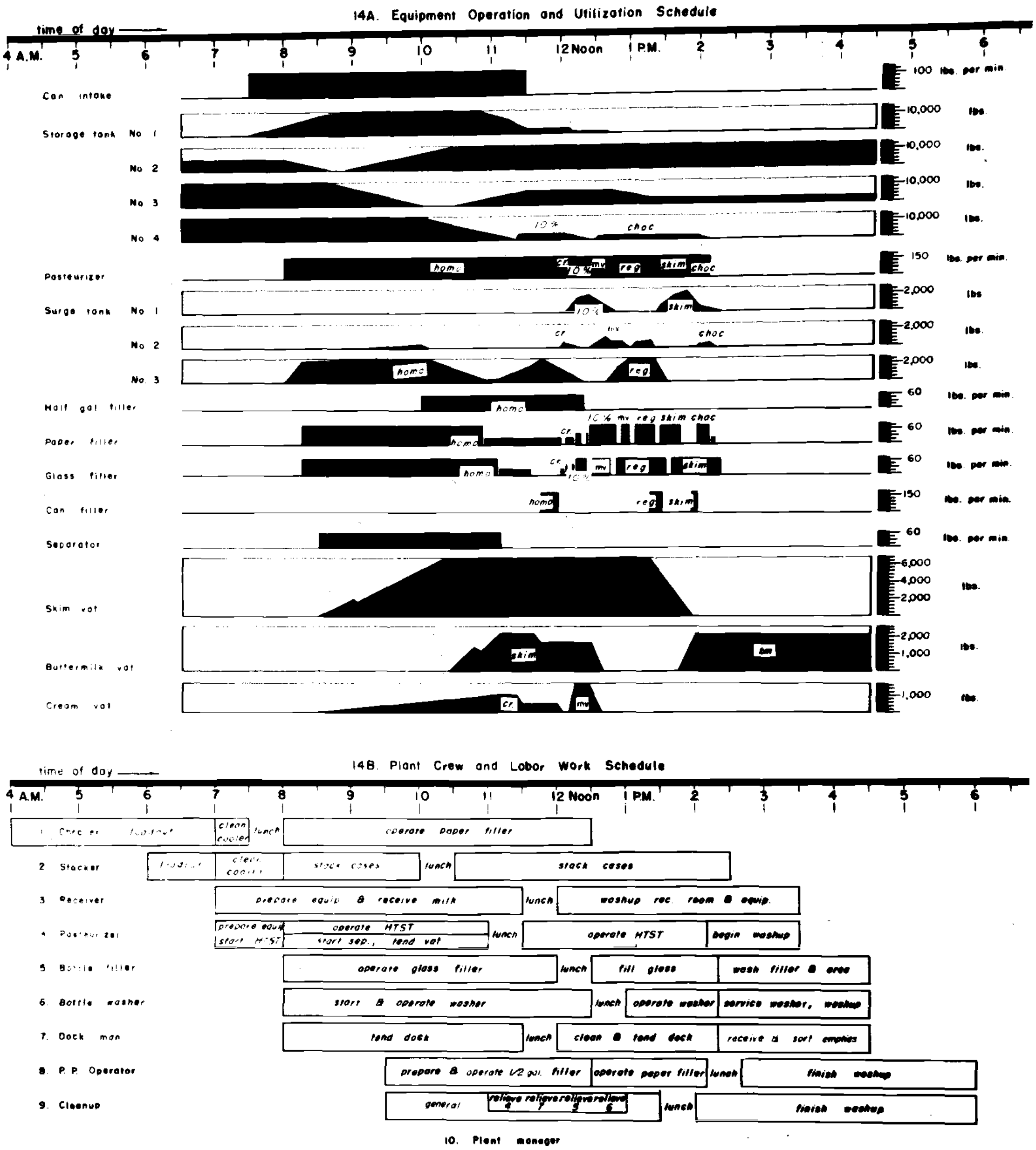


Figure 14. Labor and equipment operation and utilization schedules for plant 4X with can intake and glass and paper output.

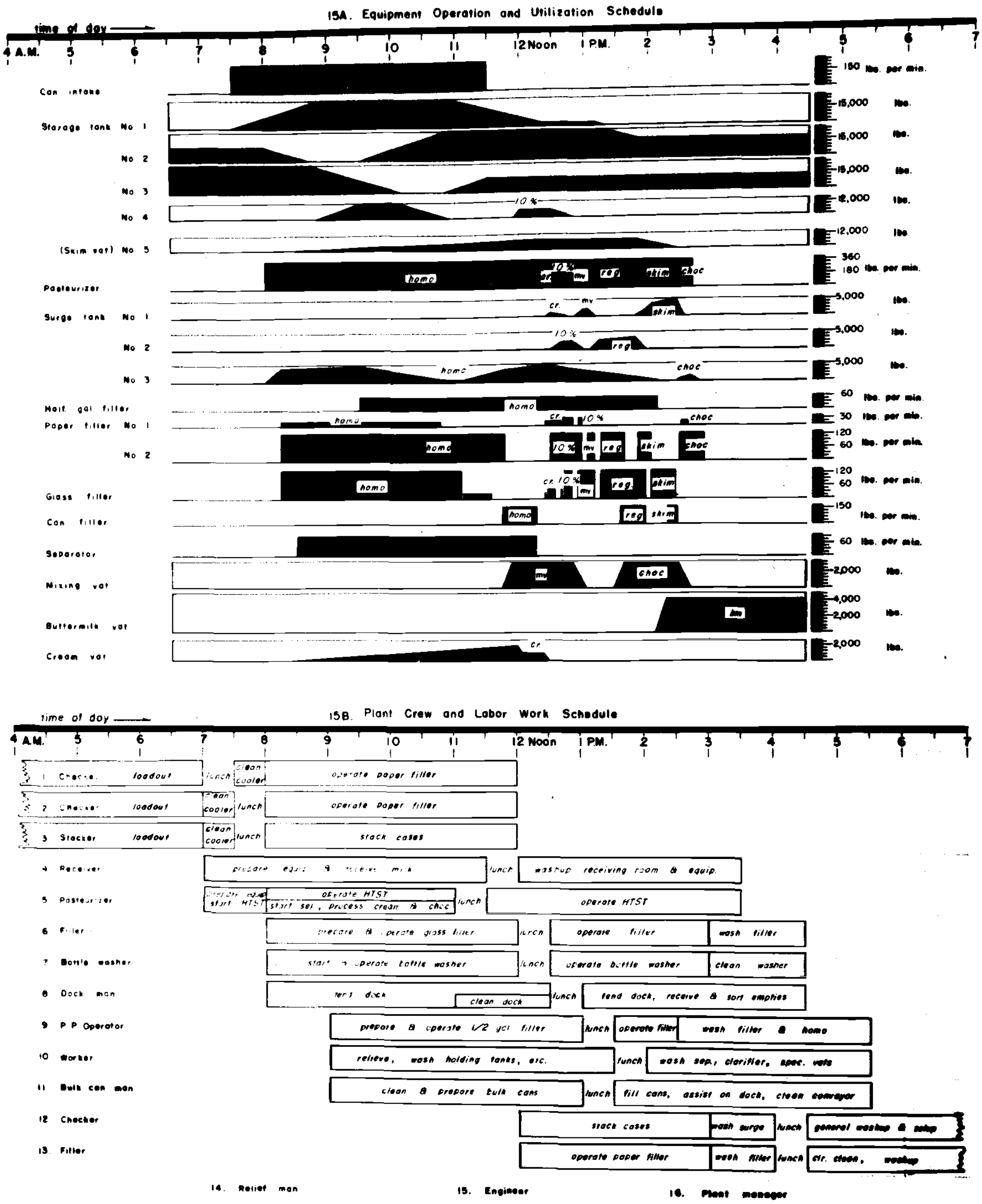


Figure 15. Labor and equipment operation and utilization schedules for plant 6X with can intake and glass and paper output.

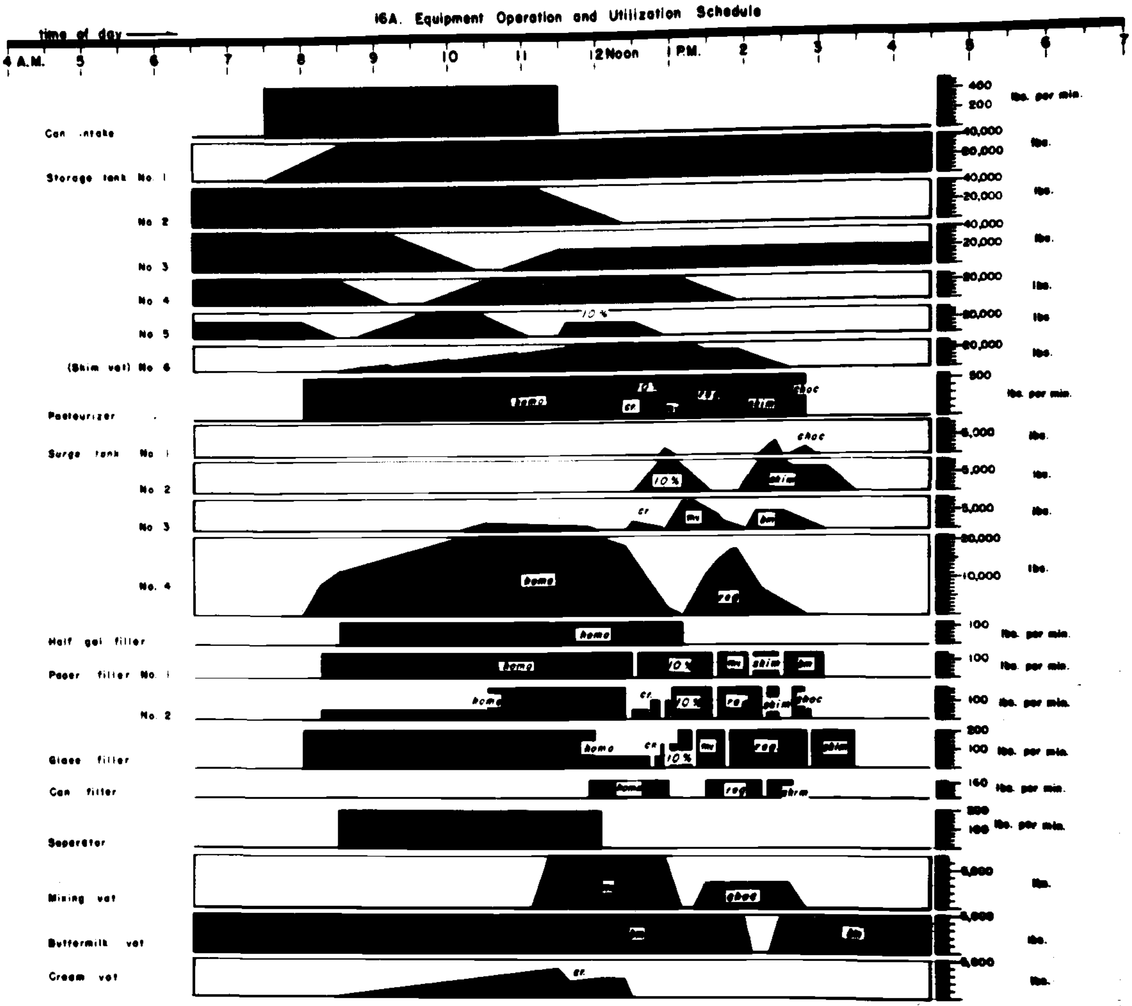
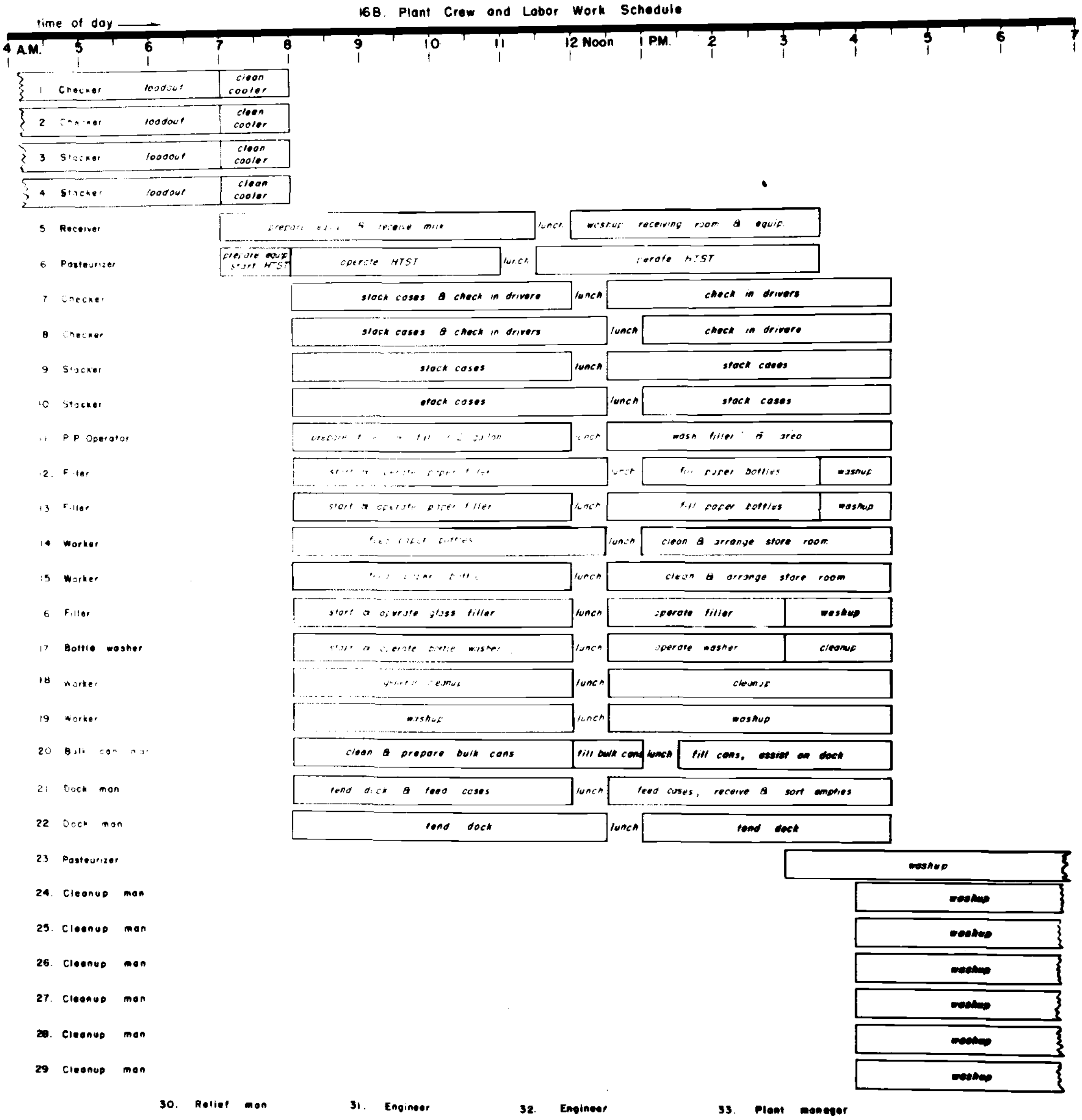


Figure 16. Labor and equipment operation and utilization schedules for plant 16X with can intake and glass and paper output.

16B. Plant Crew and Labor Work Schedule



the other hand, receiving was assumed to continue during the waiting periods while tanks of milk were standardized and the overnight holding tanks washed. Receiving during these periods was possible because of the reserve storage space in the receiving tank and the operation of the separator.

The short time pasteurizer was assumed to operate at its rated capacity. All pieces of bottle handling equipment were assumed to operate at 80 percent of the rated capacity of the manufacturer. All tanks and vats were assumed to hold the volume listed by the manufacturer although, in actual practice, they usually held up to ten percent more.

All products were pasteurized by the high temperature short time method. The processing order for the products was homogenized milk, cream, half and half, multivitamin milk, regular milk, skim milk, and chocolate drink. The chief concern in choosing a processing sequence was to allow the residual butterfat in higher testing products to be rinsed out by lower testing products. This sequence also permitted early washing of the homogenizer on the odd days when chocolate drink was not processed.

Preparation of processing equipment was assumed to begin around 7:00 A.M. The pasteurizer was assumed to commence operating about 8:00 A.M. and run continuously until the daily product was processed. The breaks in the bar representing the pasteurizer in the schedules were to indicate the times of day for changes between products.

The homogenizer operated while processing homogenized milk, half and half, multivitamin milk, and chocolate drink.

The bottle filling operation was generally assumed to commence about 15 minutes after starting the pasteurizer. For 16X, the glass filler began immediately after starting the pasteurizer because a filler large enough to operate within the time schedule used in other plants was not available (Figure 16A). The time required for changing from one product to another was assumed to be about five minutes for all sizes of fillers. The time necessary for changing the size of the container was assumed to be two minutes.

The separator was started about 8:30 A.M. and operated until the skim milk and cream needs were filled. Cream was accumulated in a holding vat for standardization, one day for 20 percent cream and the next for 32 percent cream. Cream also was pumped from this vat into a raw milk holding tank for standardization as half and half. Multivitamin was prepared in the empty cream vat in the smaller plants and in a mixing vat in the larger sizes of plants. Skim milk was accumulated in the skim vat and the buttermilk vat in the three smallest plants. In the two larger plants, skim milk was accumulated in a raw milk holding tank. Skim milk was pumped from the accumulating vat for use in standardizing various fluid products and for use in chocolate drink and buttermilk. Buttermilk was generally set every other day and bottled the following day. In 16X, this occurred daily since a standard vat large enough for an every-other-day set was not available.

After the establishment of the above standards, the equipment operation schedules were developed as follows: Across the top of the schedule was placed a time of day scale. The periods of operation for the receiving, processing, bottle filling, and separating equipment were plotted against the time scale to show how long each operation lasted. For instance, the half gallon filler in plant X was operated between 10:15 and 11:15 A.M. (Figure 12A). The paper filler in this same plant, on the other hand, commenced filling quarts of homogenized milk at 8:15 A.M. and was switched to half pints at 10:30 A.M. From 10:45 to 11:15 A.M., the filler was idle. At 11:15 A.M., cream was bottled in half pints for about three minutes and, then, after the change over, in pints for about three minutes. After another five minute change over period, pints of half and half were bottled, and, then, quarts of half and half. Multivitamin milk was bottled for seven minutes, and, after another change over, regular milk was bottled for 13 minutes. At this time, 12:20 P.M., the filler operator went to lunch. After lunch, the skim milk was ready to bottle. Finally, chocolate drink was bottled. The filler was ready to wash and service by 1:30 P.M.

For tanks and vats, filling and emptying rates were graphed against the same time scale. Thus, for any hour of the day, the amount of product in any of the tanks or vats was easily determined by sight. For instance, the number two surge tank in plant AX was empty until about 9:10 A.M. (Figure 14A). At that time, the overflow of homogenized milk from surge tank number one started entering at the rate of five pounds a minute. At 10:00 A.M., however, the half gallon filler was started and the level of the milk declined at the rate of 51 pounds a minute. The level dropped from 250 pounds to zero in about five minutes. The tank was empty until 12:00 noon. At that time, about 500 pounds of cream was pumped in from the pasteurizer only to be drained back out into the fillers. At 12:27 P.M., multivitamin milk began to enter the tank. At 12:40 P.M., the pasteurizer switched from multivitamin to regular milk. Therefore, the level of multivitamin milk dropped from about 1200 pounds at 12:40 to about 730 pounds at 12:50 P.M. At that time, the glass filler was switched to another product. The paper filler then emptied the tank between 12:54 and 1:01 P.M. Shortly after, the tank began to fill again with the overflow of regular milk from surge tank number one. At 1:23 P.M., it was empty again and remained that way until 1:58 P.M. when it began to receive chocolate drink. Finally, at 2:15 P.M., it was empty and ready to wash.

Thus, the developement of these schedules proved valuable for checking the selection of plant equipment and scheduling their operation. Equipment operating periods and down time were readily apparent. For tanks and vats, the proportion of the capacity utilized and, hence, the suitability of their size were easily determined. Equipment misfits and improper scheduling of plant operations were easy to detect and correct.

Plant Crew and Labor Work Schedules

Schedules also were of value in developing the plant crew and assigning them their major tasks (Figures 12B, 13B, 14B, 15B, and 16B). For instance, in plant 8X (Figure 15B), the operator of the pasteurizer arrived at work an hour before the processing operation commenced. His duty was to chemically sterilize equipment before operation began. About 8:00 A.M., he started the pasteurizing equipment on homogenized milk. When the pasteurizing operation got underway, he started the separator. Between 11:00 and 11:30 A.M., he ate lunch. After lunch, he shut down the separator and changed the products being pasteurized. At 12:25 P.M., the cream started through the pasteurizer. In five minutes, half and half was started through. After that, multivitamin milk, regular milk, skim milk, and chocolate drink were pasteurized in that order. Finally, at 2:45 P.M., the processing was completed and the equipment ready to wash. At 3:30 P.M., the operator of the pasteurizer went home while members of the cleanup crew took over the washup of the equipment. Thus, with the help of the equipment operation schedules, the duties of each member of all the processing crews were developed.

The labor requirements for washing and preparing equipment in the smaller plants were adapted from the information presented in Conner, Spencer, and Pierce (15, p. 19-24), Carter, Brundage, and Bradfield, (13, p. 41), and Scott (39, p. 16, 19, 20, and 23). For the larger plants, the crews were scheduled from information obtained in the interview of plant managers. In all cases, the washup and setup labor requirements were scheduled to fit the equipment operation schedule.

In Table 5 is listed the number of men shown in Figures 12B, 13B, 14B, 15B, and 16B, and the total man hours per year required in each

Table 5. The number of men and total man hours per year required in five model plants with can intake and glass and paper output, Oregon conditions, 1956

Item	Plant size X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Number of men	5	6	10	16	32
Total man hours/year	10,400	12,480	20,800	33,280	66,560

model plant.

When the syntheses of plant equipment, plant crew, and labor work schedules were completed, they were reviewed for reasonableness by the plant managers of corresponding base plants.

Supplies

Bottle, Case, and Can Supplies

A schedule of supplies required by each model plant is shown in Table 6. All bottle, cap, case, and can supplies were held constant per unit of output. Thus, the quantity of each of these items of supply for each plant was twice the quantity for the preceding size of plant.[4] All cap and paper bottle supplies were determined by adding

[4]The records of the base plants indicated that larger plants probably used fewer of these supplies per unit of output than the smaller plants. This, of course, would be due to a smaller percentage of losses and breakage in the larger plants. However, records were not complete enough to permit accurate analysis. No other research was found to substantiate this impression. Only Henry, Bressler, and Frick commented on the possibility. They quoted Clement as saying such losses were related to general plant and labor efficiency rather than to the size of the operation (22, p. 34-36). Therefore, the rates for loss and damage in this study were considered the same for all sizes of plants.

Table 6. Schedule of supplies for five model plants with glass and paper output, Oregon conditions, 1956.

Item	Units by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Half gals*	121,043	242,086	484,172	968,344	1,936,688
Staples*	242,086	484,172	-	-	-
Wax, lbs*	-	-	27,606	55,212	110,424
Glue, lbs*	-	-	461	922	1,844
Wire, lbs*	-	-	209	418	836
Paper qts*	628,381	1,256,762	2,513,524	5,027,048	10,054,096
Paper pts*	48,430	96,860	193,720	387,440	774,880
Paper ½ pts*	290,700	581,400	1,162,800	2,325,600	4,651,200
Glass qts	26,980	53,960	107,920	215,840	431,680
Glass pts	680	1,360	2,720	5,440	10,880
Glass ½ pts	3,730	7,460	14,920	29,840	59,680
Caps*	640,285	1,280,570	2,561,140	5,122,280	10,244,560
Cases	310	620	1,240	2,480	4,960
Cans	20	40	80	160	320
General	-	-	-	-	-

*These items include an allowance of two percent for waste and damage.
**Physical quantities for general supplies were not determined. Dollar values for these costs are shown later (Table 24).

an extra 2 percent to the number of units of output requiring these supplies.

Before the usage of bottles, cases, and cans could be determined, standard lengths of life had to be adopted. The following trippage standards were used for all sizes of plants: Bottle trippage was considered to be 20 trips for all bottles. This figure was developed from the findings of other researchers.[5] No conclusions on bottle

[5]Other researchers varied widely in their reports. Henry, Bressler, and Frick allowed 45 trips per bottle (22, p. 36). Conner, Spencer, and Pierce used 30 trips for quarts and 24 trips for half pints (15, p. 46). Webster allowed 50 trips on wholesale and 20 trips on retail for all sizes of bottles (51, p. 80). Herrman and Whatley reported an average of 22 trips and a range from 17 to 29 trips for seven plants in the Memphis, Tennessee market (23, p. 13). Cook

trippage could be drawn from the records taken from the base plants because adequate beginning and ending inventories were not kept.

Cases were allowed 300 trips each. Both Webster (51, p. 80) and Conner, Spencer, and Pierce (15, p. 46) used this figure.[6]

Bulk can trippage was assumed to be 400 trips per can. This figure was used by both Conner, Spencer, and Pierce (15, p. 46) and by Webster (51, p. 8).[7]

With both cases and bulk cans, adequate inventories were not available for accurately estimating the trippage experience in the base plants.

General Plant Supplies

Base plants could not supply consumption data in either physical or monetary quantities for individual items such as soaps, cleaning powders, refrigerant, lubricants, laundry, and uniforms purchased. Reports from other researchers were not helpful in determining general supply expense for different sizes of plants.[8] Therefore,

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estimated bottle trippage in Wisconsin to vary from 4 to 28 depending upon the length of haul away from the plant (16, p. 25).

[6]Both researchers used 300 trips for quart cases, but Webster allowed only 240 trips for the smaller sizes. These were cases for glass bottles. Plant managers in this area felt cases for paper bottles had a longer life than the cases for glass bottles. However, the 300 trip figure was used since a more accurate estimate of case life in this area was not available.

[7]Although Webster used this trippage for eight-quart and forty-quart cans, he allowed only 300 trips for twenty-quart cans. However, on the basis of the number of cans purchased during the year, the base plants experienced nearer the 400 trips per can.

[8]Webster allowed 0.1 cent per quart of sales for general plant operating supplies (52, p. 14). A flat rate per quart such as this did not fit the data obtained from the records of the base plants. Monroe and Walker calculated general supplies by the equation $Y = \$6.65 + \$0.70X$, where Y equals total expenditures and X equals units

no physical quantities were established for these general plant supplies. Only a lump sum estimate in dollars and cents was presented for each size of plant (Table 24).

Fuel Oil

Fuel oil consumption was estimated by determining the annual heat requirement for each plant and converting this requirement into its fuel equivalent (Table 7). The annual requirement was determined by estimating an average hourly usage rate for each heat consuming piece of equipment. The hourly rate was multiplied by the average number of hours in use per day and again by the number of days in use during the year.

The hourly usage rate for can washers, case washers, and bottle washers, was determined by multiplying the manufacturer's boiler horsepower rating by 33,500 BTU's per horsepower as shown in Farrell (18, p. 95).[9] The hours per day of operation included an hour heat up period before actual operation began. Webster also used this method for obtaining plant operating steam requirements (51, p. 57).

The heat for pasteurization was calculated as 32 BTU's per pound of milk received. This figure was based on 75 percent regeneration

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in 10,000 pounds of milk per week (27, p. 40). This formula gave results below those experienced in the base plants.

[9]The manufacturer's horsepower rating for case, can and bottle washers was based on the amount of heat required to bring the equipment up to operating temperature in one hour. Heat of operation after the warmup period varied between different makes of equipment. Generally, however, the heat required for operation was either near or equal to the boiler horsepower rating. For this study, it was considered equal in all cases.

Table 7. Estimated heat requirements and fuel oil consumption for five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item	Heat requirements by plant size				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Can washer, CPM	2½	3	4	8	16
hourly usage, BTU's	335,000	452,000	670,000	837,500	1,675,000
hours of operation[1]	3.5	4.0	4.0	4.0	4.0
Daily usage, BTU's	1,172,500	1,808,000	2,680,000	3,350,000	6,700,000
Specialty can washer, CPM	2½	3	4	3	6
hourly usage, BTU's	335,000	452,000	670,000	452,000	804,000
hours of operation[1]	.3	.4	.6	2.6	2.6
Daily usage, BTU's	100,500	180,800	402,000	1,175,200	2,090,400
Case washer, CPM	5	10	5	5	10
hourly usage, BTU's	83,750	167,500	83,750	83,750	167,500
hours of operation[1]	4.0	5.0	5.5	5.6	7.3
Daily usage, BTU's	335,000	837,500	460,625	469,000	1,222,750
Case washer, CPM			10	15	20
hourly usage, BTU's			167,500	251,250	335,000
hours of operation[1]			5.0	5.6	6.8
Daily usage, BTU's			837,500	1,407,000	2,278,000
Bottle washer, BPM	20	28	54	110	160
hourly usage, BTU's	201,000	268,000	402,000	670,000	938,000
hours of operation[1]	4.0	5.0	5.5	5.6	7.3
Daily usage	804,000	1,340,000	2,211,000	3,752,000	6,847,400
HTST, daily lbs. of milk	14,000	28,000	56,000	112,000	224,000
Daily usage, 32 BTU's/lb.	448,000	896,000	1,792,000	3,584,000	7,168,000

Table 7. (continued)

Item	Heat requirement by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Half gallon filler, BPM			13	13	26
hourly usage, BTU's			48,520	48,520	97,040
hours of operation			2.4	4.7	4.7
Average daily usage, BTU's			116,448	228,044	442,088
Space heat for offices, lockers, and processing area					
floor space, sq. ft.	3,680	4,576	5,992	10,132	14,292
Average daily usage at 335 BTU's/sq. ft.	1,232,800	1,532,960	2,007,320	3,394,220	4,787,820
Washup					
floor space, sq. ft.	3,752	5,156	8,100	12,392	18,272
Average daily usage at 335 BTU's/sq. ft.	1,256,920	1,727,260	2,713,500	4,151,320	6,121,120
Heat loss, 1" covering on pipes					
approximate pipe footage	360	380	450	420	480
loss, BTU's/lin. ft/hr.	99	99	99	160	160
operating time, hrs.	9	10	14	14	24
Daily usage, BTU'S	320,760	376,200	623,700	940,800	1,843,200

Table 7. (continued)

Item	Heat requirement by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
	Estimated fuel consumption by size of plant				
Annual usage, BTU's[2]	1,597,437,300	2,451,507,200	3,886,153,480	6,189,161,840	10,948,300,800
Gallons of oil at 100,000 BTU's/gal[3]	15,974	24,515	38,862	61,892	109,483

[1]Hours of operation also included an hour before operation began while equipment was reaching operating temperature.

[2]Annual usage was obtained by multiplying receiving can washer daily usage by 365 days and all other daily usages by 260 days.

[3]This heat factor was 70 percent of the theoretical heat in a gallon of oil to allow for a boiler operating at 70 percent efficiency.

in the HTST pasteurizer. Milk left the regeneration section at 130 degrees and was heated to 162 degrees.

Space heat was estimated as an average of 335 BTU's per day per square foot of floor space to be heated. This was an adaptation of the method demonstrated by Webster (51, p. 57). He allowed an average of one pound of steam per three square feet of floor space.[10] For use in this study, the steam was converted into BTU's as shown in Farrall (18, p. 93).

Average daily wash water heat was estimated as 335 BTU's per day per square foot of processing area. Henry, Bressler, and Frick were the first to report this method of estimating wash water heat (22, p. 35). Again, for use in this study, the reported heat requirement was changed from steam to BTU's.

Heat loss estimates were based on surface radiation data reported in Farrall (18, p. 108). This method of estimating heat loss was substantiated by data found in a Clayton steam generator sales engineering hand manual.

After all the daily usages were calculated, the annual requirement was estimated by multiplying the average daily usages by days of operation per year. Receiving room equipment was operated 365 days per year. All other equipment operated 260 days per year. The

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[10]This estimate was checked by the formula from Heating and Air Conditioning by Allen, Walker, and James as reported in Bartlet and Gothard (3, p. 46). Daily heat consumption was calculated by the following formula: degree days for the location of the plant, multiplied by cubic feet of space over 1,000, multiplied by BTU's per degree day, all divided by operating days per year. The Willamette Valley degree days were taken as 4,380; BTU's per degree day as 890; and operating days as 260.

annual usage was converted into fuel oil equivalent at the rate of 100,000 BTU's per gallon of oil. This figure was 70 percent of the theoretical heat reported in a gallon of oil. Thus, the boilers were considered to operate at 70 percent efficiency.[11]

Electricity

The consumption of electric power was estimated from the hourly usage rates of the lights and the electrically driven equipment in the model plants (Table 8). To allow for motor inefficiency, all motor horsepower ratings were converted into watts at the rate of 1,000 watts rather than the theoretical 746 watts per horsepower.[12] The hourly usage rates for the lights and motors were multiplied by the average number of hours of operation per day and again by the number of operating days per year.[13] Estimated annual power consumption for each major user of electricity is shown in Table 9.

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[11]Reports on boiler efficiency do not agree. Henry, Bressler, and Frick estimated that boilers in small plants would operate at 60 percent efficiency, and in larger plants, 65 percent (22, p. 34). Conner, Spencer, and Pierce (15, p. 20) and Webster (51, p. 57) each used a heat factor only 75 percent of the reported theoretical heat in a gallon of fuel oil, presumably, to allow for boilers operating at 75 percent efficiency. Equipment manufacturers usually guarantee boilers to operate at 80 percent efficiency when properly fired. A representative of an engineering consultant firm recommended the use of 70 to 72 percent and never over 75 percent efficiency. For the base plants, most of these ratings were too high. When the method used in this study was checked on the base plants where actual fuel consumption was known, all but one of the boilers appeared to operate nearer 50 percent than the manufacturer's guaranteed 80 percent. The one exception was a steam generator operating about 72 percent efficient.

[12]Henry, Bressler, and Frick also used this conversion rate (22, p. 30).

[13]Researchers have varied in their estimates of power consumption. Monroe and Walker used linear regression analysis of base plant data

Table 8. Estimated hourly consumption of electricity for lights and equipment in five model plants with can intake and glass and paper output, Oregon conditions, 1956.*

Item	Watts per hour by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Receiving					
conveyor			1,000	5,000	6,000
can washer	5,500	6,000	8,500	9,000	12,000
pump	250	500	1,000	1,000	5,000
agitators	1,000	1,500	3,000	4,750	15,500
lights	500	750	750	1,000	1,250
Processing					
pump	250	500	750	1,000	2,000
clarifier	1,500	2,000	3,500	4,000	7,000
homogenizer	10,000	25,000	50,000	75,000	100,000
agitators	500	500	1,000	1,000	5,000
lights	250	250	250	250	250
Bottle handle					
conveyor		1,000	2,500	7,000	10,000
washer	5,500	6,000	6,000	9,000	12,000
glass fill	1,250	1,250	1,250	1,333	1,500
paper fill	333	500	750	1,250	2,250
half gal fill	500	500	3,333	3,333	3,833
case washer	2,000	3,000	2,000	2,000	3,000
case washer	-	-	3,000	5,000	7,500
conveyor	500	500	750	1,250	2,000
lights	1,000	1,000	1,250	1,250	1,250
Specialties					
can washer	5,500	6,000	8,500	8,500	9,000
agitators	1,000	1,500	2,000	3,250	4,500
lights	250	250	250	250	250
Cooler					
blowers	750	1,000	1,500	2,000	4,000
lights	500	1,000	1,250	1,500	1,500
General plant					
separator	1,000	2,000	2,500	3,000	6,000
boiler	1,250	1,500	2,000	3,750	10,500
compressors	15,000	30,000	55,000	90,000	160,000
pumps	2,000	4,000	6,000	10,000	30,000
air	2,000	3,000	7,000	10,500	20,000
CIP unit	750	1,000	2,000	3,000	5,000
well pump	2,000	3,000	7,500	15,000	25,000
lights	4,500	6,250	7,000	8,250	11,000

*To allow for motor inefficiency, all equipment motors were assumed to consume 1000 watts rather than the theoretical 746 watts per horsepower.

Table 9. Estimated annual consumption of electricity by lights and equipment in five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
	Annual killowatt hours by size of plant				
Receiving					
conveyor			1,314	6,570	8,103
can washer	7,428	7,884	11,169	11,826	16,206
pump	338	657	1,314	1,314	6,752
agitators	1,875	2,890	5,859	9,647	33,092
lights	1,277	1,916	2,327	3,102	3,878
Total	10,918	13,347	21,983	32,459	68,031
Processing					
pump	390	806	1,228	1,716	3,640
clarifier	1,833	2,444	4,277	5,304	11,648
homogenizer	10,140	25,350	50,700	81,900	135,200
agitators	611	611	1,222	1,326	8,320
lights	618	618	748	878	1,202
Total	13,592	29,829	58,175	91,124	160,010
Bottle Handle					
conveyor		1,612	5,005	14,742	37,440
washer	4,290	6,552	7,800	11,700	21,216
glass fill	975	1,365	1,625	1,733	2,652
paper fill	346	676	1,112	1,820	3,334
half gal fill	130	260	2,080	4,073	4,684
case washer	1,560	3,276	2,600	2,600	5,304
case washer			4,446	7,280	11,115
conveyor	130	130	195	325	520
lights	2,470	2,470	3,738	4,388	6,012
Total	9,901	16,341	28,601	48,661	92,277
Specialties					
can washer	429	624	1,326	3,536	3,744
agitators	520	780	1,040	1,690	2,340
lights	618	618	748	878	1,202
Total	1,567	2,022	3,114	6,104	7,286
Cooler					
blowers	2,957	4,234	6,460	9,198	15,768
lights	1,642	3,832	5,703	7,118	9,308
Total	4,599	8,066	12,163	16,316	25,076

Table 9. (continued)

	Annual killowatt hours by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
General plant					
separator	546	1,456	1,820	2,964	6,084
boiler	1,625	2,418	3,484	6,435	21,294
refrigeration	39,756	78,418	137,702	229,665	427,290
air	1,716	2,574	5,824	9,009	16,640
CIP unit	78	104	208	312	520
well pump	3,016	4,524	11,310	22,620	39,000
lights	11,700	17,875	22,750	27,887	48,620
Total	58,437	107,369	183,104	298,892	559,448

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Plant Total, KWH	99,014	176,974	307,140	493,556	912,128

Water

In most of the base plants, water was obtained from plant wells. Therefore, adequate base data was not available for estimating the water requirements in the model plants. However, all base plants purchased the water used in the boilers from city water systems. The model plants were assumed to do the same. In a later section, a monetary allowance is estimated for the water used in the boilers in the model plants (Table 23).

Product Loss

In this study, the product loss was assumed to be 0.8 percent of the raw milk receipts in all sizes of plants.[14]

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to estimate the power consumption in their model plants (27, p. 40). The base plants in this study did not show a linear relationship between plant volume and power consumption.

Henry, Bressler, and Frick (22, p. 28-30) and Webster (51, p. 60) used the method of synthesizing power requirements demonstrated above. When this method was tested on the base plants where power consumption was known, the estimates for the larger plants approximated actual usage. For the smaller plants, however, the estimates were considerably below actual consumption. This indicates that smaller plants may be even less efficient in their utilization of electric power than was shown by this study.

[14]Reports on product losses have varied. Webster also used 0.8 percent loss (51, p. 67). Henry, Bressler, and Frick used one percent loss (22, p. 37). Conner, Spencer, and Pierce, on the other hand, estimated product loss by finished product (15, p. 28-29). Milk was estimated at 0.75 percent loss. Cream loss was 2.0 percent for light cream and 2.25 percent for whipping cream. Skim loss was 1.0 percent. Buttermilk loss was 1.8 percent.

Losses in the base plants fell on both sides of the selected 0.8 percent loss.

The Relationships of Physical Inputs Per Quart to Size of Plant

Physical Inputs Per Quart by Cost Elements

In the preceding section, the physical requirements and total inputs were presented for five model plants receiving milk in cans and bottling milk in both paper and glass bottles. These inputs are summarized in Table 10. Each physical input total was divided by the corresponding plant output in quarts of milk to obtain physical inputs per quart equivalent (Table 11).[15] The physical inputs per quart for the cost elements of labor, fuel oil, electricity, various supplies, building space, and milk loss were obtained in this manner. Then, unit inputs of each element were examined for a relationship to size of plant (Table 11).

Labor

Labor requirements per quart declined rapidly at first, and then ceased to decline as the size of the plant became larger (Table 11). Plant X required .3705 man minutes per quart of milk. Plant 2X used .2223 man minutes per quart, or only 60 percent of that used in plant X. Plant 4X hired .1853 man minutes per quart, or only 50 percent of that in plant X. Plants 8X and 16X both required .1482 man minutes per quart, or 40 percent of the requirement in plant X. Thus, the smaller plants had substantially higher unit labor inputs per quart than the two largest plants.

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[15] The term quart equivalent in this study refers to volume only.

Table 10. Summary of total physical inputs for five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item*	Total physical inputs by size of plant X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Labor, man min.	624,000	748,800	1,248,000	1,996,800	3,993,600
Utilities					
oil, gals	15,974	24,515	38,809	61,892	109,471
power, KWH	99,014	176,974	307,140	493,556	912,128
Supplies					
half gals**	121,043	242,086	484,172	968,344	1,936,688
staples **	242,086	484,172	-	-	-
wax, lbs**	-	-	27,606	55,212	110,424
glue, lbs**	-	-	461	922	1,844
wire, lbs**	-	-	209	418	836
paper, qts**	628,381	1,256,762	2,513,524	5,027,048	10,054,096
paper, pts**	48,430	96,860	193,720	387,440	774,880
paper ½ pts**	290,700	581,400	1,162,800	2,325,600	4,651,200
glass qts	26,980	53,960	107,920	215,840	431,680
glass pts	680	1,360	2,720	5,440	10,880
glass ½ pts	3,730	7,460	14,920	29,840	59,680
caps**	640,285	1,280,570	2,561,140	5,122,280	10,244,560
cases	310	620	1,240	2,480	4,960
cans	20	40	80	160	320
Bldg., sq.ft.	8,048	10,568	15,944	24,992	36,768
Milk loss, lbs	29,200	58,400	116,800	233,600	467,800

*Physical quantities were not determined for water and general plant supplies. Equipment could not be presented in additive terms, and there are no physical quantities for taxes, interest, or insurance.
**These items included an allowance of 2 percent for waste and damage.

Table 11. Physical inputs per quart equivalent for five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item*	Physical inputs per quart equivalent by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Labor, man min	.3705	.2223	.1853	.1482	.1482
Utilities					
oil, gals	.0095	.0073	.0058	.0046	.0041
power, watts	58.79	52.54	45.59	36.63	33.85
Supplies**					
half gals	.5100	.5100	.5100	.5100	.5100
staples	1.0200	1.0200	-	-	-
wax, lbs	-	-	.0040	.0040	.0040
glue, lbs	-	-	.000067	.000067	.000067
wire, lbs	-	-	.000030	.000030	.000030
paper qts	1.0200	1.0200	1.0200	1.0200	1.0200
paper pts	2.0400	2.0400	2.0400	2.0400	2.0400
paper ½ pts	4.0800	4.0800	4.0800	4.0800	4.0800
glass qts	.0500	.0500	.0500	.0500	.0500
glass pts	.1000	.1000	.1000	.1000	.1000
glass ½ pts	.2000	.2000	.2000	.2000	.2000
caps	1.1337	1.1337	1.1337	1.1337	1.1337
cases	.0002	.0002	.0002	.0002	.0002
cans	.0001	.0001	.0001	.0001	.0001
Bldg., sq.ft.	.0048	.0031	.0024	.0019	.0014
Milk loss, lbs	.0173	.0173	.0173	.0173	.0173

*Physical quantities were not determined for water and general plant supplies. Equipment could not be presented in additive terms, and there are no physical quantities for taxes, interest, or insurance.
**The quart equivalent used for each item of supply is shown in Table 15.

One of the reasons for lower labor unit inputs in the larger plants was that members of the processing and bottling crews generally operated equipment of a larger capacity. Hence, processing and bottling unit requirements declined (Table 12B). One man tended a 3,000 pound per hour pasteurizer in plant X (Table 4). His counterpart in plant 16X tended a 35,000 pound per hour pasteurizer. Efficiency increases of this same nature were observed also in other worker positions (Figures 12, 13, 14, 15, and 16). The man receiving milk in plant X dumped up to 4,000 pounds of milk per hour. In plant 16X, he dumped up to 64,000 pounds per hour. The bottle washer operator in plant X washed up to 20 bottles per minute, but in 16X, he washed as many as 145 bottles a minute. Similar increases in efficiency occurred with the men who operated the bottle fillers, the separators, the refrigeration equipment, and the boilers. In these cases, the output per man hour was related to the size of the investment, hence, the capacity of the equipment operated by a given quantity of labor.

A second source of higher labor costs in the two smallest plants was incomplete utilization of the labor and equipment. For instance, as indicated in Figures 12A and 13A, several shut downs of the bottle fillers occurred during the processing day. In addition, the processing day ended earlier. Hence, operators of these pieces of equipment not only filled fewer units per hour than similar operators in larger plants, but they also did not fill bottles as many minutes out of the working day. This source of inefficiency probably wasn't as serious

Table 12. Average daily labor for specified functions in five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item	Size of plant				
	(6,477 qts/day	(12,954 qts/day	(25,908 qts/day	(51,816 qts/day	(103,632 qts/day
	12A. Total average man hours per day				
Processing and bottling					
receiving	4.0	4.0	4.0	4.0	4.0
pasteurizing	5.0	5.0	6.5	7.0	8.0
half gal filling	1.0	2.0	2.5	4.75	3.75
glass filling	3.75	4.25	6.25	6.25	7.00
glass bottle washing	3.75	4.25	6.25	6.25	7.00
paper filling	3.75	4.25	6.25	11.0	28.00
dock, case, cans	1.0	2.25	7.0	13.5	24.00
	22.25	26.00	38.75	52.75	81.75
Cooler					
stacking	.5	2.25	5.25	8.5	16.0
loadout	.75	2.0	4.0	10.5	28.0
Preparation, washup and management	16.50	17.75	32.00	56.25	130.25
Plant total	40.0	48.0	80.0	128.0	256.0
	12B. Average daily man minutes per quart				
Processing and bottling	.20611	.12043	.08974	.06108	.04733
Cooler	.01158	.01969	.02142	.02200	.02547
Preparation, washup, and management	.15285	.08221	.07411	.06513	.07541
Plant total	.37054	.22232	.18527	.14822	.14822

as it appeared. Spotty operation of certain equipment in plant X allowed workers time to do various odd jobs in the plant. Operational shutdowns probably could not be eliminated without hiring some additional labor to do the odd jobs. The shorter processing day allowed the same crew to wash and service the equipment.

Another reason for higher unit labor costs in the smaller plants was the higher proportion of the total quantity of labor required in the preparation, washup, and maintenance of dairy processing equipment (Figure 12B). For all sizes of plants, about the same quantities of labor were allotted to the washup of similar pieces of equipment. For each larger plant, no appreciable increase occurred in washup labor required per vat, tank, or bottle filler. Increases in floor area (Table 3), wall surfaces, and numbers of tanks and fillers (Table 4) did increase the labor required for preparation and washup. Labor required for maintenance and servicing of equipment also increased as plant volume and capacity of equipment grew. In the first four plants, these changes were not as great as the accompanying increases in plant output (Table 12A). Hence, this labor per unit of output declined as the size of plant increased (Table 12B).

Total labor inputs per quart did not decline beyond plant 8X (Table 12B). It is true that processing labor continued to decline. Except for paper fillers and the dock work, plant 16X required about the same crew operating the processing and bottling equipment as plant 8X (Figure 15B and 16B). Since 16X packaged twice the volume of 8X, the unit labor inputs for processing and bottling was less than that of 8X. On the other hand, the time required in stacking and loadout increased steadily in every subsequent size of plant. However, this was not the prime reason that total labor inputs ceased to decline. The crew for all functions other than processing was more than double that of 8X. Additional washup and setup men were required. Extra personnel was necessary for servicing, repairing, and storing duties.

While a detailed analysis of the situation in the base plants was not made, it appeared that both management limitations and union specifications of worker duties tended to limit the responsibilities of each worker to fewer major tasks as the size of the plant grew larger. Management limitations resulted primarily from a growing chain of command coupled with less personal direction of the workers. Since the plant manager had greater difficulty in personally overseeing the work of each man, he tended to assign one man to only one major task. This technique seemed necessary for assigning duties and fixing responsibilities when the number of major tasks became too great for simultaneous personal direction. The net result was that the base plant, like plant 16X, lost the efficiencies gained in larger milk handling equipment to higher inputs in servicing the general plant and the various processing cost centers.

Observation of the labor requirements in plant 16X indicated larger plants such as 32X or 64X should expect rising total labor unit inputs.

Fuel Oil

The unit inputs in gallons of oil per quart of milk declined throughout the full range of plant sizes studied (Table 11). Plant X used .0095 gallon of oil per quart of output. Plant 2X required .0073 gallon per quart, or 77 percent of the requirement in plant X. Plant 4X burned .0058 gallon, plant 8X about .0046 gallon, and plant 16X only .0041 gallon of fuel oil per quart of output. These quantities were 60 percent, 47 percent, and 42 percent, respectively, of the amount burned in plant X. Thus, each larger sized plant required less heat per unit of output than the preceding size.

The major source of heat savings occurred because of the greater number of units processed per piece of heat consuming equipment. Equipment such as bottle washers, case washers, and can washers required a quantity of heat equivalent to an hour of operation before they reached operating temperature (see footnote 9, p. 68). This fixed warmup heat was spread over more units in the larger plants and the heat required per quart declined (Table 13). No marked decline per unit occurred for bulk can washing in the first three plants because the washer in the receiving room was used. Hence, there was no warmup heat to spread among a larger number of units. Plants 8X and 16X had a separate can washer for bulk cans. Therefore, the quantity of heat per can was less in the larger of these two plants but was more than the smaller plants with no fixed heat to allocate among the number of units handled.

Heat requirements per quart of output also declined sharply for

Table 13. BTU's per quart for specified pieces of equipment in five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item	BTU's per quart by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
can washer	254.1	195.9	145.2	90.8	90.8
bulk can washer	153.6	138.2	153.6	224.5	199.7
case washer	57.5	71.9	53.0	27.0	35.2
case washer	-	-	57.4	48.2	39.0
bottle washer	370.0	308.3	254.4	215.8	196.9
HTST	69.2	69.2	69.2	69.2	69.2
½ gal filler	-	-	31.9	31.2	23.3
space heat	190.3	118.3	77.5	65.5	46.2
washup	194.0	133.3	104.7	80.1	59.1
heat loss	49.5	29.0	24.1	18.2	17.8
Plant total	948.5	727.8	576.1	459.4	406.3

space heat, wash water heat, and heat loss (Table 13). The cubic feet of building did not expand as fast as plant output (Table 7). Likewise, the washup heat per quart was less as the size of plant grew larger because the floor surfaces and equipment surfaces to be cleaned did not increase as fast as plant volume. The length of the steam lines did not change much as the size of plant increased. Hence, heat loss per quart also declined.

The data developed in this study indicated that plants larger than 16X should experience even greater reductions in quantities of fuel required per quart if output is increased through the use of larger sized equipment. Increased output with the use of multiple units of existing sizes would not permit heat economies in equipment; only the heat requirements for space heat and heat loss could be spread over more units.

Electricity

Each successive increase in plant size was accompanied by a reduced consumption of electricity per quart (Table 11). Plant X used 58.79 watts per quart of output.[16] The other plants ranged between

[16]Apparently plants are currently using more electricity than in former years. In 1948, Herrmann and Whatley reported seven plants in the Memphis, Tennessee area that were averaging only 5.66 watts per quart of milk (23, p. 15). The same year, Henry, Bressler, and Frick presented a 4,800 quart a day plant that used 11.9 watts per quart (22, p. 99). Their data was based on prewar processing relationships. In 1953, Conner's 14,780 quart model plant was estimated to require 26.6 watts per quart. Webster's estimate published in 1955 for a 6,400 quart a day plant was 47.5 watts per quart. Only these two most recent studies came close to the usage in the five model plants in this study.

this figure and 31.15 watts per quart in plant 16X. This was only 56 percent of that for plant X.

The economies in power consumption were due primarily to greater efficiency in the larger sized equipment (Table 14). For example, refrigeration equipment consumed 23.6 watts per quart of output in plant X, but only 15.8 watts in plant 16X. Likewise, homogenizers, the other largest single user of power required 7.6 watts per quart of output in plant X but only 6.3 watts per quart in 16X. Similar increases in processing efficiency, but on a smaller scale, were observed for most of the equipment in the five sizes of plants.

Supplies

The per quart requirements for various kinds of supplies (Table 10) were determined by dividing the respective supply by their quart equivalent (Table 11). Quart equivalents for each kind of supply are presented in Table 15.

All paper container and cap supplies (Table 1, p. 34) were increased two percent to allow for waste and damage (Table 10). Thus, for each quart of milk packaged in half gallon containers, .51 instead of .50 cartons were required (Table 11). Similarly, for each quart of milk packaged in half pint cartons, 4.08 instead of 4.00 bottles were used.

The fraction of a bottle required for milk bottled in glass was obtained by dividing the number of bottles required per quart equivalent by the average number of trips per bottle. Thus, four bottles

Table 14. Power requirements per quart by specified function for five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item	Watts by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Receiving					
can washer	4.411	2.341	1.658	.878	.601
agitators	1.113	.858	.870	.716	1.228
other	.959	.764	.735	.815	.696
Total	6.483	3.963	3.263	2.409	2.525
Processing					
clarifier and pump	1.088	.726	.635	.394	.432
homogenizer	7.585	9.480	9.481	7.658	6.320
agitators	.363	.182	.181	.098	.309
other	.599	.423	.293	.193	.180
Total	8.071	8.856	8.636	6.764	5.938
Bottle handling					
case conveyor	-	.532	.826	1.217	1.546
case washer	1.030	2.899	1.150	.575	.587
case washer	-	-	1.171	.959	1.230
glass filler	1.726	1.208	.719	.383	.293
glass washer	7.661	5.798	3.451	2.588	2.347
paper filler	.486	.475	.391	.320	.293
half gal fill	.548	.548	2.190	2.145	1.233
conveyor	.086	.043	.032	.027	.021
lights	1.631	.816	.617	.362	.248
Total	6.540	5.397	4.723	4.018	3.809
Specialties					
can washer	2.522	1.834	1.949	2.599	1.376
other	4.197	2.578	1.649	1.184	.817
Total	5.780	3.729	2.871	2.814	1.680
Cooler	2.731	2.395	1.806	1.211	.931
General plant					
boiler	.965	.718	.525	.478	.790
refrigeration	23.607	23.282	20.441	17.047	15.858
air	1.019	.764	.865	.669	.618
well pump	1.791	1.343	1.689	1.679	1.447
other	7.318	5.770	3.678	2.313	2.049
Total	34.699	31.877	27.181	22.185	20.762
Plant total	58.793	52.543	45.594	36.634	33.851

Table 15. Quart equivalent for each kind of supply for five model plants with glass and paper output, Oregon conditions, 1956.

Item	Quart equivalent by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
half gals	237,340	474,680	949,360	1,898,720	3,797,440
staples	237,340	474,680	-	-	-
wax	-	-	949,360	1,898,720	3,797,440
glue	-	-	949,360	1,898,720	3,797,440
wire	-	-	949,360	1,898,720	3,797,440
paper qts	616,060	1,232,120	2,464,240	4,928,480	9,856,960
paper pts	23,740	47,480	94,960	189,920	379,840
paper ½ pts	71,250	142,500	285,000	570,000	1,140,000
glass qts	539,590	1,079,180	2,158,360	4,316,720	8,633,440
glass pts	6,780	13,560	27,120	54,240	108,480
glass ½ pts	18,645	37,290	74,580	149,160	298,320
caps	565,015	1,130,030	2,260,060	4,520,120	9,040,240
cases	1,514,005	3,028,010	6,056,020	12,111,040	24,224,080
cans	170,095	340,190	680,380	1,360,760	2,721,520
general	1,684,100	3,368,200	6,736,400	13,472,800	26,945,600

per quart of milk put up in half pints divided by the average of 20 trips per bottle gave .20 half pint glass bottles per quart equivalent.

Per unit quantities for case and container supplies were assumed to be constant for all sizes of plants. Hence, no physical economies were shown for the five sizes of plants.

Unlike containers and cases, general plant supplies were not assumed to be constant for all sizes of plants. However, physical quantities could not be determined for these supplies. Therefore, no relationship between physical inputs per quart and size of plant is presented.

<u>Building</u>

The building space requirements did not increase nearly as fast as output in the different sizes of plants (Table 10). The number of square feet per 1,000 quarts per year in plant X was 4.779 (Table 16). In plant 2X, the number was 3.138 or less than 66 percent of the requirement for plant X. Plant 4X used 2.367 square feet or 50 percent of the amount used in plant X. Plant 8X required 1.855 sqare feet and 16X only 1.365 square feet per quart of output. These requirements were 39 and 29 percent respectively of the floor space per quart in plant X. Per unit physical requirements for building space were, therefore, a definite source of savings in the larger plants.

The most important reason for the smaller per unit requirement for floor space was the larger equipment used by the larger plants. Increases in output were obtained primarily from the same number of pieces of equipment but with larger processing capacities (Table 4). Thus, in the respective processing areas of the various plants, the floor space requirements did not change very much (Figure 11 and Table 3). Space for pasteurizing ranged from .143 square foot per 1,000 quarts per year in plant X to .012 square foot in plant 16X. The bottle filling and specialty areas showed a similar relationship to size of plant. The total for all processing areas ranged from .591 square foot per 1,000 quarts in plant X to .104 square foot in plant 16X. This was 18 percent of the space per 1,000 quarts required in plant X.

Non processing plant areas did expand for each increase in plant size, but at a lower rate than increases in plant output (Table 3). Therefore, floor space per 1,000 quarts decreased, but not as fast as in the receiving and processing areas (Table 16). Non processing areas per 1,000 quarts ranged from 4.779 square feet in plant X to 1.365 square feet in plant 16X. Plant 16X required only 29 percent as much area as plant X.

Equipment

The five plants varied considerably in their physical requirements for equipment. However, these differences were mainly in the capacity of each unit and not in the number of pieces of each type of equipment (Table 4). Thus, physical inputs per quart for the equipment in each processing center, unlike gallons of oil or killowatt hours of electricity, could not be summed and compared.

Taxes, Interest, Insurance, and Other Costs

Taxes, interest, and insurance could not be determined in physical quantities.

Other inputs included plant licenses and product loss. One standard set of plant license fees and costs was adopted for all sizes of plants. Thus, as is shown in a later section, the larger the volume of output, the smaller the unit requirement for a license (Table 26).

As reported earlier, a standard product loss was assumed. Hence, no physical economies in product loss were reported for the different sizes of plants.

Table 16. Floor space per 1,000 quarts by specified functions for five model plants based on an analysis of Oregon plants, 1956.

Item	Square feet by size of plant X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Processing areas					
HTST	.143	.071	.036	.025	.012
surge tanks	.029	.019	.017	.014	.012
bottle wash	.318	.177	.127	.074	.041
glass fill	.283	.198	.113	.058	.053
paper fill	.101	.068	.055	.051	.037
half gal fill	.489	.295	.303	.052	.126
vats	1.034	.517	.259	.224	.144
Total	.591	.340	.227	.149	.104
Percent of plant X	100	57.5	38.4	25.2	17.6
Non-processing areas					
receiving	.299	.178	.100	.115	.084
cooler	.299	.287	.229	.192	.118
bottle dock	.380	.284	.213	.194	.191
bulk cans	1.105	.727	.523	.470	.378
boiler	.133	.078	.057	.040	.020
refrigeration	.166	.107	.065	.057	.054
paper storage	.818	.582	.375	.316	.188
other storage	1.366	.922	.571	.362	.242
truck shed	.990	.517	.502	.407	.293
offices	.314	.223	.194	.154	.122
other	.399	.352	.282	.183	.133
Total	4.187	2.798	2.140	1.706	1.260
Percent of plant X	100	66.8	51.1	40.7	30.1
Plant Total	4.779	3.138	2.367	1.855	1.365
Percent of plant X	100	65.7	49.5	38.8	28.6

Total Physical Inputs Per Quart

The various kinds of physical inputs could not be totaled to show the net relationship between plant size and total inputs because the individual items were not in comparable terms. To make these physical quantities additive all physical units were converted into dollars and cents.

Since the purpose of this section was to show only the effects of physical efficiencies, the prices used for each of the various items were the same for all sizes of plants. These were the prices for plant X (Table 17). In the next section, the effect of changing prices will be added to show the net relationship between costs per quart and the size of plant.

Table 17. List of prices for the physical inputs of model plant X, Oregon prices, 1956.

labor, per day	$20.76	paper ½ pts,@	$ 1.1530¢
fuel oil, per gal	15.8¢	glass qts,@	12.875¢
electricity, per KWH	1.3924¢	glass pts,@	11.250¢
nested half gals,@	5.170¢	glass ½ pts,@	7.258¢
staples,@	.040¢	caps@	.322¢
half gals,@	2.310¢	cases@	$ 4.9575
wax, per lb	10.71¢	cans@	$ 8.75
glue, per lb	29.0¢	floor space, per sq.ft.	$ 0.92369
wire, per lb	33.65¢	product loss, per cwt.	$ 5.20
paper qts,@	1.9088¢		
paper pts,@	1.5630¢		

Labor quantities were multiplied by $20.76 per day to give total values for the labor (Table 18). Gallons of fuel oil were multiplied by 15.8 cents. Electricity was converted into dollars at the average rate of 1.3924 cents per killowatt hour. Floor space was multiplied by 92.369 cents. This was the annual depreciation and maintenance allowance per square foot of building in plant X. Product loss was taken as $5.20 per hundred weight of loss. The plant license fee was $100 for all plants.

Except for half gallons, all supplies were the same price per unit for all sizes of plants. Plants X and 2X used staples and nested, preformed half gallon cartons. The other three plants formed the half gallon cartons at the time of filling. They used wax, glue, wire, and the less expensive carton. Thus, the half gallon supplies were one price for X and 2X, and another for 4X, 8X, and 16X.

As noted earlier, the physical inputs for equipment were not presented in comparable units. Therefore, prices for equipment of various capacities were assumed to reflect differences in the physical quantities only.

For water, no attempt was made to separate the physical from the price changes for the various sizes of plants. Water costs were estimated in a lump sum from the equation $Y = \$423.78 + \$7.63X$, where Y equaled total annual expenditure for water and X equaled annual raw milk receipts in millions of pounds (Table 18). This equation was developed from an analysis of the expenditures for water in the base plants.

As noted earlier, determination of the physical requirements for general plant supplies could not be made. As with equipment and water costs, the sums used for general plant supplies (Table 18) are those

Table 18. Summary of total costs with the same price for all physical inputs for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Total costs by size of plant: X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Labor	$26,966.40	$ 32,390.90	$ 53,984.80	$ 86,375.70	$172,751.40
Utilities					
fuel oil	$ 2,523.96	$ 3,873.37	$ 6,140.20	$ 9,778.94	$ 17,296.42
power	1,378.68	2,464.19	4,276.53	6,872.25	12,700.47
water	450.00	480.00	535.00	645.00	870.00
Total	$ 4,352.64	$ 6,817.56	$ 10,951.73	$ 17,296.19	$ 30,866.89
Supplies					
half gals	$ 6,257.94	$ 12,515.88	$ 10,965.11	$ 21,930.22	$ 43,860.44
staples	96.85	193.70	-	-	-
wax	-	-	2,956.97	5,913.94	11,827.88
glue	-	-	133.77	267.54	535.08
wire	-	-	70.56	141.12	282.24
paper qts	11,994.92	23,989.84	47,979.68	95,959.36	191,918.72
paper pts	756.95	1,513.90	3,027.80	6,055.60	12,111.20
paper ½ pts	3,351.84	6,703.68	13,407.36	26,814.72	53,629.44
glass qts	3,473.68	6,947.36	13,894.72	27,789.44	55,578.88
glass pts	76.50	153.00	306.00	612.00	1,224.00
glass ½ pts	270.72	541.44	1,082.88	2,165.76	4,331.52
caps	2,061.71	4,123.42	8,246.84	16,493.68	32,987.36
cases	1,536.79	3,073.58	6,147.16	12,294.32	24,588.64
cans	175.00	350.00	700.00	1,400.00	2,800.00
general	7,473.85	9,376.21	10,766.41	12,739.79	13,872.14
Total	$37,526.75	$ 69,482.01	$119,685.26	$230,577.49	$449,547.54
Building					
depn.	$ 5,309.90	$ 6,972.54	$ 10,519.51	$ 16,489.19	$ 24,258.75
maint	2,123.96	2,789.02	4,207.80	6,595.68	9,703.50
Total	$ 7,433.86	$ 9,761.56	$ 14,727.31	$ 23,084.87	$ 33,962.25
Equipment					
depn	$ 8,863.00	$ 11,922.80	$ 21,694.10	$ 31,108.40	$ 50,649.00
maint	4,431.50	5,961.40	10,847.05	15,554.20	25,324.50
Total	$13,294.50	$ 17,884.20	$ 32,541.15	$ 46,662.60	$ 75,973.50
Taxes	$ 1,835.72	$ 2,416.48	$ 3,944.35	$ 5,891.48	$ 9,040.19
Interest	$ 5,189.20	$ 6,830.95	$ 11,149.80	$ 16,665.20	$ 25,554.55
Insurance	$ 649.47	$ 863.78	$ 1,445.88	$ 2,154.87	$ 3,340.56
Other	$ 1,618.40	$ 3,136.80	$ 6,173.60	$ 12,247.20	$ 24,394.40
Plant Total	$98,866.94	$149,584.24	$254,603.88	$440,955.60	$825,431.28

for the actual costs to the various model plants (see page 115 for the development of these estimates). These sums contained elements of both physical economies and price reductions to the larger sizes of plants. However, the greatest share of the change in cost per unit for these items probably was due to physical efficiencies. For instance, the quantity of uniforms per quart to purchase or laundry was smaller in the larger plants because the number of workers per quart was lower. The quantity of soaps and cleaners required per quart was less in the larger plants because the number and area of the tanks and fillers and the square feet of floor space to be cleaned did not increase as rapidly as volume. The same was true of chemical disinfectants, and bottle and can washer supplies. A similar relationship existed for lubricants, refrigerants, and rest room supplies.

There are no physical units for taxes, interest, or insurance. Therefore, these were calculated on the values for the lot, building, and equipment in the manner shown in a later section (Tables 30, 31, and 32). Changes in these costs per quart of output reflect only differences in physical facilities for the five sizes of plants.

Summary of Total Physical Inputs Per Quart

The physical units when converted into dollars, displayed the same relationships between the various cost elements and size of plant as was shown in Table 11.

The sum of the monetary values for inputs of each cost element showed a very definite decline in the total physical inputs required per quart for each increase in size of plant (Table 19 and Figure 17). These values declined from a high of 5.8706 cents per quart for plant X to a low of 3.0633 cents per quart for plant 16X. The decline was rapid between the first three plant sizes. Between plants 4X and 16X, the decline was more gradual. Total physical inputs for plant 16X were only 52 percent of those for plant X.

The size of plant for maximum physical efficiency probably was larger than plant 16X. From all appearances, throughout the full range of plants, the inputs required per quart of output for all physical costs except labor were still declining. Hence, the low point on the long run average input-output relationship curve was not established by this study.

Table 19. Summary of unit costs with the same price for all physical inputs for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Unit costs by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Labor	1.6012¢	.9617¢	.8014¢	.6411¢	.6411¢
Utilities					
fuel oil	.1499¢	.1150¢	.0911¢	.0726¢	.0642¢
power	.0819	.0732	.0635	.0510	.0471
water	.0267	.0143	.0080	.0048	.0032
Total	.2585¢	.2025¢	.1626¢	.1284¢	.1145¢
Supplies					
half gals	2.6367¢	2.6367¢	1.1550¢	1.1550¢	1.1550¢
staples	0.0408	0.0408	-	-	-
wax	-	-	.3115	.3115	.3115
glue	-	-	.0141	.0141	.0141
wire	-	-	.0074	.0074	.0074
paper qts	1.9470	1.9470	1.9470	1.9470	1.9470
paper pts	3.1885	3.1885	3.1885	3.1885	3.1885
paper ½ pts	4.7043	4.7043	4.7043	4.7043	4.7043
glass qts	6438	.6438	.6438	.6438	.6438
glass pts	1.1283	1.1283	1.1283	1.1283	1.1283
glass ½ pts	1.4520	1.4520	1.4520	1.4520	1.4520
caps	.3649	.3649	.3649	.3649	.3649
cases	.1015	.1015	.1015	.1615	.1015
cans	.1029	.1029	.1029	.1029	.1029
general	.4438	.2784	.1598	.0946	.0515
Total	2.2289¢	2.0629¢	1.7767¢	1.7114¢	1.6684¢
Building	.4414¢	.2898¢	.2186¢	.1713¢	.1260¢
Equipment	.7894¢	.5310¢	.4831¢	.3463¢	.2794¢
Taxes	.1090¢	.0717¢	.0586¢	.0437¢	.0335¢
Interest	.3081¢	.2028¢	.1655¢	.1237¢	.0948¢
Insurance	.0386¢	.0256¢	.0215¢	.0160¢	.0124¢
Other	.0961¢	.0931¢	.0916¢	.0909¢	.0905¢
Plant total	5.8706¢	4.4411¢	3.7795¢	3.2729¢	3.0633¢
Percent of plantX	100	75.6	64.4	55.8	52.2

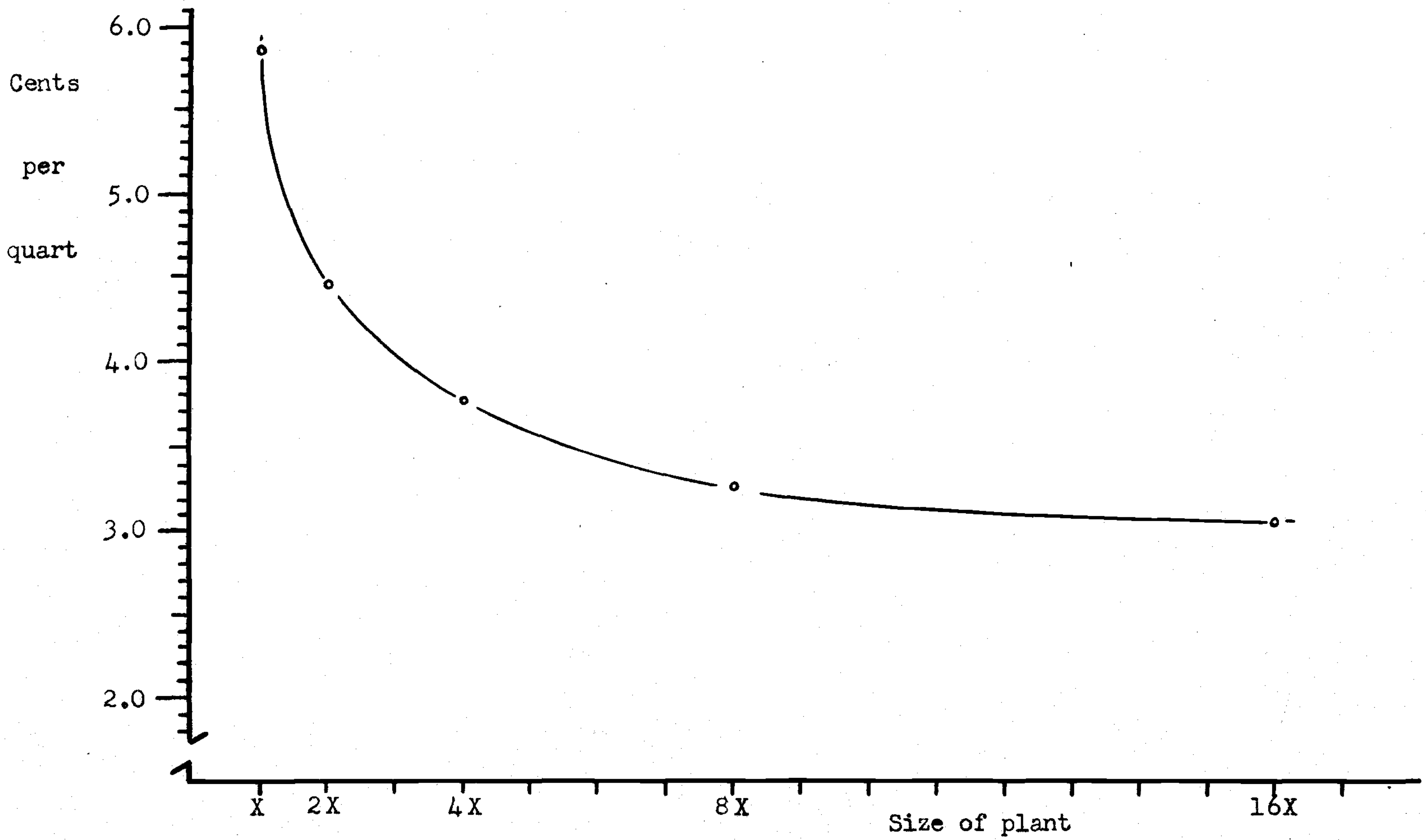

Figure 17. The relationship between total physical inputs per quart equivalent and size of plant for five model plants with can intake and glass and paper output, Oregon conditions, 1956.

The Relationships of Processing Costs Per Quart to Size of Plant

Developing Costs by Cost Element

In the preceding section, the costs per unit of each physical input were considered the same for all sizes of plants. In the reports from the actual base plants, this was not found to be the case. Generally, the cost of each unit of physical input diminished as the quantity purchased grew larger. Since larger plants used greater quantities of each input, these plants experienced monetary savings in addition to the physical efficiencies already noted. Therefore, the purpose of this section was to develop and apply actual prices to the different quantities of physical inputs and establish their effect on costs per quart in the five sizes of plants.

Labor

The 1956 union contract common to this area was assumed standard for all model plants. According to this contract, the wages for each individual laborer depended upon his job classification and upon the time of day he worked. Therefore, each crew member was classified according to his duties as developed in the labor and equipment utilization schedules (Figures 12B,13B,14B,15B,and16B). The plant crew, union pay rates, and annual labor costs were developed for each model plant (Table 20). The average daily wage included an allowance of 38 cents per hour to cover vacations, double time provisions for six legal holidays, contributions to the health and welfare fund, and

Table 20. Plant crew and labor costs for five model plants with can intake and glass and paper output, Oregon wage rates, 1956.*

Size of plant	Job	No. of men	Wage per day	Annual labor cost	Labor cost per quart	Percent of plant X
X (1,684,100 quarts)	plant manager	1		$ 6,000.00		
	receiver	1	$20.16	5,241.60		
	bottle filler	1	20.16	5,241.60		
	bottle filler	1	20.16	5,241.60		
	bottle washer	1	20.16	5,241.60		
		5		$ 26,966.40	1.6012¢	100
2X (3,368,200 quarts)	plant manager	1		$ 6,000.00		
	checker, filler	1	$20.57	5,348.20		
	receiver	1	20.16	5,241.60		
	bottle filler	1	20.16	5,241.60		
	bottle washer	1	20.16	5,241.60		
	dock, cooler	1	20.16	5,241.60		
		6		$ 32,314.60	.9594¢	59.9
4X (6,736,400	checker	1	$20.67	$ 5,374.20		
	dock, loadout	1	20.16	5,241.60		
	pasteurizer	1	20.48	5,254.60		
	receiver	1	20.16	5,241.60		
	bottle filler	2	20.16	10,483.20		
	bottle washer	1	20.16	5,241.60		
	purepak operator	1	20.58	5,324.80		
	cleanup	1	20.26	5,267.60		
	plant manager	1		6,000.00		
		10		$ 53,429.20	.7931¢	49.5
8X (13,472,800 quarts	checker, filler	2	$20.72	$ 10,774.40		
	stacker	1	20.31	5,280.60		
	pasteurizer	1	20.48	5,324.80		
	receiver	1	20.16	5,241.60		
	bottle filler	1	20.16	5,241.60		
	bottle washer	1	20.16	5,241.60		
	dock man	1	20.16	5,241.60		
	purepak operator	1	20.53	5,337.80		
	bulk can filler	1	20.21	5,254.60		
	cleanup	2	20.51	10,665.20		
	checker, stacker	1	20.91	5,436.60		
	relief man	1	20.48	5,324.80		
	engineer	1		5,500.00		
	plant manager	1		6,000.00		
		16		$ 85,865.00	.6373¢	39.8

Table 20. (continued)

Size of plant	Job	No. of men	Wage per day	Annual labor cost	Labor cost per quart	Percent of plant X
16X (26,945,600 quarts)	checker	2	$21.07	$ 10,956.40		
	stacker	2	20.66	10,743.20		
	pasteurizer	1	20.48	5,324.80		
	receiver	1	20.16	5,241.60		
	checker	2	20.57	10,696.40		
	stacker	2	20.16	10,483.20		
	purepak operator	1	20.48	5,324.80		
	bottle filler	5	20.16	26,200.00		
	bottle washer	1	20.16	5,241.60		
	bulk can filler	1	20.16	5,241.60		
	dockman	2	20.16	10,483.20		
	pasteurizer	1	21.13	5,493.80		
	cleanup	7	20.91	38,056.20		
	relief man	1	20.48	5,324.80		
	engineer	2		11,000.00		
	plant manager	1		6,000.00		
		32		$171,819.60	.6377¢	39.8

*Labor requirements are based on analysis of Oregon plants, 1956. Wage rates included a 38 cents per hour allowance to cover vacations, double time provisions for six legal holidays, contributions to the health and welfare fund, and ten cents per hour to the union pension fund. The rate also includes an additional ten cents for hours worked before 5:00 A.M. and after 5:00 P.M.

ten cents per hour to the union pension fund. The rate also included an additional ten cents per hour for hours worked before 5:00 A.M. or after 5:00 P.M.

The plant managers and engineers were on salaries. The managers in plants X and 2X were working managers who supervised the activities in the plant in addition to their regular plant job. For the three larger plants, the sole duty of the plant manager was to supervise the operation and keep the necessary records of the plant.

A standard rate schedule such as was adopted for use in this study did not allow differences in wage rates for labor doing corresponding work in different sizes of plants. Thus, in a sense, there were no economies in price per unit of labor for the larger plants. However, workers in different jobs got paid different wages. The proportion of workers at the different pay levels varied between the different sizes of plants. This variation resulted in different average wages per man day. Plant X with a fifth of its labor paid at the plant manager level, averaged $20.76 per man per day. Plant 2X, with one more man but the same cost for management, averaged $20.71 per man day. Plant 4X, had three more men and averaged $20.55 per man per day. Plant 8X added a second salaried man and six other men to its crew and had to pay a few bonuses for night hours. This plant averaged $20.64 per man per day. Plant 16X had even a higher proportion of its labor in the higher pay brackets and averaged $20.65 per man per day. This variation between sizes of plants would have been more pronounced had not there been an unusually small difference between the rates of pay for different job levels. The range of wages between highest and lowest pay levels for plant workers was only $106.60 per year. However, this small range was large enough to indicate that possible economies and diseconomies of size can appear in average labor cost per man per day even when a standard wage schedule is adopted. Plants larger than 16X apparently should expect the proportion of the plant crew in the higher wage levels to increase, thus causing average labor cost per man day also to increase.

The variation in rates of pay for the worker at different wage levels were so small that the labor cost per quart did not change materially from the figures shown earlier. Labor costs declined in the same manner as the size of plant grew larger (Figure 18). Cost per quart decreased from 1.6012 cents in plant X to .6373 cent in plant 8X and then increased to .6377 cent in plant 16X (Table 20). Thus, the larger plants had labor costs about 40 percent of that for plant X.

Fuel Oil

The fuel oil prices for the model plants were based on information obtained from the base plants and on the oil company price quotations as of March 1, 1957.

These prices varied according to the volume of oil purchased by the different sizes of plants (Table 21). Plant X paid 15.8 cents per gallon. At the other extreme, plant 16X paid only 9.6 cents per gallon or only 61 percent of the cost to plant X.

Thus, in addition to the physical economies in fuel consumption the larger plants also had price economies (Figure 19). Plant 16X used only 58 percent as much fuel oil per quart and had a net cost only 26 percent of that for plant X.

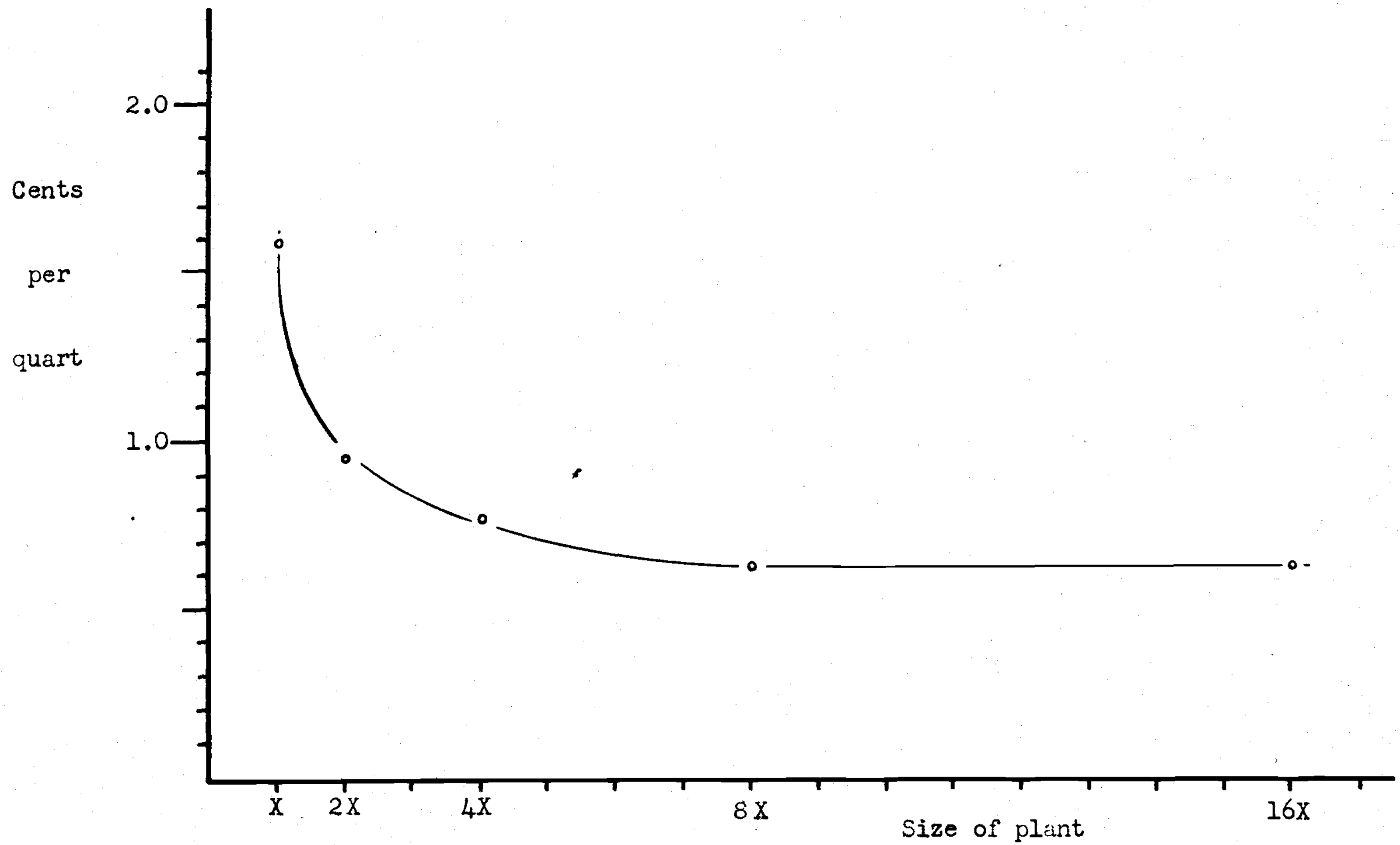

Figure 18. The relationship between labor cost per quart equivalent and size of plant for five model plants with can intake and glass and paper output, Oregon wage rates, 1956.

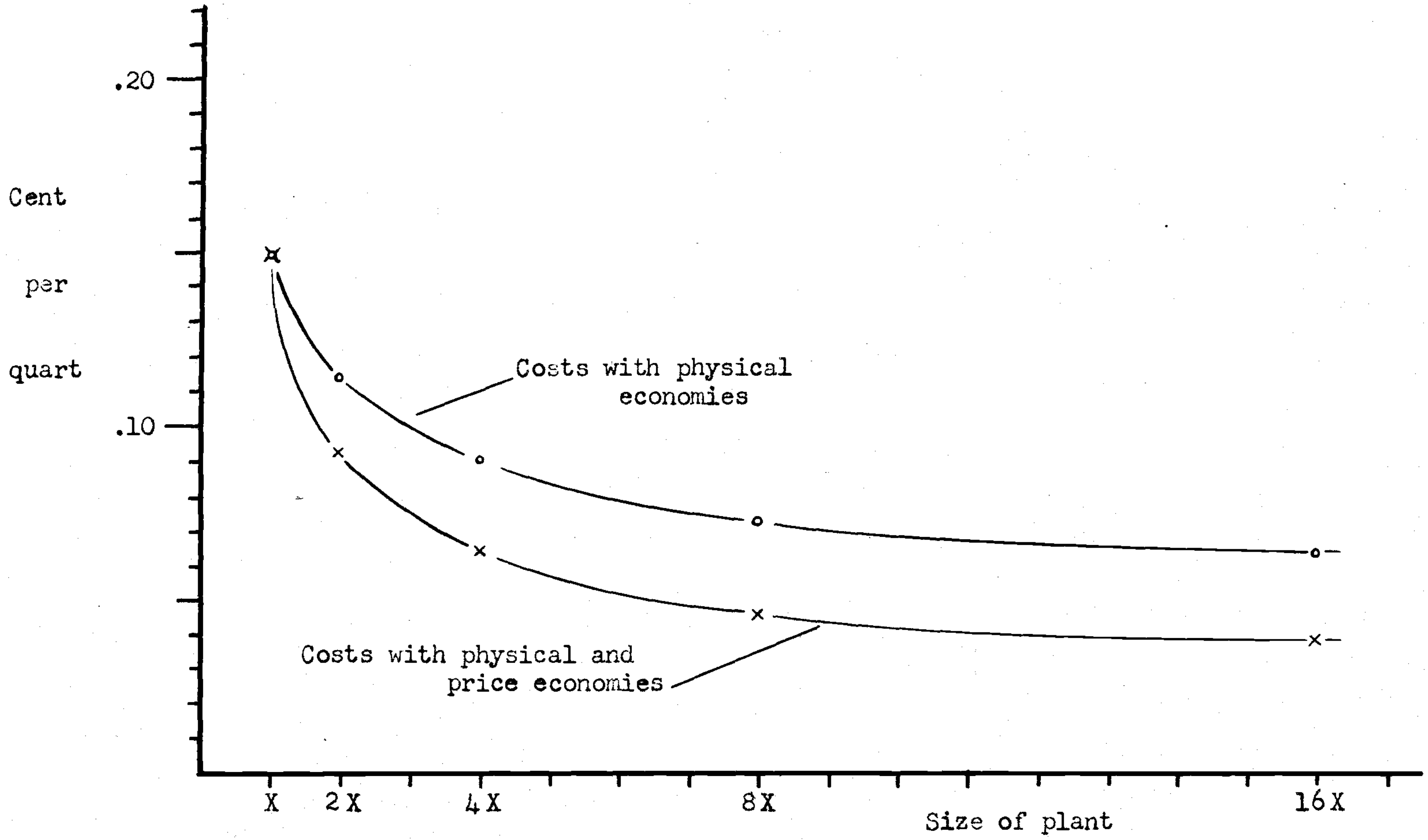

Figure 19. Comparison of physical inputs and costs per quart equivalent for fuel oil in five model plants with can intake and glass and paper output, Oregon prices, 1956.

Table 21. Fuel oil costs for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Gallons of oil	15,974.4	24,515.1	38,808.6	61,891.6	109,470.7
Price per gal.	15.8¢	12.7¢	11.3¢	10.3¢	9.6¢
Total annual fuel oil cost	$2,523.96	$3,113.42	$4,385.37	$6,374.83	$10,509.19
Fuel oil cost per quart	.1499¢	.0924¢	.0651¢	.0473¢	.0390¢
Percent of plant X	100	61.6	43.4	31.6	26.0

Electricity

As in the case of fuel oil, electric power also varied in price per unit according to the amount used. The average price per killowatt hour for each of the model plants was determined with information obtained from the power and light company. To develop average price per killowatt hour, the average monthly consumption of power was estimated for each model plant. An average demand (maximum consumption for a 30 minute interval) was estimated for each plant. With this information, the average monthly power bill was calculated from the power company rate schedule (Table 22). The average monthly power bill divided by average monthly power consumption gave the over-all average price per killowatt hour.

Table 22. Power costs for five model plants with can intake and glass and paper output, Oregon rates, 1956.

Item	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
	Size of plant				
Annual KWH	99,014	176,974	307,140	493,556	912,128
Average monthly KWH	8,251.2	14,747.8	25,595.0	41,129.7	76,010.6
First 150 KWH @3.75¢	$ 5.63	$ 5.63	$ 5.63	$ 5.63	$ 5.63
Next 350 KWH @2.50¢	14.38	14.38	14.38	14.38	14.38
Next 1,000 KWH @1.50¢	29.38	29.38	29.38	29.38	29.38
Next 13,500 KWH @1.00¢	67.51	132.48	164.38	164.38	164.38
Next 25,000 KWH @ .80¢			84.76	364.38	364.38
Next 60,000 KWH @ .60¢				6.78	216.07
Demand charge	18.00	30.00	60.00	108.00	216.00
Total	$114.89	$191.86	$309.14	$479.16	$796.45
Average/KWH	1.3924¢	1.3001¢	1.2078¢	1.1650¢	1.0478¢
Annual power cost	$1,278.68	$2,302.32	$3,709.68	$5,749.92	$9,557.40
Power cost/qt	.0819¢	.0684¢	.0551¢	.0427¢	.0355¢
Percent of plant X	100	83.5	67.3	52.1	43.3

Power prices ranged from 1.3924 cents per killowatt hour for plant X to 1.0478 cents for plant 16X (Table 22). As was noted earlier, larger plants also experienced definite reductions in quantities of power required per quart (Figure 20). The maximum reduction in cost per quart for electricity was in plant 16X. This plant used only 56 percent as many watts per quart and had a net power cost per quart only 43 percent of that for plant X.

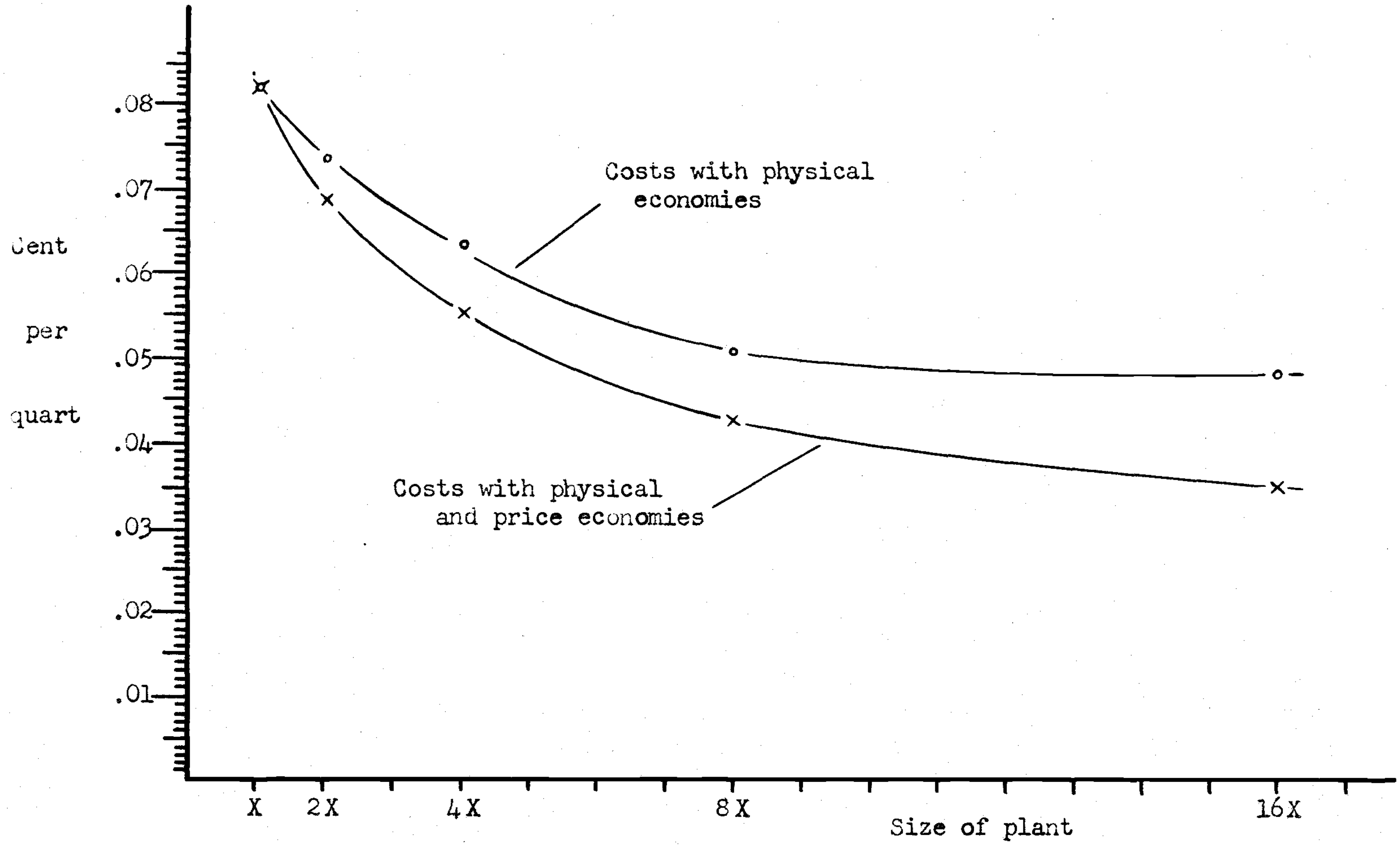

Figure 20. Comparison of physical inputs and costs per quart equivalent for electricity in five model plants with can intake and glass and paper output, Oregon prices, 1956.

Water

As noted earlier, the expenditure for water was estimated as a lump sum. No physical quantities were determined. The dollar sum for water expenditure by the model plants was estimated by the equation Y = $423.78 ≠ $7.63X, where Y equaled total annual expenditure for water and X equaled annual raw milk receipts in millions of pounds (Table 23). This equation was derived from an analysis of expenditures for boiler water in the base plants.

Unit costs, in this case, were the same as those shown in the preceding section.

Table 23. Estimated annual expenditures on boiler water for five model plants with can intake and glass and paper output, Oregon conditions, 1956.

Item	Size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Annual water cost	$450	$480	$535	$645	$870
Cost per quart	.0267¢	.0143¢	.0080¢	.0048¢	.0032¢
Percent of plant X	100	53.6	30.0	18.0	12.0

Supplies

The physical supplies for all five model plants were listed earlier in Table 5. As with other cost items, supplies often cost less per unit when purchased in larger quantities. Therefore, to keep the sizes of the orders in the same proportion as the size of plants, standards for the lengths of time between orders were established.

The standards were as follows: All model plants were assumed to order paper bottles every two months. Wax was ordered monthly and wire twice a year. Cases were ordered every two months. Glass bottles were ordered monthly. Cans were replenished twice a year. Cap prices were based on annual usage.[17]

As was noted earlier, all cap and paper bottle supply requirements were increased two percent to allow for loss and damage. This allowance was chosen on the basis of the experience in the base plants.[18] When the size of the orders had been determined for each item of supply, the proper purchase price was determined from the reports of the supply houses. Total costs and costs per quart for each item of supply were calculated (Table 24).

Physical quantities per quart for most supplies were assumed to be the same in all sizes of plants.

Marked differences appeared between the five plants in the prices paid for some supplies. For others, little or no difference appeared (Table 24).

Generally, the larger plants did not have a great unit cost

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[17]Conner, Spencer, and Pierce assumed a more frequent resupply for most items. In their study, bottles and caps were replenished every 15 days, cases every 30 days, and cans every six months (15, p. 46). Practice in the base plants varied considerably. However, supplies were not generally ordered as often as reported in Conner, Spencer, and Pierce.

[18]Webster (51, p. 80) and Conner, Spencer, and Pierce (15, p. 46) also used a two percent allowance. A representative of the Excello Corporation recommended a figure of 1.5 percent, but this appeared too low in the light of the experience in the base plants.

Table 24. Schedule of supplies for five model plants with glass and paper output, Oregon prices, 1956.

Plant size	Item	Units	Total cost	Quart equivalent	Cost per quart equiv.
X	paper ½ gals.	118,670	$ 6,257.94*	237,340	2.637¢
	staples	237,340	96.85*	237,340	.041
	paper qts.	616,060	11,994.92*	616,060	1.947
	paper pts.	47,480	756.95*	23,740	3.189
	paper ½ pts.	285,000	3,351.84*	71,250	4.704
	glass qts.	26,980	3,473.68	539,590	.644
	glass pts.	680	76.50	6,780	1.128
	glass ½ pts.	3,730	270.72	18,645	1.452
	caps	627,730	2,061.71*	565,015	.365
	cases	310	1,536.79	1,514,005	.102
	cans	20	175.00	170,095	.103
	general		7,473.85	1,684,100	.444
			$ 37,526.75	1,684,100	2.228¢
2X	paper ½ gals.	237,340	$ 11,558.46*	474,680	2.435¢
	staples	474,680	174.67*	474,680	.037
	paper qts.	1,232,120	23,989.87*	1,232,120	1.947
	paper pts.	94,960	1,513.90*	47,480	3.189
	paper ½ pts.	570,000	6,703.68*	142,500	4.704
	glass qts.	53,960	6,947.35	1,079,180	.644
	glass pts.	1,360	153.00	13,560	1.128
	glass ½ pts.	7,460	541.45	37,290	1.452
	caps	1,255,460	3,649.62*	1,130,030	.323
	cases	620	3,019.34	3,028,010	.100
	cans	40	350.00	340,190	.103
	general		9,376.21	3,368,200	.278
			$ 67,977.55	3,368,200	2.018¢
4X	paper ½ gals.	474,680	$ 10,965.11*	949,360	1.155¢
	wax, lbs.	27,065	2,956.97*	949,360	.311
	glue, lbs.	452	133.77*	949,360	.014
	wire, lbs.	205	70.56*	949,360	.007
	paper qts.	2,464,240	47,789.50	2,464,240	1.939
	paper pts.	189,920	2,989.93	94,960	3.149
	paper ½ pts.	1,140,000	13,400.30	285,000	4.702
	glass qts.	107,920	13,694.70	2,158,360	.644
	glass pts.	2,720	305.45	27,120	1.126
	glass ½ pts.	14,920	1,082.90	74,580	1.452
	caps	2,510,920	7,299.24*	2,260,060	.323
	cases	1,240	6,075.64	6,056,020	.100
	cans	80	700.00	680,380	.103
	general		10,766.41	6,736,400	.160
			$118,430.48	6,736,400	1.758¢

Table 24. (continued)

Plant size	Item	Units	Total cost	Quart equivalent	Cost per quart equiv.
8X	paper ½ gals.	949,360	$ 20,980.86*	1,898,720	1.105¢
	wax, lbs.	54,130	5,527.41*	1,898,720	.291
	glue ,lbs.	904	267.56*	1,898,720	.014
	wire, lbs.	410	133.91*	1,898,720	.007
	paper qts.	4,928,480	95,428.44*	4,928,480	1.936
	paper pts.	379,840	5,967.59*	189,920	3.142
	paper ½ pts.	2,280,000	26,779.65*	570,000	4.698
	glass qts.	215,840	27,789.40	4,316,720	.644
	glass pts.	5,440	486.88	54,240	.898
	glass ½ pts.	29,840	2,165.79	149,160	1.452
	caps	5,021,840	13,471.58*	4,520,120	.298
	cases	2,480	11,930.72	12,111,040	.099
	cans	160	1,400.00	1,360,760	.103
	general		12,739.79	13,472,800	.094
			$225,069.58	13,472,800	1.671¢
16X	paper ½ gals.	1,898,720	$ 40,062.99*	3,797,440	1.055¢
	wax, lbs.	108,260	10,116.10*	3,797,440	.266
	glue, lbs.	1,808	535.12*	3,797,440	.014
	wire, lbs.	820	241.72	3,797,440	.006
	paper qts.	9,856,960	190,424.60*	9,856,960	1.932
	paper pts.	759,680	11,909.80*	379,840	3.135
	paper ½ pts.	4,560,000	53,349.26*	1,140,000	4.680
	glass qts.	431,680	55,578.80	8,633,440	.644
	glass pts.	10,880	973.76	108,480	.898
	glass ½ pts.	59,680	4,331.57	298,320	1.452
	caps	10,043,680	26,943.18*	9,040,240	.298
	cases	4,960	23,468.90	24,224,080	.097
	cans	320	2,432.00	2,721,520	.089
	general		13,872.14	26,945,600	.051
			$434,239.94	26,945,600	1.612¢

*These costs include an allowance of 2% for waste and damage.

advantage with the preformed bottle, glass bottle, case, or can supplies. All plants were large enough to obtain quart and half pint glass bottles at the maximum discount. Pint bottle costs per quart equivalent, however, were .023 cent lower for plant 16X. With bulk cans, only 16X was large enough to obtain a price discount. For 16X, cases cost 95 percent as much as they cost plant X. The preformed paper bottles cost 98 and 99 percent as much for large plants as they did for small plants. In all of these items, there were no great savings to larger plants.

For caps and paper half gallons, reductions in unit prices were more pronounced. Plant X paid 2.678 cents per quart of milk packaged in half gallon preformed nested containers. For plant 2X, this same type of container cost only 92 percent of that price. Plant 4X, using a carton formed at the time of filling paid only 56 percent as much as plant X, or 1.487 cents per quart for the cartons, wax, glue, and wire . For plant 16X, the cost was only 1.341 cents or 50 percent of the cost for plant X. Part of the savings in container costs for the bottles formed at the time of filling were lost in higher bottle filler depreciation costs.

Cap costs ranged between .365 and .298 cent per quart equivalent. This allowed 16X a unit cap cost of only 79 percent of that for plant X.

No physical quantities were established for general plant supplies. Therefore, monetary expenditures for these supplies were determined as follows: The actual total expenditure for supplies by each base plant was obtained from plant income tax records. From this total expenditure was subtracted the known costs for paper bottles, staples, wax, glue, wire, glass bottles, caps, cases, and cans. The residual was attributed to general plant supplies such as soaps, cleaning powders, chemicals, refrigerant, lubricants, and uniforms.

Each residual was converted into a percentage of all other supply costs. The percent for each plant was multiplied times the totals of the costs for cases and containers in the respective model plants to arrive at the sum for general plant supplies. Hence, the allowance for general plant supplies in the model plants were based on an analysis of the experience in the base plants. For plant X, the allowance was 25 percent of the cost for all other supplies. For 2X, the allowance was 16 percent; for 4X, it was 10 percent; for 8X, it was six percent; and for 16X, it was 5.3 percent.

The greatest source of reduction in supply costs came from general plant supplies. Unit costs for those supplies declined from .444 cent for plant X to .051 cent for plant 16X. However, as mentioned earlier, the chief source of this reduction in unit cost was physical economies rather than reduced purchase price per unit of supply.

Total supply costs changed from an average of 2.228 cents per quart in plant X to 1.612 cents per quart in plant 16X. Thus, larger plants had savings up to .616 cent per quart. Of this sum, over half or .393 cent was from general plant supplies. The other .223 cent was due entirely to the price reductions. Thus, the net cost per quart for supplies to 16X was 72 percent of the cost for supplies in plant X. Nine percent of this reduction was from reduced prices.

Table 24 also shows the comparative container costs per quart equivalent for different sizes and types of containers. For all plants, the bulk can was by far the cheapest container (Figure 21). On a quart basis, this method cost only .103 to .089 cent per quart. The second cheapest forms of containers were glass bottles. Quart bottle costs were .644 cent for all plants. Pints ranged from 1.128 to .898 cents per quart equivalent. All half pints were 1.452 cents per quart equivalent. Among the preformed paper bottles, container costs increased for quarts, half gallons, pints, and half pints in that order. For plant X, these costs per quart equivalent were 1.947, 2.678, 3.189, and 4.704 cents, respectively. Half gallon containers formed at the time of filling cost less per quart equivalent than all other containers except cans and glass quarts and pints. However, as noted earlier, part of this savings in container costs was lost to higher bottle filler depreciation and maintenance costs.

Building Construction, Depreciation, and Maintenance Costs

As indicated in a previous section building space requirements per quart of milk showed a marked decline as the plant size increased (Table 11). Construction cost estimates generally have shown, also, a declining cost per square foot of building as the size increased.

As was reported earlier, a standard building system, plant arrangement, and building materials were selected. Current material and construction costs were determined and cost estimates for the five plants were made with the advice of a member of an engineering consultant firm.

Construction costs did not double for each subsequent size of plant (Table 25). Only moderate increases occurred in the requirements for site preparation, concrete work, walls, and roofing in the larger plants. These, in turn, only increased moderately the necessary investment for each larger size of plant.

The lives of the buildings were estimated at 20 years. Hence, each was depreciated at five percent per year.[19]

The annual allowance for building and maintenance repairs was two percent of the cost of construction (Table 26). Structures depreciated over a longer length of time probably would have required a greater allowance to cover added roof and processing room floor repair. The tile overlay in the processing rooms have proven particularly troublesome in most dairy plants.

Total building depreciation and maintenance costs for the model plants displayed lower costs per quart than those shown from physical efficiencies (Figure 22). These costs per quart ranged from .4414 cent in plant X to .0850 cent in plant 16X. Thus, plant 16X required

[19] Walker, Preston, and Nelson selected a steel and concrete slab roof construction as the most practical of the alternatives in their synthetic analysis of butter-powder plants (50, p. 30). This type of roof would have lengthened the expected life to about 50 years, but, also, would have materially increased the cost of the structure (35, p. 22 and 25).

Table 25. Building Cost Estimates for Five Model Plants, 1956 Prices

		Model Plants				
		1X (14,000 lbs. per day)	2X (28,000 lbs. per day)	4X (56,000 lbs. per day)	8X (112,000 lbs. per day)	16X (168,000 lbs. per day)
Miscellaneous Data	Building area	8,000	9,600	14,600	22,400	[illegible]
	Building cubage	160,000	192,000	292,000	448,000	672,000
	Outside dimensions	100 x 80 x 18	100 x 96 x 18	100 x 144 x 18	140 x 160 x 20	140 x [illegible] x [illegible]
	Perimeter	360	392	492	600	[illegible]
	Exterior wall surface	3,900	4,240	5,490	12,750	15,[illegible]
	Exterior window area	1,100	1,200	1,450	1,750	2,[illegible]
	Exterior glass brick area	2,200	2,400	2,900	1,500	[illegible]

Construction element	Price	Unit	1X Units	1X Cost	2X Units	2X Cost	4X Units	4X Cost	8X Units	8X Cost	16X Units	16X Cost
1. Site preparation												
Grading and leveling	$ .20	sq.yd.	2,200	$ 440	2,500	$ 500	3,500	$ 700	4,800	$ 960	6,000	$ 1,[illegible]
Excavation	1.60	cu.yd.	135	216	140	224	170	272	200	320	220	[illegible]
2. Concrete work												
Footings and foundations[1]	65.00	cu.yd.	65	4,225	70	4,550	95	6,175	120	7,800	140	9,[illegible]
Floor, 4" with hardever	.59	sq.ft.	6,656	3,927	8,032	4,739	12,336	7,278	19,580	11,552	29,284	17,[illegible]
Floor, 4" with quarry tile	2.25	sq.ft.	1,848	4,158	2,536	5,706	3,608	8,118	5,412	12,177	7,484	16,[illegible]
3. Walls												
Concrete block, 8"	.72	sq.ft.	10,340	7,445	11,600	8,352	12,410	8,935	17,030	12,262	18,250	13,[illegible]
Concrete block, 8" with face tile	2.47	sq.ft.	3,160	7,805	3,680	9,090	4,360	10,769	5,760	14,227	6,160	15,[illegible]
Wall finish, furred and plastered	.45	sq.ft.	2,240	1,008	2,800	1,260	2,800	1,260	5,600	2,520	6,080	2,[illegible]
Glass block, 8"	3.50	sq.ft.	2,200	7,700	2,400	8,400	2,900	10,150	3,500	12,250	5,300	[illegible]
4. Roof												
Trusses	350.	each	6	2,100	7	2,450	10	3,500	-	-	-	-
Trusses	700.	each	-	-	-	-	-	-	11	7,700	16	11,200
Decking, ½" ply	.33	sq.ft.	8,400	2,772	10,080	3,326	15,330	5,060	23,520	7,762	35,280	11,642
Roofing, corrugated aluminum	.98	sq.ft.	8,400	8,232	10,080	9,878	15,330	15,023	23,520	23,050	35,280	[illegible]
5. Insulation												
Roof, 1" ridged	.20	sq.ft.	8,400	1,680	10,080	2,016	15,330	3,066	23,520	4,704	35,280	7,[illegible]
Cooler, 8 40 10"	1.20	sq.ft.	1,928	2,314	3,416	4,099	4,808	5,770	7,224	8,669	8,616	10,[illegible]
6. Windows and doors												
Window, steel frames	.80	sq.ft.	1,100	880	1,200	960	1,450	1,160	1,750	1,400	2,650	2,120
Doors, wood	4.20	sq.ft.	255	1,071	330	1,386	300	1,260	300	1,260	360	1,512
7. Painting, 3 coats	.10	sq.ft.	31,840	3,184	36,480	3,648	43,780	4,378	62,220	6,222	76,260	7,626
8. Gutters and down spouts	.67	lin.ft.	240	161	272	182	368	247	400	268	560	375
9. Heat and ventilate												
System	.06	cu.ft.	160,000	9,600	192,000	11,520	292,000	17,520	448,000	26,880	672,000	40,320
Oil storage	.12	gal.	1,000	120	2,000	240	3,000	360	4,000	480	5,000	600
10. Electrical system	.90	sq.ft.	6,000	5,400	7,900	7,110	9,000	8,100	11,600	10,440	16,600	14,940
11. Plumbing[2]			-	3,960	-	4,550	-	5,610	-	6,480	-	7,280
12. Perimeter fencing, 6' chain link	3.00	lin.ft.	420	1,260	460	1,380	540	1,620	620	1,860	780	2,340
13. Miscellaneous, scaffolds, metal, etc.			-	2,033	-	2,363	-	3,122	-	3,990	-	5,133
14. Contractor's profits[3]		30%		24,507		29,379		38,835		55,570		75,440
Total Construction Cost Estimate				106,198		127,308		168,288		240,803		326,907

[1]Including forms, steel, and pipe service ducts.

[2]Fixtures include washroom fixtures, fountains, sink and hose stations, and floor drains.

[3]Overhead 5%, fees, permits, and surveys 10%, contingencies 5%, profits 10%.

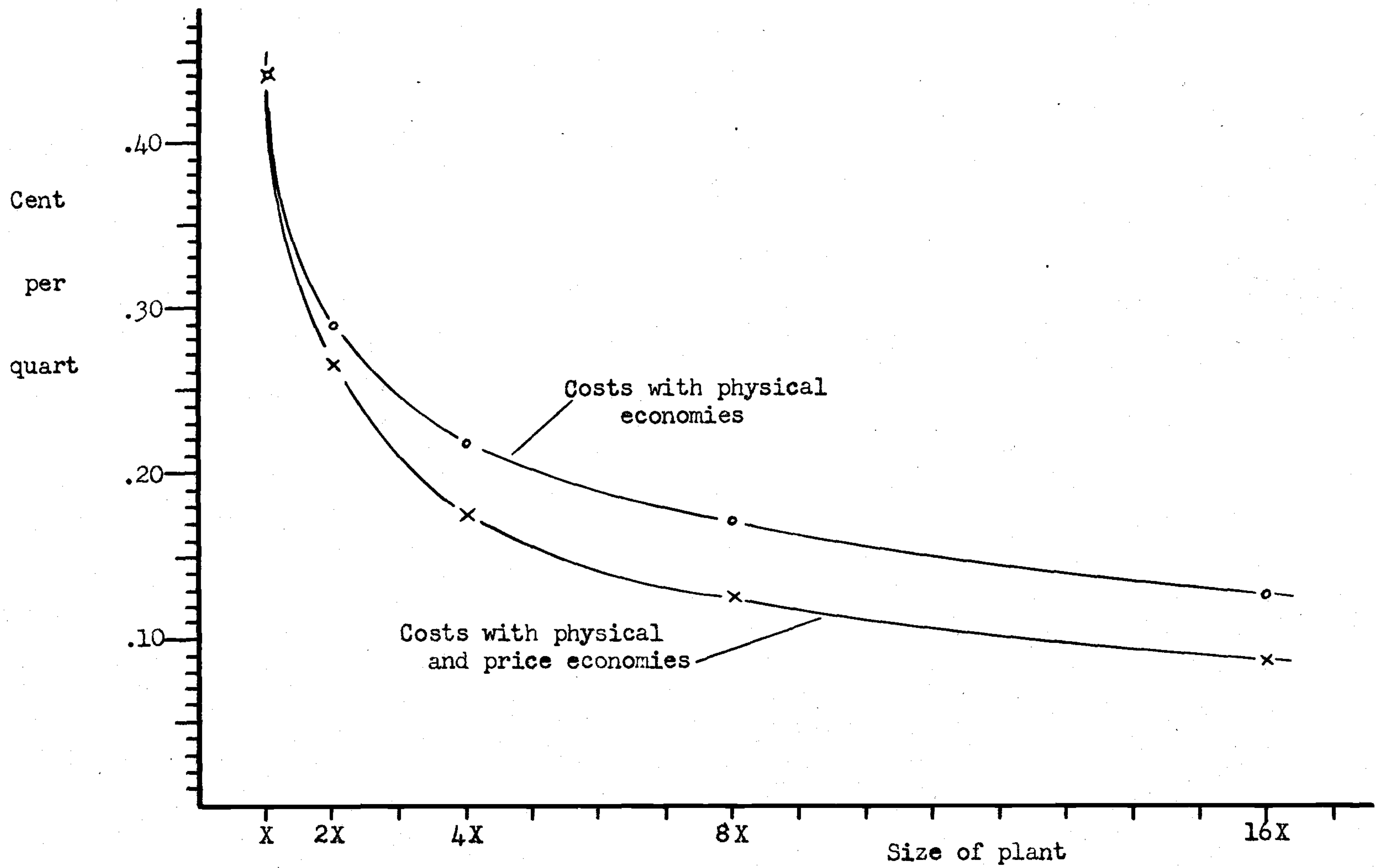

Figure 22. Comparison of physical inputs and costs per quart equivalent for building depreciation and maintenance costs in five model plants, Oregon construction cost estimates, 1956.

Table 26. Total and unit costs for building maintenance and repair for five model plants, Oregon prices, 1956.

Item	Investment and costs by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Investment in building	$106,198	$127,308	$168,288	$240,803	$326,907
Allowance for maintenance	$2,123.96	$2,546.16	$3,365.76	$4,816.06	$6,538.14
Annual cost per quart	.1261¢	.0756¢	.0500¢	.0357¢	.0243¢
Percent of plant X	100	60.0	39.7	28.3	19.4

only 29 percent as much floor space and had only 19 percent of the cost per quart in plant X.

Thus, small plants displayed a severe cost disadvantage in building expense. In actual practice the disparity in these costs was not as great as shown by the models. Larger plants generally had more luxurous buildings than was shown for the models. Conference rooms, tea or banquet rooms, and hostess kitchens were incorporated into the plant building. But even with these additions, the larger actual plants had building costs less than 50 percent of those in the smaller plants.

Inventory of Equipment and Equipment Costs

The type and capacity of the equipment for the model plants (Table 27) were selected on the basis of the standards presented earlier and the size of investment determined. As near as possible the standards used in selecting equipment were consistant with

Table 27. Inventory of equipment by cost center for five model plants, 1956 prices.

Equipment	X (14,000 lbs/day) Size	X Cost	2X (28,000 lbs/day) Size	2X Cost	4X (56,000 lbs/day) Size	4X Cost	8X (112,000 lbs/day) Size	8X Cost	16X (224,000 lbs/day) Size	16X Cost
Can Receiving										
can conveyor		$ 442		$ 442		$3,116		$ 5,230		$ 9,527
can dump		30		45		85		95		95
scales	1,000 lbs	100	1,000 lbs	898	1,000 lbs	898	1,000 lbs	898	1,000 lbs	941
weigh tank	500 lbs	1,075	750 lbs	1,200	1,000 lbs	1,312	1,000 lbs	1,312	1,000 lbs	1,660
receiving tank	800 lbs	625	1,000 lbs	705	1,200 lbs	745	1,500 lbs	870	2,000 lbs	1,158
vacuum sampler	-	-	-	-	-	-	-	-	-	550
can washer	R., 2½ CPM	1,180	R., 3CPM	1,865	St.,4CPM	3,049	St.,8 CPM	5,937	St.,16CPM	9,227
plate cooler	4,000#/hr	2,000	8,000#/hr	2,200	16,000#/hr	2,900	32,000#/hr	4,620	64,000#/hr	7,000
pump, centrifugal	¼ HP	160	½ HP	196	1 HP	283	1 HP	283	5 HP	434
storage tanks	1,000 gal	4,684	1,500 gal	5,273	1,500 gal	5,273	3,000 gal	7,377	5,000 gal	9,846
storage tanks	1,000 gal	4,684	1,000 gal	4,684	1,500 gal	5,273	3,000 gal	7,377	5,000 gal	9,846
storage tanks			1,000 gal	4,684	1,500 gal	5,273	3,000 gal	7,377	5,000 gal	9,846
storage tanks					1,500 gal	5,273	1,500 gal	5,273	3,000 gal	7,377
storage tanks									3,000 gal	7,377
sanitary pipe		735		971		1,557		1,838		3,146
pump, centrifugal	¼ HP	160	½ HP	196	3/4 HP	260	1 HP	283	2 HP	399
Total Can Receiving		15,875		23,359		35,297		48,770		78,429
Processing										
HTST	3,000#/hr	7,192	5,400#/hr	8,499	9,600#/hr	11,738	18,000#/hr	16,032	35,000#/hr	22,500
timing pump	3,000#/hr	558	5,400#/hr	658	9,600#/hr	1,011	18,000#/hr	1,041	35,000#/hr	1,186
homogenizer	3,000#/hr	4,100	5,400#/hr	5,510	9,600#/hr	8,680	18,000#/hr	10,400	35,000#/hr	11,620
clarifier	5,000#/hr	3,135	6,000#/hr	3,643	12,000#/hr	4,720	22,000#/hr	5,711	22,000#/hr	5,711
clarifier									22,000#/hr	5,711
crane		545		545		545		545		1,090
surge tanks	100 gal	1,209	150 gal	1,439	300 gal	2,275	600 gal	3,240	1,000 gal	5,021
surge tanks	150 gal	1,439	300 gal	2,275	300 gal	2,275	600 gal	3,240	1,000 gal	5,021
surge tanks					300 gal	2,275	600 gal	3,240	1,000 gal	5,021
sanitary pipe		2,976		3,171		4,354			2,500 gal	7,059
miscellaneous		145		145		145		4,625		7,041
Total Processing		21,299		25,885		38,018		145		218
								48,219		77,171
Bottle Handling										
case conveyor		469		3,728		9,082				
case washer	5 CPM	1,255	10 CPM	2,551	5 CPM	1,255		17,591		21,980
case washer					10 CPM	2,551	5 CPM	1,255	10 CPM	2,551
bottle washer	20 BPM	2,960	28 BPM	3,710	54 BPM	6,416	15 CPM	3,659	20 CPM	4,355
bottle conveyor		1,945		2,118		3,515	110 BPM	13,620	160 BPM	21,640
bottle filler, glass	20 BPM	1,103	30 BPM	2,005	50 BPM	3,659		4,639		9,140
bottle filler, paper	35 BPM	10,000	35 BPM	10,000	50 BPM	23,090	100 BPM	6,916	145 BPM	8,771
bottle filler, paper							50 BPM	23,090	110 BPM	38,000
bottle filler, ½ gal	10 BPM	5,680	10 BPM	5,680	16 BPM	37,500	75 BPM	19,800	120 BPM	35,000
sanitary pipe		1,526		1,625		3,205	16 BPM	37,500	33 BPM	70,000
miscellaneous				2,756		3,488		3,402		6,602
Total Bottle Handling		24,938		34,173		93,761		5,575		6,030
								137,047		224,069

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Table 27. (continued)

Equipment	Model Plants X (14,000 lbs/day) Size	Cost	2X (28,000 lbs/day) Size	Cost	4X (56,000 lbs/day) Size	Cost	8X (112,000 lbs/day) Size	Cost	16X (224,000 lbs/day) Size	Cost
Specialties										
can washer	2½ CPM	131	3 CPM	207	4 CPM	338	8 CPM	3,012	6 CPM	6,033
can filler, hand		208		208		243		243		243
can filler, mechanical	-	-	-	-	-	-		1,240		1,465
vats, cream	50 gal	1,139	100 gal	1,098	200 gal	1,649	300 gal	3,147	600 gal	4,886
vats, buttermilk	75 gal	1,098	150 gal	1,649	300 gal	3,147	600 gal	4,886	600 gal	4,886
vats, chocolate							400 gal	3,662	800 gal	5,653
vats, skim	200 gal	2,136	400 gal	3,662	800 gal	5,653	1,500 gal	5,273	3,000 gal	7,377
pumps, centrifugal	2 - ½ HP	392	2 - 3/4 HP	520	2 - 3/4 HP	520	3 - 3/4 HP	780	3 - 2 HP	1,197
sanitary pipe		1,934		1,934		2,256		3,076		4,721
starter incubator		128		128		128		322		322
Total Specialties		7,166		9,406		13,934		25,641		36,783
Cooler										
cooler blowers	15,000 BTU	379	25,000 BTU	553	35,000 BTU	726	50,000 BTU	1,106	70,000 BTU	1,452
General Plant										
separator	1,400#/hr	3,585	2,000#/hr	4,333	4,000#/hr	5,231	6,000#/hr	6,140	6,000#/hr	6,140
separator									6,000#/hr	6,140
timing pump	1,400#/hr	387	2,000#/hr	558	4,000#/hr	558	6,000#/hr	658	6,000#/hr	658
timing pump									6,000#/hr	658
bowl crane		545		545		545		545		1,090
boiler	25 HP	2,814	30 HP	3,196	50 HP	4,018	85 HP	7,236	80 HP	5,968
boiler									125 HP	8,444
compressors	7½ HP	1,640	7½ HP	1,640	15 HP	2,245	25 HP	3,362	40 HP	4,771
compressors	7½ HP	1,640	7½ HP	1,640	15 HP	2,245	25 HP	3,362	40 HP	4,771
compressors			15 HP	2,245	25 HP	3,362	40 HP	4,771	40 HP	4,771
compressors									40 HP	4,771
condenser	8.8T	832	17.5T	1,295	33.2T	1,758	67.8T	2,795	149T	5,349
ice builder	4,600 lbs	2,915	9,000 lbs	4,854	19,200 lbs	8,214	36,000 lbs	13,000	71,000 lbs	22,000
pump, industrial	2 - 1 HP	466	2 - 2 HP	620	2 - 3 HP	660	2 - 5 HP	694	3 - 10 HP	1,335
air compressor	2 PH	460	1 HP	375	2 HP	460	3 HP	535	10 HP	1,284
air compressor			2 HP	460	5 HP	685	7½ HP	1,193	10 HP	1,284
sink		245		245		245		245		515
acid dispenser		68		68		68		68		68
bottle shaker	12 bottle	102	24 bottle	116	24 bottle	116	36 bottle	124	36 bottle	124
centrifuge	12 bottle	83	24 bottle	118	24 bottle	118	36 bottle	186	36 bottle	186
water bath	24 bottle	73	24 bottle	73	24 bottle	73	36 bottle	100	36 bottle	100
acidity tester		25		25		25		25		25
bottle washer	12 bottle	39	24 bottle	80	24 bottle	80	36 bottle	104	36 bottle	104
miscellaneous		30		60		60		70		70
pipe wash tank	10 ft	378	10 ft	378	12 ft	392	12 ft	392	12 ft	392
sep. disc washer		773		773		773		773		1,545
C.I.P. unit	3/4 HP	934	1 HP	977	2 HP	1,061	3 HP	1,083	5 HP	1,102
floor scrub machine	-	-	-	-		330		330		990
wash sink		295		350		360		360		720

Table 27. (continued)

Equipment	Model Plants: X (14,000 lbs/day) Size	Cost	2X (28,000 lbs/day) Size	Cost	4X (56,000 lbs/day) Size	Cost	8X (112,000 lbs/day) Size	Cost	16X (224,000 lbs/day) Size	Cost
pump	2 HP	384	3 HP	518	7½ HP	948	15 HP	1,525	25 HP	2,373
water tank	220 gal	150	315 gal	200	750 gal	275	1,500 gal	325	3,000 gal	538
chlorinator		110		110		300		300		300
Total General		$18,973		$25,852		$35,205		$50,301		$88,586
Total Investment		$88,630		$119,228		$216,941		$311,084		$506,490
Annual Depreciation		8,863.00		11,922.80		21,694.10		31,108.40		50,649.00
Equipment Costs per Quart		.5263¢		.3540¢		.3220¢		.2309¢		.1880¢

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practices followed in the base plants. The price for each piece of equipment was the average of the prices from three suppliers of dairy equipment. These prices were obtained in the late fall of 1956. To the extent possible, each piece of equipment was similar in quality and accessories to the corresponding equipment in the other model plants.

All equipment was depreciated at 10 percent per year. This figure was obtained from the reports of the base plants.[20]

The annual allowance for the repair and maintenance of equipment was 5 percent per year of the new cost (Table 28). This figure was

Table 28. Total and unit allowances for equipment maintenance and repair for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Investment and costs by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Investment in equipment	$88,630	$119,228	$216,941	$311,084	$506,490
Allowance for repairs	4,431.50	5,961.40	10,847.05	15,554.20	25,324.50
Annual cost per quart	.2631¢	.1770¢	.1610¢	.1154¢	.0940¢
Percent of plant X	100	65.6	61.2	43.9	35.7

[20]All base plants used this rate for income tax purposes. In actual practice, different types of equipment had different lengths of life. Most pieces lasted more than ten years. One of the reasons a standard depreciation rate was used by the base plants undoubtedly was its simplicity. Ten percent of the purchase cost was easy to calculate. However, another reason appeared that was economically more sound. All base plants analyzed had obsolete equipment on their books not fully depreciated, yet no longer in use in the plant. Plant managers reasoned that while equipment did not always wear out in ten years, it most likely would be replaced in that time.

based on Webster's report on the experience in his area (52, p. 14). Very little research has been published on the repair costs for dairy equipment.[21] The base plants comprised too small a sample to establish a rate common to Oregon plants. However, their reports indicated that an allowance of at least 5 percent was needed.

Equipment depreciation and repair costs per quart ranged from a high of .7894 cent in plant X to a low of .2820 cent in plant 16X (Figure 23). Equipment costs per quart in plant 16X were only 36 percent of that for plant X.

In actual practice, the differences in equipment costs between the various sizes of plants was not quite as great as shown for the models. Larger plants generally had equipment with polished and stainless steel exteriors. The smaller plants, on the other hand, more often had pieces of equipment with tinned and painted exteriors. Lighter weight equipment also was used. But even with these differences, the average cost per quart for equipment in the two largest base plants was only about 52 percent of the average for the two smallest plants.

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[21] The report of Monroe and Walker on capital costs for five model fluid milk plants included an allowance for repairs that was about 4.5 percent of the new cost of the equipment (27, p. 34-36). Walker, Preston, and Nelson found repairs in butter-powder plants to be a function of the size of the investment and the volume of milk processed (50, p. 35).

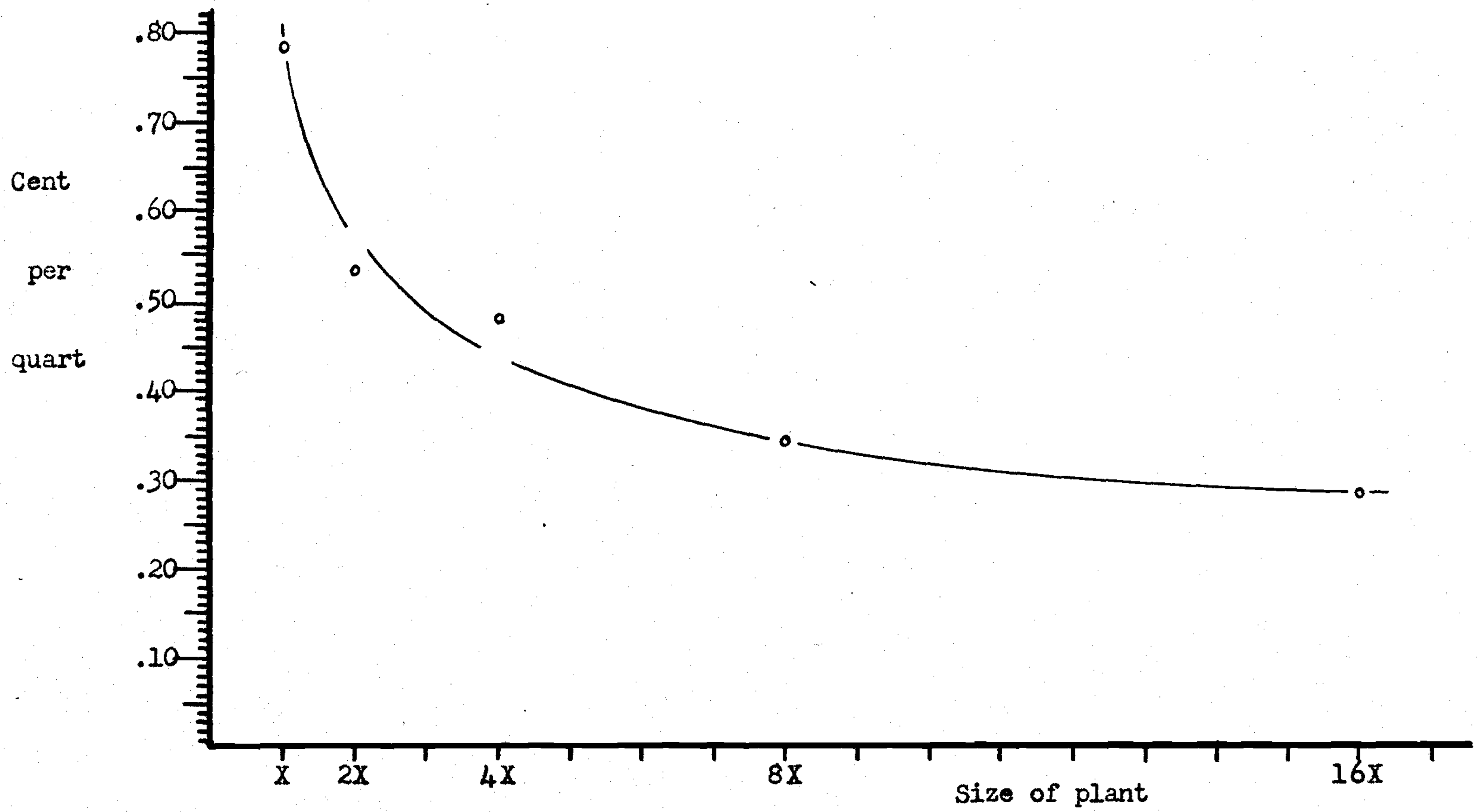

Figure 23. Comparison between equipment depreciation and maintenance costs per quart equivalent and size of plant for five model plants with can intake and glass and paper output, Oregon, 1956.

Taxes, Interest, and Insurance

Taxes

The tax value of all real and personal property was estimated as 24 percent of the "true cash value". The sum used as the true cash value for the building and equipment was 50 percent of the original costs to simulate investment when half depreciated. This choice for average investment required the assumption that buildings and equipment would be worn out when fully depreciated and would not be discarded for obsolescense prior to that time.

The value of the building lots for the base plants varied considerably according to location of the lot in relation to the rest of the city or town as well as upon the size of the lot. Variations in lot assessments reflected in processing costs through variations in taxes and interest. To eliminate sources of variation in these costs not directly associated with plant size, all lot values were calculated at a standard rate of 32.5 cents per square foot.[22] The resulting values are listed in Table 29.

The tax rates reported by the base plants were not the same. Therefore, a standard rate of $73.70 per thousand was selected. It was the 1956 rate for a typical base plant. The estimated tax was calculated as shown in Table 30.

Cost per quart for real estate and property taxes were .1090 cent for plant X, .0686 cent for plant 2X, .0530 cent for plant 4X,

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[22] This rate was reported by Webster as the average for several communities.

Table 29. Estimated values for building lots for five model plants, Oregon conditions, 1956.

Item	Size of plant X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Lot, sq.ft.*	19,600	22,400	28,700	39,600	54,000
Value at					
32.5¢/sq.ft.	$6,370	$7,280	$9,328	$12,870	$17,550

*Each lot extended 20 feet beyond the building on three sides and 40 feet on the fourth.

Table 30. Estimated average investment and taxes for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Size of plant X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Investment					
building*	$53,099	$63,654	$84,144	$120,402	$163,454
equipment*	44,315	59,614	108,471	155,542	253,245
lot	6,370	7,280	9,328	12,870	17,550
Average total					
investment	$103,784	$130,548	$201,943	$288,814	$434,249
Tax value**	$24,908	$31,332	$48,466	$69,315	$104,220
Taxes at					
$73.70/$1000	$1,835.72	$2,309.17	$3,571.94	$5,108.52	$7,681.02
Tax cost/qt	.1090¢	.0686¢	.0530¢	.0379¢	.0285¢
Percent of					
plant X	100	62.9	48.6	34.8	26.0

*Average investment or 50 percent of the original cost.
**Tax value was 24 percent of average investment used as "true cash value".

.0379 cent for plant 8X, and .0286 cent for plant 16X. The tax per quart for 16X was only 26 percent of the amount for plant X (Figure 24).

Interest

Not all of the base plants paid interest charges. For this study, interest was assumed to be a cost of operation whether paid on a loan or retained by the operator. Therefore, a standard interest rate of 5 percent of the average total investment was selected and interest costs calculated (Table 31). The average total investment was the same as shown for tax purposes.

Interest charges per quart ranged from .3081 cent per quart for plant X to .0806 cent for plant 16X. Costs to 16X were only 26 percent of the costs to plant X (Figure 24).

Table 31. Estimated interest on investment for five model plants with can intake and glass and paper output, Oregon rates, 1956.

Item	Size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Average total investment	$103,784	$130,548	$201,943	$288,814	$434,249
Interest at 5 percent	$5,189.20	$6,527.40	$10,097.15	$14,440.70	$21,712.35
Interest cost per quart	.3081¢	.1938¢	.1499¢	.1072¢	.0806¢
Percent of plant X	100	62.9	48.6	34.8	26.0

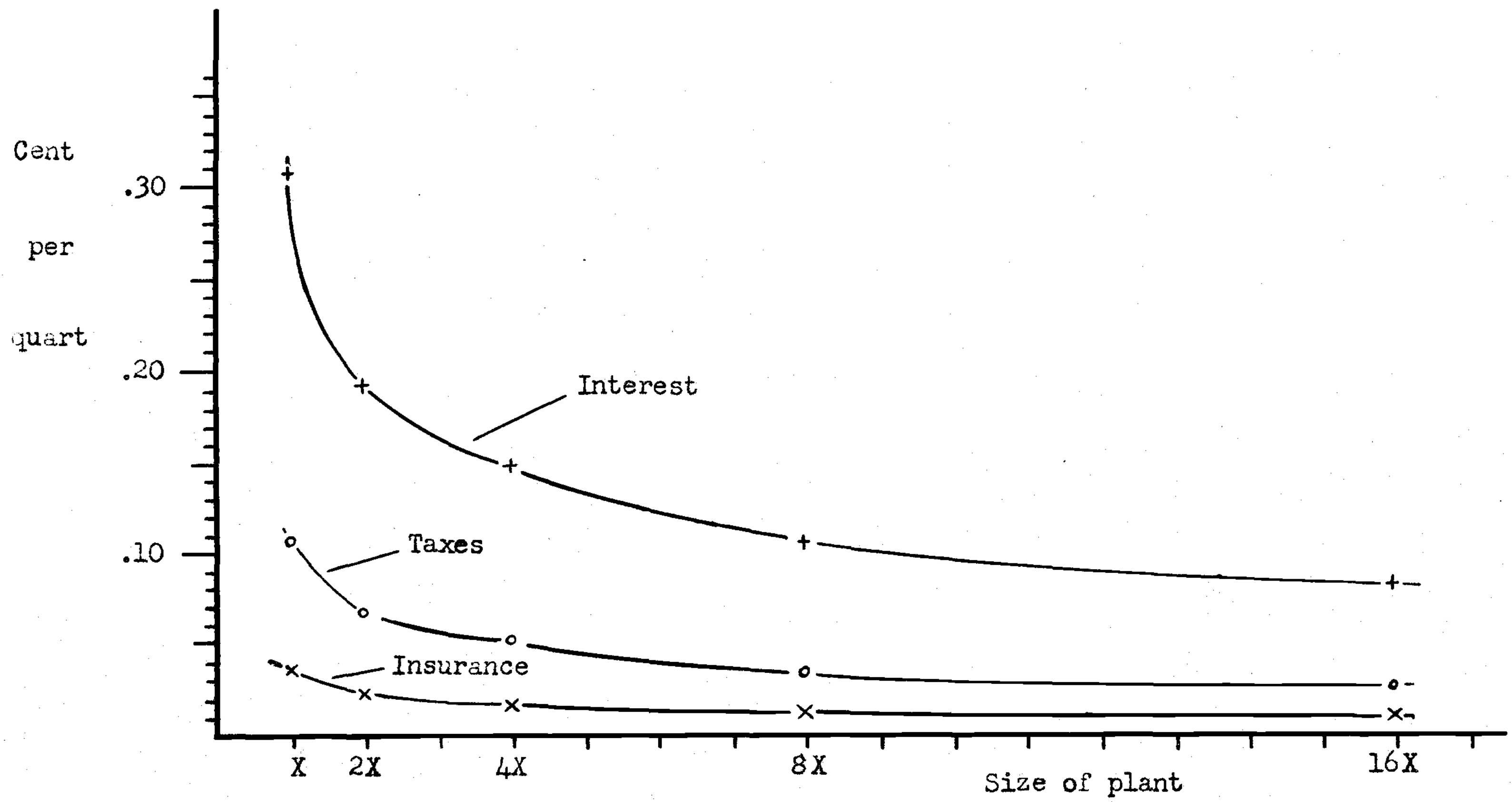

Figure 24. The relationship between taxes, interest, and insurance costs per quart equivalent and size of plant for five model plants with can intake and glass and paper output, Oregon, 1956.

Insurance

The amount of insurance carried by the base plants varied considerably. The risk of loss by fire was considered a cost in this study, whether borne by the plant operator or by an insurance company. Therefore, insurance costs were figured on 100 percent of the average depreciated value (Table 32). The average depreciated value of both buildings and equipment was assumed to be the average investment, or 50 percent of the new cost. The annual rate for buildings on a three year contract was $5.80½ per $1,000 of value. The annual cost for contents under a three year contract was $7.70 per $1,000.[23] The insurance rates used in this study were obtained from an agency handling accounts in the Willamette Valley.

Insurance costs per quart to plant X were .0386 cent. For 2X, they were .0246 cent; for 4X, .0196 cent; for 8X, .0141 cent; and for 16X they were .0109 cent. As a percent of the cost to X, these were 64 percent, 51 percent, 37 percent, and 28 percent, respectively.

Other Costs

Other costs included a monetary allowance for product loss and for plant licenses (Table 33).

[23] Insurance rates were considerably reduced when the plant and contents were insured at 100 percent of value. The annual rate for buildings on a three year contract changed from $10.75 to $5.80½ per thousand per year when insured at 100 percent of value. For contents, the change was from $12.83 1/3 to $7.70.

Table 32. Estimated insurance costs for five model plants with can intake and glass and paper output, Oregon rates, 1956.

Item	Size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Bldg. costs*	$53,099	$63,654	$84,144	$120,402	$163,454
Ins. at $5.805/$1000	308.24	369.51	488.46	698.93	948.85
Equip. costs*	$44,315	$59,614	$108,471	$155,542	$253,245
Ins. at $7.70/$1000	341.23	459.03	835.23	1,197.67	1,949.97
Total Ins.cost	$649.47	$828.54	$1,323.68	$1,896.60	$2,933.47
Ins. cost per quart	.0386¢	.0246¢	.0196¢	.0141¢	.0109¢
Percent of plant X	100	63.7	50.8	36.5	28.0

*Average investment or 50 percent of the new cost.

Table 33. Other costs for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Loss, lbs	29,200	58,400	116,800	233,600	467,800
Price, $	5.20	5.20	5.20	5.20	5.20
Value	$1,518.40	$3,036.80	$6,073.60	$12,147.20	$24,294.40
License	100.00	100.00	100.00	100.00	100.00
Total	$1,618.40	$3,136.80	$6,173.60	$12,247.20	$24,394.40
Cost/qt	.0961¢	.0931¢	.0916¢	.0909¢	.0905¢
Percent of plant X	100	96.9	95.3	94.6	94.2

The product loss was valued at a class one price of $5.20 per hundred weight.[24]

Base plant license fee reports varied widely. A standard set of fees and costs of $100 was selected for use in this study. This was higher than the state license fee, but not as high as some of the city license fees and costs in this area.

The net effect was a slight reduction in cost per quart as the size of plant grew larger (Table 33). For plant X, the cost was .0961 cent per quart. For 16X, it was .0905 cent or 95 percent of the cost to X. This reduction per quart was due entirely to the fixed plant license fee that was divided among more quarts as the size of the plant grew larger.

Total Unit Costs

Total costs are summarized in Table 34. Costs per quart for each cost element are shown in Table 35.

Total unit costs declined throughout the entire range of model plants (Table 35 and Figure 25). Total costs per quart in plant X were 5.8706 cents. For plant 2X, they were 4.3283 cents; for 4X, they were 3.6515 cents; for 8X, they were 3.1242 cents; and for 16X, they were 2.9043 cents. As a percent of the cost to X, these were 74 percent, 62 percent, 53 percent, and 50 percent.

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[24]In the base plants where milk was used for manufactured products, too, product loss was charged off at manufacturing milk rates.

Table 34. Summary of total costs for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Total costs by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Plant labor	$26,966.40	$ 32,314.60	$ 53,429.20	$ 85,865.00	$171,819.60
Utilities					
fuel oil	$ 2,523.96	$ 3,113.42	$ 4,385.37	$ 6,374.83	$ 10,509.19
power	1,378.68	2,302.32	3,709.68	5,749.92	9,557.40
water	450.00	480.00	535.00	645.00	870.00
Total	$ 4,352.64	$ 5,895.74	$ 8,630.05	$ 12,769.75	$ 20,936.59
Supplies					
half gals	$ 6,354.79	$ 11,733.13	$ 14,126.41	$ 26,909.74	$ 50,955.93
paper qts	11,994.92	23,989.87	47,789.50	95,428.44	190,424.60
paper pts	756.95	1,513.90	2,989.93	5,967.59	11,909.80
paper ½ pts	3,351.84	6,703.68	13,400.30	26,779.65	53,349.26
glass qts	3,473.68	6,947.35	13,894.70	27,789.40	55,578.80
glass pts	76.50	153.00	305.45	486.88	973.76
glass ½ pts	270.72	541.45	1,082.90	2,165.79	4,331.57
caps	2,061.71	3,649.62	7,299.24	13,471.58	26,943.18
cases	1,536.79	3,019.34	6,075.64	11,930.72	23,468.90
cans	175.00	350.00	700.00	1,400.00	2,432.00
general	7,473.85	9,376.21	10,766.41	12,739.79	13,872.14
Total	$37,526.75	$ 67,977.55	$118,430.48	$225,069.58	$434,239.94
Building					
depn	$ 5,309.90	$ 6,365.40	$ 8,414.40	$ 12,040.15	$ 16,345.35
maint	2,123.96	2,546.16	3,365.76	4,816.06	6,538.14
Total	$ 7,433.86	$ 8,911.56	$ 11,780.16	$ 16,856.21	$ 22,883.49
Equipment					
depn	$ 8,863.00	$ 11,922.80	$ 21,694.10	$ 31,108.40	$ 50,649.00
maint	4,431.50	5,961.40	10,847.05	15,554.20	25,324.50
Total	$13,294.50	$ 17,884.20	$ 32,541.15	$ 46,662.60	$ 75,973.50
Taxes	$ 1,835.72	$ 2,309.17	$ 3,571.94	$ 5,108.52	$ 7,681.02
Interest	$ 5,189.20	$ 6,527.40	$ 10,097.15	$ 14,440.70	$ 21,712.35
Insurance	$ 649.47	$ 828.54	$ 1,323.68	$ 1,896.60	$ 2,933.47
Other	$ 1,618.40	$ 3,136.80	$ 6,173.60	$ 12,247.20	$ 24,394.40
Plant Total	$98,866.94	$145,785.56	$245,977.41	$420,916.16	$782,574.16

Table 35. Summary of unit costs for five model plants with can intake and glass and paper output, Oregon prices, 1956.

Item	Unit costs by size of plant				
	X (1,684,100 quarts)	2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
Plant labor	1.6012¢	.9594¢	.7931¢	.6373¢	.6377¢
Utilities					
fuel oil	.1499¢	.0924¢	.0651¢	.0473¢	.0390¢
power	.0819	.0684	.0551	.0427	.0355
water	.0267	.0143	.0080	.0048	.0032
Total	.2585¢	.1751¢	.1282¢	.0948¢	.0777¢
Supplies**					
half gals	2.6775¢	2.4718¢	1.4880¢	1.4173¢	1.3418¢
paper qts	1.9471	1.7470	1.9393	1.9363	1.9319
paper pts	3.1885	3.1885	3.1486	3.1422	3.1355
paper ½ pts	4.7043	4.7043	4.7019	4.6982	4.6798
glass qts	.6438	.6438	.6438	.6438	.6438
glass pts	1.1283	1.1283	1.1263	.8976	.8976
glass ½ pts	1.4520	1.4520	1.4520	1.4520	1.4520
caps	.3649	.3230	.3230	.2980	.2980
cases	.1015	.0997	.1003	.0985	.0969
cans	.1029	.1029	.1029	.1029	.0894
general	.4436	.2784	.1598	.0946	.0515
Total	2.2283¢	2.0182¢	1.7581¢	1.6705¢	1.6115¢
Building	.4414¢	.2646¢	.1749¢	.1251¢	.0850¢
Equipment	.7894¢	.5310¢	.4831¢	.3463¢	.2820¢
Taxes	.1090¢	.0686¢	.0530¢	.0379¢	.0286¢
Interest	.3081¢	.1938¢	.1499¢	.1072¢	.0806¢
Insurance	.0386¢	.0246¢	.0196¢	.0141¢	.0109¢
Other	.0961¢	.0931¢	.0916¢	.0909¢	.0905¢
Plant Total	5.8706¢	4.3283¢	3.6515¢	3.1242¢	2.9043¢
Percent of plant X	100	73.7	62.2	53.2	49.5

**Cost per unit of milk bottled in respective kind of containers.

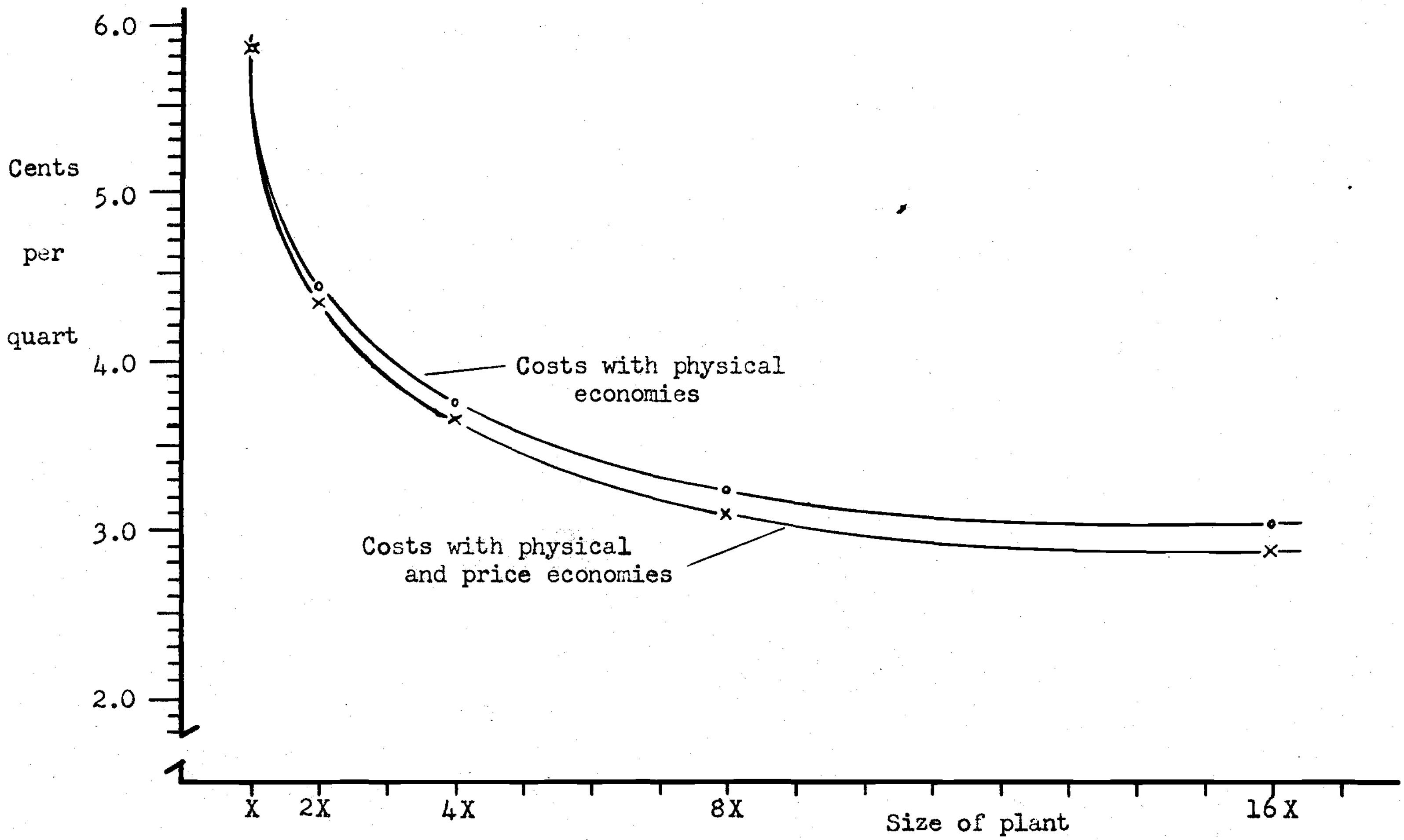

Figure 25. Comparison of total physical inputs and total costs per quart equivalent in five model plants with can intake and glass and paper output, Oregon prices, 1956.

Thus, the largest model plant processed milk for 2.9663 cents a quart less than the smallest plant (Table 36A). Physical efficiencies accounted for 2.8073 cents or 94.6 percent of the savings. The rest of the saving in larger plants was due to the lower prices associated with the purchase of larger quantities.

Container costs and general supply costs were the largest items of expense for all sizes of plants. No physical efficiencies were allowed for container supplies, but price reductions permitted a savings in the larger model plants that amounted to 9 percent of the supply costs in plant 16X. Additional savings for general plant supplies brought the sum to .6168 cent per quart (Table 36A) or 20.8 percent of the total reduction (Table 36B).

Labor was the next largest item of expense in all plants. There were only minor differences in labor costs due to labor price per man hour (.0034 cent for plant 16X). Physical efficiencies, however, brought the total savings to .9635 cent (Table 36A) per quart or 32.5 percent of the total reduction in cost per quart in plant 16X. (Table 36B).

Building costs per quart showed a greater percent reduction between plant X and 16X than any other cost element. However, those costs were such a small part of the total cost that their net effect was less than for either labor or supplies. Reduced building space requirements accounted for .1620 cent or 5.5 percent of the total savings to plant 16X. Reduced building cost per square foot of space accounted for another .1944 cent. Total savings from building costs

Table 36. Costs per quart equivalent for five model plants compared to the costs in the smallest plant, Oregon prices, 1956.

Item	Plant X (1,684,100 quarts)	Difference from plant X by size of plant: 2X (3,368,200 quarts)	4X (6,736,400 quarts)	8X (13,472,800 quarts)	16X (26,945,600 quarts)
		36A. Difference in cents per quart			
Labor	1.6012¢	.6418¢	.8081¢	.9639¢	.9635¢
Utilities	.2585	.0834	.1303	.1637	.1808
Supplies	2.2283	.2101	.4712	.5578	.6168
Building	.4414	.1768	.2665	.3163	.3564
Equipment	.7894	.2584	.3063	.4431	.5074
Taxes	.1090	.0404	.0560	.0711	.0804
Interest	.3081	.1143	.1582	.2009	.2275
Insurance	.0386	.0140	.0190	.0245	.0277
Other	.0961	.0030	.0045	.0052	.0056
Total	5.8706¢	1.5423¢	2.2191¢	2.7464¢	2.9663¢
		36B. Cost element as a percent of the difference			
Labor	27.3	41.6	36.4	35.1	32.5
Utilities	4.4	5.4	5.8	6.0	6.1
Supplies	38.0	13.6	21.2	20.3	20.8
Building	7.5	11.5	12.0	11.5	12.0
Equipment	13.4	16.8	13.8	16.1	17.1
Taxes	1.9	2.6	2.5	2.6	2.7
Interest	5.2	7.4	7.1	7.3	7.7
Insurance	.7	.9	.9	.9	.9
Other	1.6	.2	.2	.2	.2
Total	100.0	100.0	100.0	100.0	100.0
		36C. Cost element as a percent of plant X			
Labor	100	59.9	49.5	39.8	39.8
Utilities	100	67.7	49.6	36.7	30.1
Supplies	100	90.6	78.9	75.0	72.3
Building	100	60.0	39.7	28.3	19.4
Equipment	100	65.6	61.2	43.9	35.7
Taxes	100	62.9	48.6	34.8	26.0
Interest	100	62.9	48.6	34.8	26.0
Insurance	100	63.7	50.8	36.5	28.0
Other	100	96.9	95.3	94.6	94.2
Total	100	73.7	62.2	53.2	49.5

accounted for 12.0 percent of the total savings per quart in plant 16X.

The cost element with the second greatest percentage reduction in costs per quart in the larger plants was equipment. However, like building costs, these costs were so small a part of the total costs that their net effect was less than either labor or supplies. Reduced equipment cost per quart accounted for .5067 cent (Table 36A) or 17.1 percent of the total savings to plant 16X (Table 36B).

Taxes, interest, and insurance costs per quart followed the same general pattern as building and equipment costs. Reduced taxes, interest, and insurance due to physical efficiencies accounted for .3150 cent or 10.6 percent of the savings per quart to plant 16X. Additional savings from lower investments in buildings accounted for another .0206 cent per quart. Thus, total reduction was .3356 cent (Table 36A) or 11.3 percent for plant 16X (Table 36B).

Utilities were a relatively small part of the total processing costs per quart. However, they accounted for .1449 cent per quart or 4.9 percent of the savings to plant 16X on physical efficiencies alone. Their total effect was a reduction in costs per quart of .1808 cent (Table 36A) or 6.1 percent of the net savings to plant 16X (Table 36B).

Other costs accounted for about .2 percent of the savings in all of the larger sizes of plants (Table 36B).

This study did not locate the low point in the long run average cost curve. From all appearances, labor costs per quart have ceased to decline. For some supply items, increased volume would not be accompanied by reduced unit prices.

On the other hand, unit costs appeared still to be falling but at a declining rate for utilities, general plant supplies, and all capital costs such as depreciation, maintenance, taxes, interest, and insurance.

Unit costs for the smaller plants, both model and actual, were unduly high because some items of cost such as labor or equipment could not be combined in such a way as to permit utilization of their full capacity. Plant X, for instance, had considerable unused filler capacity. A plant reorganization that included a slightly larger pasteurizer and a longer processing day would have permitted a considerable increase in volume with little additional total cost. However, under the fixed assumptions of a given volume and method of operation, the illustrated combination of labor and equipment gave the smallest unit cost.

Operators of actual plants are usually faced with the first assumption of a fixed volume of output at least in the short run. However, the method of plant operation can be changed in the short run. Therefore, further research comparing the costs of different methods of processing for several sizes of plants would be valuable to plant operators for short run decisions.

Summary and Conclusions

The purpose of this study was to determine the relationship between size of plant and unit processing costs.

There were too few plants and not enough similarity between the plants in Oregon to allow a meaningful statistical analysis of the cost-volume relationships in actual plants. Therefore, the synthetic budget was used to minimize variation between plants except for size.

Five synthetic models were budgeted to represent the medium to large sizes of plants in Oregon. The smallest, designated plant X, processed an average of 14,000 pounds of raw milk a day, five days a week. The subsequent models processed twice the amount of milk as the preceding size of plant. They were designated 2X, 4X, 8X, and 16X.

Data from a study of six actual plants were used as a guide in establishing the type and amount of physical inputs required for processing milk in the various sizes of model plants. Physical input-output relationships reported by other researchers also served as a guide.

Each model plant was assumed to receive milk in cans and to package the product in bulk cans, glass bottles, and preformed paper cartons. A third of the plant output went into glass bottles, 10 percent into bulk cans, and 56 percent into paper cartons. Both paper and glass quart, pint, and half-pint bottles were used. About 69 percent of the plant output went into quarts, 1.8 percent into pints, 5 percent into half-pints, and 14 percent into half gallons. Half gallons were packaged in paper only. As a percent of the total output, homogenized milk was 69 percent, regular milk 11 percent, skim milk 6 percent, half and half 6 percent, multivitamin milk 3 percent, buttermilk 2 percent, chocolate drink 2 percent and the creams 1 percent. These assumptions were representative of the practices found in the actual plants.

The labor requirements and duties of each crew member were determined with the aid of detailed labor and equipment operation schedules. Fuel oil consumption was determined from the heat requirements per hour and the number of hours of operation for each piece of heat consuming equipment. In a similar manner, consumption of electricity was synthesized from the hourly rates of consumption and the number of hours of use for each motor and light. Supply requirements were determined by first establishing the types of supplies required for the assumed plant output and, then, adopting usage, breakage, and trippage standards for each type of supply.

A standard building system, bill of material, and plant layout were selected for all sizes of plants. Material and construction data necessary for estimating construction costs were obtained. A standard list of equipment varying between plants, for the most part, only in size or capacity was selected.

When completed, the budgets were checked for reasonableness by dairy plant owners and equipment sales engineers. Finally, 1956 prices were applied to the physical budgets and the net processing costs determined for each size of plant.

Total processing costs per quart declined as the size of plant increased. The rate of decline was relatively rapid between plants X, 2X, and 4X, but leveled off somewhat between 4X, 8X, and 16X. The lower costs per quart in the larger plants resulted both from lower physical inputs per quart and from reduced prices per unit of input.

Labor costs per quart ranged from 1.60 cents in plant X to .64 cent in plant 16X. Since the schedule of wage rates was standard for all sizes of plants, this reduction in labor cost was due, primarily, to fewer man minutes required per quart in the larger plants.

Fuel costs per quart of milk in plant X came to .15 cent. In plant 16X, it cost only .04 cent. Plant 16X used only 58 percent as much oil per quart but, because lower prices were paid for oil, had a net cost only 26 percent of that for plant X.

As with fuel oil, electricity requirements per quart and prices per killowatt declined as the size of plant increased. Power consumption ranged from 58.8 watts per quart in plant X to 33.8 watts in plant 16X. Costs were .082 cent per quart in plant X, but only .036 cent in plant 16X. Thus, plant 16X used only 56 percent as many watts per quart and had a net power cost only 42 percent of that for plant X.

Container and case supplies per quart were assumed constant for all sizes of plants. Therefore, no physical economies were available for these supplies in the larger plants. However, price reductions for the greater quantities purchased by the larger plants allowed savings up to .22 cent per quart for plant 16X.

General plant supplies per quart such as soaps, chemicals, refrigerant, and lubricants varied according to the size of the plant. These supplies cost .444 cent per quart in plant X. Cost decreased rapidly in each subsequent size of plant to only .052 cent in plant 16X.

Total supply costs per quart for plant X were 2.23 cents. For the largest plant, these costs were only 1.61 cents or 72 percent of the cost to plant X. Price reductions for larger purchases accounted for 9 percent of this difference.

Building costs showed the greatest percentage change in requirement per quart between the various sizes of plants. Plant X required .0048 square foot per quart per year while 16X required only .0014 square foot. The net depreciation and maintenance costs for these areas were .441 cent per quart in plant X and .085 cent in plant 16X. Thus, 16X required only 29 percent as much floor space per quart and experienced only 19 percent as much building expense as plant X.

Equipment depreciation and maintenance costs per quart declined rapidly between the first three plants and then began to decline a little more gradual. These costs per quart were .79 cent in plant X, but only .28 cent in plant 16X. This was 35 percent of the cost in plant X.

Taxes, interest, and insurance costs were calculated at the same rates for all sizes of plants. They were based on building, lot, and equipment values. Since the size of investment per quart for these items decreased with each larger plant, taxes, interest, and insurance costs per quart also declined. Costs per quart of milk for these three items ranged from .46 cent per quart in plant X to .12 cent in plant 16X. Thus, plant 16X paid only 26 percent as many of these costs per quart as plant X.

Total processing costs in plant X were 5.87 cents per quart. In plant 2X, they were 4.33 cents; for 4X, 3.65 cents; for 8X, 3.12 cents; and for 16X, 2.90 cents per quart. As a percent of the processing costs in plant X, these were 74 percent for 2X, 62 percent of 4X, 53 percent for 8X, and 49 percent for 16X.

The largest model plant processed milk for 2.97 cents a quart less than the smallest plant. Differences in the quantities of physical inputs per quart accounted for 94.6 percent of this saving. The rest of the advantage in the larger plants was due to lower prices that accompanied the purchase of larger quantities of physical inputs.

More efficient use of labor was the biggest source of savings in the larger plants. This cost element accounted for 32.4 percent of the net savings in plant 16X. Reductions in supply costs per quart were responsible for another 20.8 percent of the savings. Changes in equipment depreciation and maintenance costs per quart accounted for 17.2 percent of the savings in 16X while reductions in building depreciation and maintenance costs were responsible for 12.1 percent. Reduced taxes, interest, and insurance costs per quart accounted for 11.3 percent of the savings. Fuel oil, electricity, and boiler water costs accounted for 6.1 percent of the total savings to plant 16X.

This study did not locate the low point in the long run average cost curve. From all appearances, labor costs per quart had ceased to decline. For some supply items, increased volume would not be accompanied by reduced unit prices. For most cost elements, however, unit costs appeared still to be falling, but at a declining rate. This was true for fuel oil, electricity, water, general plant supplies, and all building and equipment costs such as depreciation, maintenance, taxes, interest, and insurance.

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