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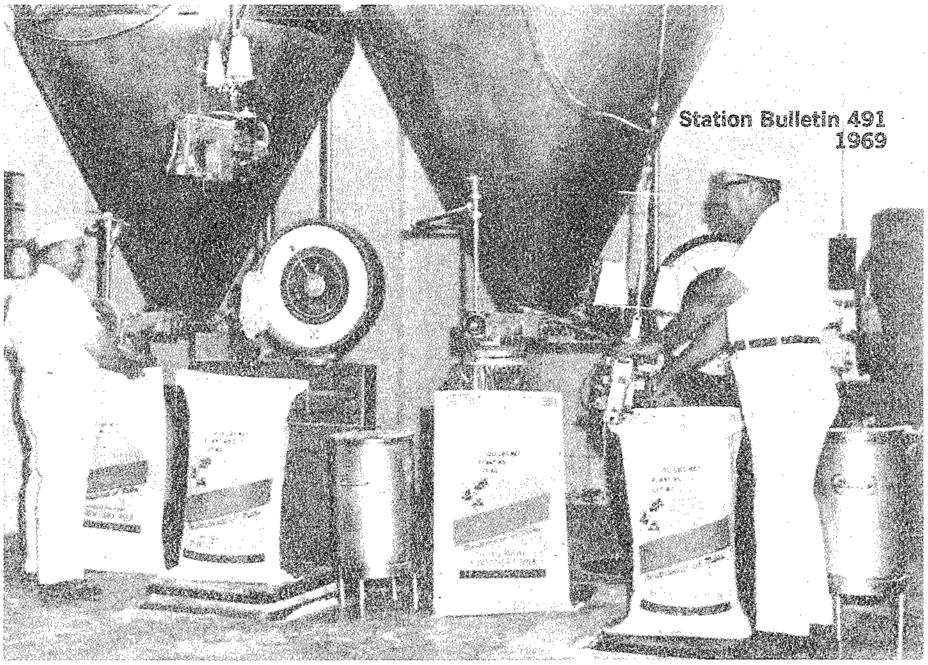
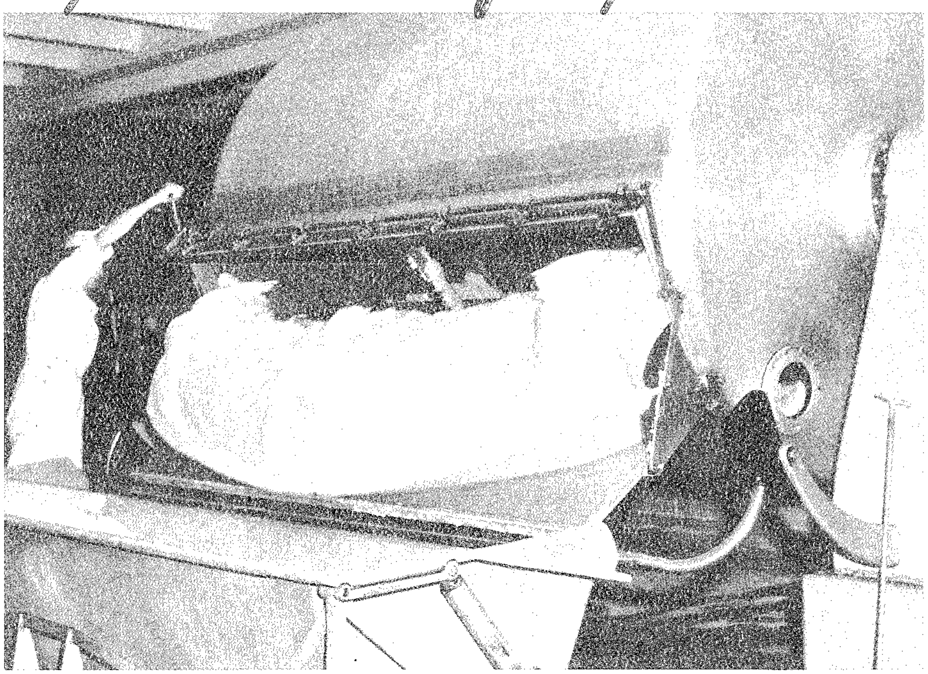


Processing Costs in Butter-Nonfat Dry Milk Plants



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AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MINNESOTA

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Cover photos: (Top) Workers packaging and weighing dry milk in preparation for storage. (Bottom) Unloading butter from a churn into a butter boat preparatory to packaging.

PROCESSING COSTS IN BUTTER-NONFAT DRY MILK PLANTS

J. William Hanlon and E. Fred Koller*

Much of the milk produced in Minnesota is processed into butter, nonfat dry milk (NFDM), and dried buttermilk. In 1964, 73 percent of Minnesota's total milk production was processed into these products. This processing is done by several types of plant organizations, including specialized butter plants, specialized NFDM plants, and combination butter-NFDM plants that manufacture both butter and NFDM. The combination plants accounted for about 80 percent of Minnesota's annual NFDM production in 1962, up from 63 percent in 1957.

The major objectives of this study were to determine and analyze relationships between processing costs and plant size in butter-NFDM plants. Processing cost is one of three broad aspects of the larger problem of determining optimal plant size; the other two aspects are the cost of milk procurement and the cost of marketing finished products.

Determining which size plant has the lowest average processing costs is of constant concern within the dairy industry, both for the planning of new plants and for the expansion or merger of existing ones. Butter-NFDM plants in Minnesota range from those capable of handling about 200,000 pounds of whole milk per day to those that can process nearly 2 million pounds daily. There is a trend toward larger plants. In 1957, about 78 percent of Minnesota's total NFDM production was manufactured in plants with daily whole milk capacities of 200,000 pounds or more.[1] This figure increased to 86 percent in 1960 and to about 90 percent in 1962.[2] Questions have been raised within the industry about whether or not this trend is resulting in increased efficiency.

Managers and others familiar with the butter and NFDM industry agree that butter-NFDM plants with less than a 200,000 pound daily whole milk capacity are inefficient relative to the state's larger plants. But there are some unanswered questions regarding the comparative costs of larger plants. For instance, can a plant with a daily capacity of over 1 million pounds achieve costs lower than a plant with a 600,000 or 700,000 pound capacity? This study was designed to answer this and other related questions.

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The authors acknowledge with appreciation the generous cooperation of the managers of butter-NFDM plants, dairy equipment dealers, dairy technologists, engineers, and others in the industry who supplied the basic data for this study. Credit is due to S. T. Coulter, Department of Food Science, and S. A. Engene, Department of Agricultural Economics, for many helpful suggestions.

[1] Koller, E. Fred and Richard J. Goodman, "Minnesota's Dry Milk Industry is Changing," *Minnesota Farm Business Notes*, Univ. of Minn., Dec. 1957.

[2] Koller, E. Fred and J. William Hanlon, "The Minnesota Dry Milk Industry," *Minnesota Farm Business Notes*, Univ. of Minn., Apr. 1962.

Objectives

The general objective of this study was to obtain information on costs and efficiencies in butter-NFDM plants. The specific objectives were to estimate and analyze two basic types of cost relationships for butter-NFDM plants with annual whole milk capacities of 140 to 470 million pounds or corresponding daily capacities of 500,000 to 1,700,000 pounds. The cost relationships studied were the relationship between plant size and cost (longrun cost or economies of size relationships) and the relationship between costs and volume of milk processed within given plants (shortrun cost relationships).

Both short and longrun cost relationships are useful to decision makers in the milk processing industry. They facilitate answering questions about what size plant can achieve the lowest cost for processing any given annual volume of milk, what annual volume is required to attain the lowest costs in the industry, and how costs behave as annual volume fluctuates within given plants. The cost information in this study also provides achievement standards for operating plants.

Theoretical Considerations

In economic theory, the relationship between changes in inputs and changes in outputs usually is distinguished by the length of the time period during which the changes occur. The short run is a period sufficiently short so that some but not all of the inputs can be varied in quantity, and the long run is sufficiently long so that all inputs, including plant and equipment, can be varied. Inputs that are variable in the short run give rise to variable costs, while fixed inputs give rise to fixed costs.

The shortrun period for which costs were estimated in this study was 1 year, since this is the period within which managers make many important decisions. Plant administrators may be able to make limited increases in plant capacity within a year's time by adjusting existing equipment or by adding minor equipment. But it is quite unlikely that any major modifications in plant and equipment could be accomplished in less than a year from the time an initial decision to modify is made. The approval of major capital expenditures, the processing of bids, and the completion of installation more than likely would take over a year.

Decisions regarding labor in butter-NFDM plants also are often made on an annual basis. Even though monthly variations in milk receipts are large, with the lowest month often being less than 50 percent of the peak month, plant managers usually hire most of their labor on a yearly basis to obtain skilled, experienced men. The low production months are then used for vacations and plant and equipment maintenance.

In the long run, output can be changed by varying either the output rate per hour of plant operation or the number of hours of plant operation. Shortrun variations in output are limited to the latter.

The relationships of total annual cost to annual hours of plant operation and to rate of output per hour of plant operation are shown in figure

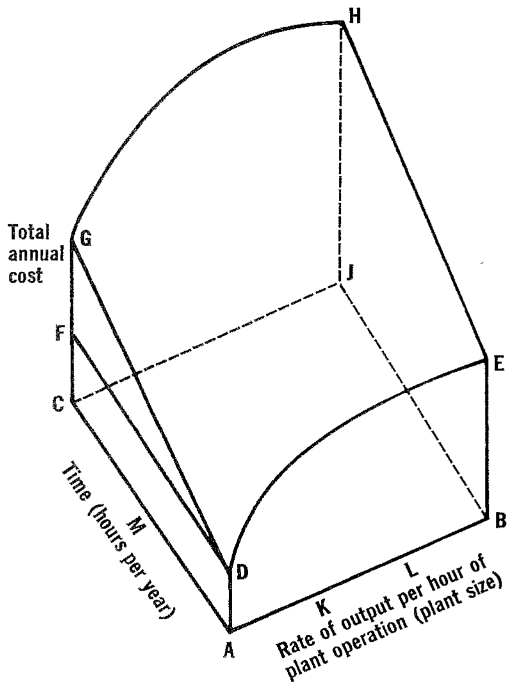


Figure 1. Theoretical cost structure of butter-NFDM plants.

1. The four sides of the diagram are formed by areas ACGD, CJHG, BJHE, and ABED. The area DGHE is a total cost surface formed by elevations from the time rate plane (the plane labeled ABJC).

Any point on the rate axis (A, K, L, or B) represents a plant with a fixed hourly capacity. When moving from point A to point B, successive points represent plants with different combinations of building and equipment and progressively larger hourly capacities. Building and equipment are long term investments, so movement along the rate axis assumes that capital has not been committed. Since all costs are variable, this represents the longrun situation.

Point A represents operation at the zero level. Movement along the time axis, such as from point A to point C, represents operating a given plant a greater number of hours per year. This is a shortrun movement; capital has been commited. A plant is at maximum annual capacity when it operates at point C, the maximum possible number of hours of operation per year, given the typical monthly variation in milk receipts. At this operational level, line CF represents fixed costs and line FG represents variable costs.

A cross section taken from the time-cost plane of figure 1 is shown in figure 2. This figure represents a shortrun cost relationship — the relationship between cost and hours of operation or between cost and annual volume. Point C in figure 2 represents operation of a particular plant at its maximum annual capacity. This cost-time relationship includes both fixed and variable costs. The fixed costs include overhead costs such as

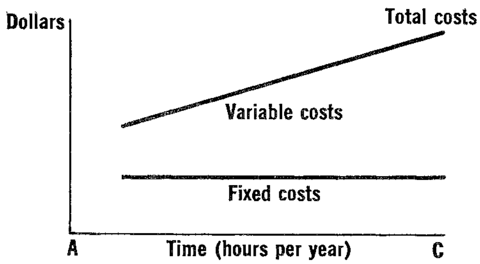


Figure 2. Theoretical relationship between annual cost and hours of plant operation per year.

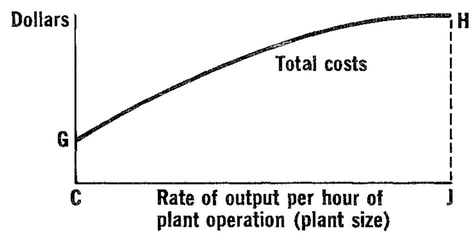


Figure 3. Theoretical relationship between annual cost and rate of output per hour of plant operation.

those for administration and depreciation, as well as the costs of labor, fuel, electricity, and supplies required to start, warmup, and clean equipment. Variable costs include the cost of labor, fuel, electricity, and supplies that change as the annual volume in a given plant changes.

In figure 2, the total variable costs for a butter-NFDM plant are linear with respect to volume. This indicates that, as volume changes by successive equal increments, the change in cost always is the same. Earlier studies indicate that this is true in actual plant operation, with minor exceptions such as quantity discounts on electricity and supplies.[3] This linearity, combined with the presence of fixed costs, causes average total cost to decrease as volume increases within a given plant. Therefore, the lowest average cost attainable for a plant is obtained at its maximum annual volume.

The plane CGHJ from figure 1 is shown in figure 3. Curve GH shows the total costs obtained by various size plants when operated at their respective maximum annual capacities. This curve represents plants operating 24 hours per day (including cleanup) during May, the month of peak milk receipts. A butter-NFDM plant obtains its lowest average cost at maximum annual capacity, so curve GH represents the total costs from which the longrun average cost curve is derived.

The short and longrun average cost (or economies of size) curves that result from the above theoretical total cost model are shown in figure 4. Curves AB, CD, EF, and GH are shortrun curves, each one representing a particular plant. The low points of these shortrun curves (B,

[3] Juers, Linley E., "An Economic Analysis of the Operating Costs of Butter-Powder Plants with Particular Reference to the Problems of Joint Costs," Unpub. Ph.D. thesis, Univ. of Minn., July 1957, and Thompson, Russell G., "An Approach to Estimating Optimum Sizes of Butter-Powder Plants," Unpub. Ph.D. Thesis, Univ. of Minn., Aug. 1962.

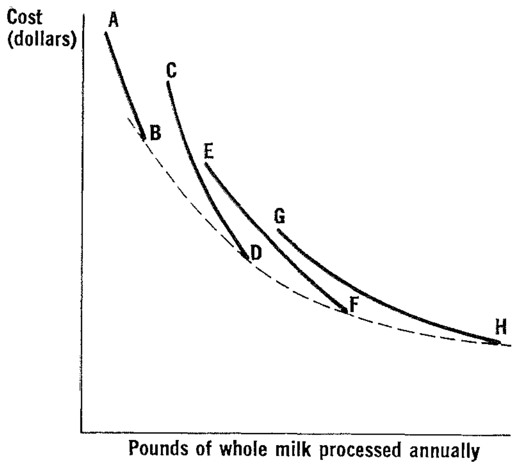


Figure 4. Theoretical shortrun and longrun average cost curves.

D, F, and H) are points on the longrun average cost curve. Each of these points indicates the lowest possible average cost of processing a particular annual volume of whole milk. When these four points are joined, the resulting curve, BDFH, is the longrun average cost curve. This curve sometimes is called the longrun planning curve because it is a useful tool for planning the optimal size plant for any annual volume.

When the longrun average cost curve shows lower costs at higher volumes, economists say that there are economies to size in the industry, meaning that larger plants can obtain lower costs. When this curve shows higher costs at higher volumes, there are diseconomies to size. If it shows no change in costs as volume changes, the industry is one of constant costs.

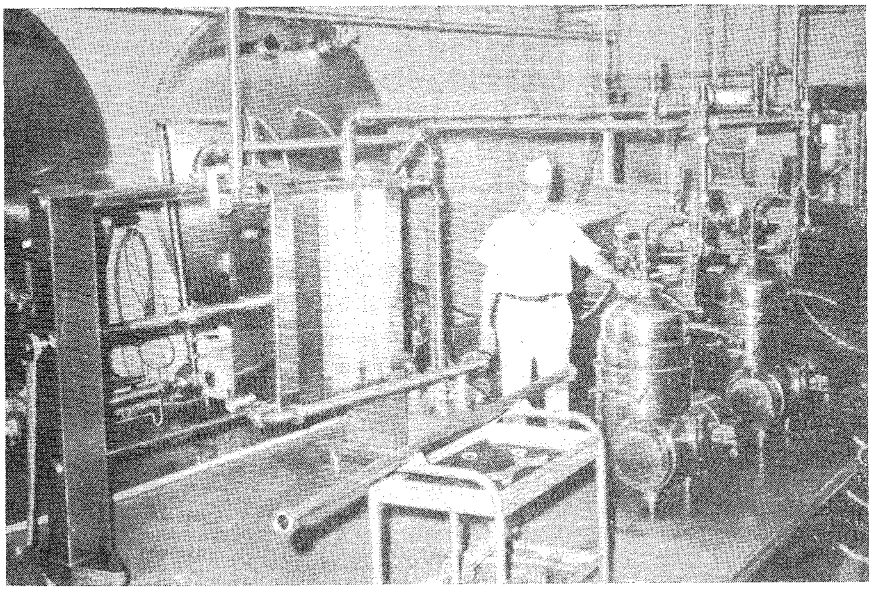
RESEARCH PROCEDURE

The cost estimates in this study largely represent the actual performance of four butter-NFDM plants that were studied in detail. Certain adjustments were made in historical plant data to obtain estimates of efficiencies and costs that could be compared from plant to plant. Efficiency refers to the amount of output obtained per unit of physical input. The procedures for estimating costs and efficiencies varied among plants as the nature of the data obtained from each plant varied.

All cost estimates, with the exception of certain overhead items, represent input prices or price schedules that were standardized among plants. Differences in estimated costs among plants then could be attributed to differences in efficiencies rather than to differences in input prices.

The Production Process

The production process in a butter-NFDM plant is briefly described below.



Plant worker checking cream separators and pasteurizer.

Most Minnesota butter-NFDM plants receive whole milk in 10-gallon cans or in bulk tank trucks. With can receiving, the cans are dumped and washed, the milk is weighed, and a testing sample is taken. When whole milk is received in bulk, the driver does the sampling and measuring of quantities at the farm, and the milk is pumped from the truck tank into the plant.

Upon receipt, the milk may be cooled and pumped to storage or it may be heated and separated into skim milk and cream immediately. After separation, the cream is pasteurized, cooled, stored for several hours, and churned into butter. An increasing number of plants now pasteurize the whole milk prior to separation, thus eliminating the cream pasteurization step.

After churning, the butter usually is packed in either 1 pound prints or 68 pound boxes. The packaged butter is then put into refrigerated storage. Buttermilk, a byproduct of the churning process, is pumped to storage after churning, from where it is either dried or sold in fluid form.

The skim milk from the separator is either cooled and stored prior to evaporation or pumped directly to the evaporator, where it is condensed from about 9 percent nonfat solids to over 40 percent. The condensed skim milk is pumped into the spray dryer, where most of its moisture is removed, resulting in NFDM containing about 97 percent nonfat milk solids and about 3 percent moisture. The NFDM then may be packaged in a variety of ways, depending on its use and destination. Often, it is put into 100 pound paper bags for commercial users or government sale.

Several other processes that occur in a butter-NFDM plant may be described as intermediate. These processes include the production or acquisition of inputs used in the other processes. For example, the production of refrigeration is an intermediate process, since refrigeration is required in several other processes. The purchase or production of electricity also is an intermediate process.

Data Sources

Four of Minnesota's more efficient butter-NFDM plants were selected for detailed cost studies. First, a questionnaire sent to all milk drying plants in Minnesota provided information relative to plant capacities, percentage of capacity at which each one operated, and types and quantities of products produced and milk processed. Based on this information, 10 plants were selected for further study. All of these plants produced insignificant quantities of products other than butter, NFDM, and buttermilk; were within the annual capacity range of 140 to 470 million pounds of whole milk; operated near their maximum annual capacities; and received and processed relatively high ratios of whole to skim milk. Finally, four plants from this group of 10 were selected for detailed cost analyses. The four plants finally selected for study were representative of the full range of annual capacities of 140 to 470 million pounds of whole milk and had histories of low annual costs.

Data on costs and quantities of inputs and outputs for the four plants were obtained from plant records, plant observations, and interviews with the managers, technical plant personnel, and dairy equipment engineers. Monthly data were obtained for the fuel and electricity inputs from all four plants. Hours of labor actually used were obtained for weekly periods from plants I and III and for 2-week periods from plant II. Hourly labor data were not available from plant IV, so monthly cost data were used as an alternative. The data for plant I covered the fiscal year ending in 1963, as well as part of 1964. Data from the other three plants covered the fiscal year ending in 1964.

Some data were obtained from plants other than the four referred to above. These data served to support the validity of the data obtained from the four primary plants. Some of the technical input-output relationships used when developing fuel and electricity costs were obtained from dairy equipment engineers.

Assumptions

Three assumptions were used for all plants when estimating and analyzing their costs.

Product Yields

When converting milk products into whole milk equivalents and vice versa, the assumptions were:

(1) Whole milk contained 3.5 percent milkfat and 8.5 percent nonfat solids.

(2) The yield of butter per pound of fat received in whole milk was 1.23 pounds.
(3) Whole milk yielded 8 pounds of NFDM per 100 pounds.
(4) Whole milk yielded 4.5 pounds of fluid buttermilk per 100 pounds.

Monthly Distribution of Milk Receipts

The monthly distribution of whole milk receipts used as standard in this study was the monthly percentage distribution of Minnesota's 1963 production of spray process NFDM. All annual costs estimated in this study were based on this distribution. The distribution was: 9.34 percent of the total annual whole milk receipts were received in January, 9.22 percent in February, 10.43 percent in March, 10.29 percent in April, 11.00 percent in May, 10.13 percent in June, 7.69 percent in July, 5.89 percent in August, 4.94 percent in September, 5.73 percent in October, 6.67 percent in November, and 8.67 percent in December.

Annual Capacity

The maximum annual whole milk capacity for a butter-powder plant was defined in this study as the amount processed when any part of the plant operated at maximum daily capacity in the month of May, while production for other months followed the standard monthly distribution. The maximum daily capacity for the receiving, separating, cream, and butter process of a plant is the amount of whole milk that can be processed in 22 hours of operation. About 2 hours are required in every 24-hour period for cleanup and setup of the equipment used in these processes. The maximum daily capacity for the skim milk segment of a plant is the amount of skim milk that can be processed in 20 hours of product flow. About 4 hours per 24-hour period are required for cleanup and setup of skim milk equipment.

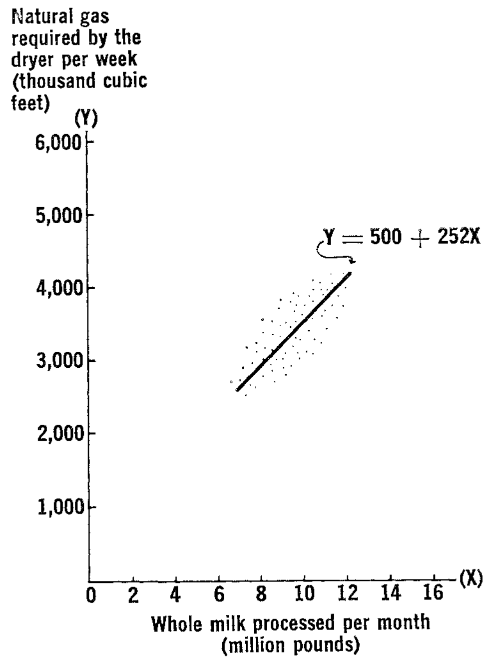
Cost Measurement Methods

The selection of techniques used for estimating costs was guided mainly by the type of data available from each plant. A general goal of this study was to estimate shortrun cost curves representing efficiencies that actually were obtained by the four plants. Therefore, the only adjustments made in actual plant data were those required to obtain cost and efficiency relationships that could be compared among plants. The major data adjustment was to make the fuel and electricity data representative of whole milk processing. The four plants received both whole and skim milk.

A Note on Regression Analysis

Simple linear regression analysis was used to estimate the relationships between inputs, costs, and output, using weekly or monthly data. A hypo-

Figure 5. An illustration of simple linear regression analysis.



thetical example of the data used for regression and the results obtained are illustrated in figure 5. Each dot represents a quantity of whole milk processed by a hypothetical plant in a particular month and the quantity of natural gas used by the dryer in that month. The dot distribution shows that the gas used to process a given amount of whole milk in a particular month was not always the same as that required in some other month for the same amount of whole milk. For example, the figure shows that the amount of gas used to process 12 million pounds of whole milk varied from about 3 million cubic feet in some months to about 4 million in others. Such variations may have been caused by month-to-month variations in weather or by variations in the solids content of the milk. Other causes may have been month-to-month variations in stack losses of powder and other inefficiencies in the drying process.

The line through the dots in figure 5 was determined by simple linear regression. Any point on this line represents an estimate of the average amount of natural gas required to produce a particular amount of whole milk. The regression line can be used to estimate the amount of gas required to process any monthly quantity of whole milk, including quantities outside the range covered by the data. From the figure, for example, the regression estimate of the amount of gas required to process 18 million pounds of whole milk is about 5 million cubic feet. Also, the regression line indicates an estimate of 1 million cubic feet to process 2 million pounds of whole milk.

However, the reliability of such estimates may be questionable. Gas estimates made for NFDM quantities outside the range covered by the data are not as reliable as estimates made for quantities within it. For example, the gas estimate made for 10 million pounds of whole milk is more reliable than one made for 16 million pounds, and the latter estimate is more reliable than one made for 20 million pounds of NFDM.

As shown in figure 5, the regression estimate suggests that about 500,000 cubic feet of natural gas are required per month to process 0 pounds of whole milk. In other words, this is an estimate of the fixed input, or the amount of gas required to heat and clean the dryer. This requirement does not change as additional milk is processed. The regression line also shows that the amount of gas required increases as output increases beyond 0. This increase is about 252,000 cubic feet per million pounds of milk. This is the variable component of the gas input, since it changes with the amount of milk processed. This division of inputs into fixed and variable was necessary for estimating the input requirements for various amounts of output in a given plant.

The equation for the regression shown in figure 5 is:

$$Y = 500 + 252X$$

where:

Y = The amount of natural gas used by the dryer per month in units of 1,000 cubic feet

X = The amount of whole milk processed per month in units of 1 million pounds

The number 500 in the above equation is the estimated monthly fixed fuel requirement, and the number 252 is the estimated variable fuel requirement. The regression equation can be used to estimate fuel requirements. For example, the following calculation results in an estimate of the amount of fuel required to process 18 million pounds of whole milk in 1 month:

$$Y = 500 + 252\ (18)$$

$$Y = 500 + 4{,}536$$

$$Y = 5{,}036 \text{ (estimated gas requirement in thousand cubic feet)}$$

Regression estimates of the general type illustrated above were used to estimate efficiencies and costs for labor, fuel, and electricity for the four plants at various annual volumes of whole milk processed. Data adjustments and specific estimating procedures are described below.

Adjustment of Data to Whole Milk Basis

All plants included in the study purchased some skim milk as well as whole milk for processing, so the ratios of butter to NFDM produced were not representative of whole milk operations. Plant records did not differentiate between the fuel and electricity used for butter and that used for NFDM. For example, the boiler produces steam for the entire plant. Separate measurements of the amount of steam going to the evaporator and the amount going to the whole milk and cream centers usually are not made. To obtain cost relationships that could be compared among plants, historical data were adjusted to whole milk bases for all four plants.

The monthly fuel and electricity data of plants I, III, and IV were adjusted by adding estimates of the fuel and electricity required to run the whole milk equivalent of the purchased skim milk through the whole milk processes. Plant II was adjusted to a whole milk organization by subtracting the estimated amounts required to run the purchased skim milk through the skim milk processes from the fuel and electricity actually used. The adjusted data for all four plants represented the fuel and electricity required to process whole milk, so interplant comparisons of efficiency and cost relationships developed from these data could be made. This adjustment was not required for labor because plant records differentiated between labor used for butter and that used for NFDM.

Labor Estimates

The procedure used to estimate annual labor costs consisted of two basic steps for plants I, II, and III. First, simple linear regression techniques were used to estimate the physical labor requirements for various volumes of milk processed. Second, the lowest cost method of obtaining the estimated required labor at standard wage rates was determined for each plant. The schedule of standard wage rates represented in all labor cost estimates in this study is shown in table 1.

Physical labor-output data were not obtained for plant IV, so cost-volume relationships were estimated directly from cost-volume data. Maintaining comparability of labor costs among plants while making this estimate was possible because the wage rate schedule used by plant IV was identical to that shown in table 1.

The procedure used to determine the lowest cost method of obtaining the required hourly labor is described below. The creamery labor of plant I is used in this illustration. As used below, the term hourly refers to labor paid an hourly wage, in contrast to labor paid a fixed monthly salary.

First, a regression equation was estimated using weekly data from plant I. This equation for hourly creamery labor was:

$$L^w_c = 186 + .085204\, W^w$$

where:

L^w_c = Man-hours of hourly creamery labor required per week

W^w = The amount of whole milk processed per week, thousand pound units

Second, this weekly equation was converted to a monthly basis by multiplying the fixed labor, 186 man-hours per week, by the number of weeks in a month. A 28-day month has exactly 4 weeks, a 30-day month has 4.28 weeks, and a 31-day month has 4.43. The above equation, converted to a monthly basis for a 28-day month, is:

$$L^m_c = (4)\,(186) + .085204\, W^m$$

$$L^m_c = 744 + .085204\, W^m$$

Table 1. Standard wages, salaries, and benefits in butter-NFDM plants

Labor classification*	Base hourly rate		Additions to base rate§		Gross hourly rate††		Gross monthly salary**
	Straight time†	Overtime‡	Straight time	Overtime	Straight time	Overtime	
	dollars						
Plant superintendent, chief engineer, and chief mechanic	2.59	3.88	.40	.22	2.99	4.10	570
Working foreman	2.43	3.64	.37	.21	2.80	3.85	534
Dryer and evaporator operator and buttermaker	2.37	3.56	.37	.20	2.74	3.76	522
Boiler room helper	2.31	3.46	.36	.20	2.67	3.66	509
Separator man and assistant buttermaker	2.25	3.38	.35	.19	2.60	3.57	496
Powder packer, common laborers, and laboratory technicians	2.18	3.27	.34	.19	2.52	3.46	480

* Office workers were paid either $450 or $534 per month, depending on their responsibilities.

† This wage schedule approximates those used in several Minnesota plants in 1965.

‡ This is 1.5 times the base straight time rate.

§ This includes social security at 4.2 percent of the base hourly rates, workmen's compensation at 1.33 percent of the base hourly rates, employee liability insurance at .162 percent of the base hourly rates, 80 hours of paid vacation per employee per year, 56 hours of paid sick leave per employee per year, and 48 hours of paid holidays per employee per year.

†† This is the base hourly rate plus additions.

** This is for employees who were paid monthly rather than hourly rates; it is the gross straight time hourly rate times 44 hours per week times 4.333 weeks per month.

For a 30-day month, the equation is:

$L^m_c = (4.28)(186) + .085204\, W^m$

$L^m_c = 796 + .085204\, W^m$

For a 31-day month, the equation is:

$L^m_c = 4.43\,(186) + .085204\, W^m$

$L^m_c = 824 + .085204\, W^m$

where:

L^m_c = Man-hours of creamery labor required per month

W^m = Amount of whole milk processed per month, thousand pound units

Third, the above monthly equations were used to estimate the man-hours of labor required during each **month** at several **annual** whole milk volumes.

Fourth, the lowest cost method of obtaining these estimated required man-hours was determined using these restrictions and assumptions:

(1) The plant manager preferred to hire men for the full year, rather than seasonally. Therefore, each employee was paid for a minimum of 8 hours per day and 40 hours per week for a full year.

(2) Annual receipts of whole milk were distributed monthly according to the standard distribution described earlier.

(3) Maximum annual volume of whole milk processed was defined as the volume at which either the drying or cream processing stage operated at maximum daily capacity during the peak month.

(4) The straight time and overtime wage rates were consistent with the standard rates shown in table 1.

(5) The overtime premium wage rate was paid for all hours worked in excess of 8 hours per day and 40 hours per week.

(6) Labor productivity was constant regardless of the number of hours each man worked.

The calculations made to determine the lowest cost method of obtaining the estimated required man-hours are described below.

(1) The man-hours of straight time labor supplied per month by several different size crews were determined. Using an eight-man crew and a 30-day month as an example, this is:

$30/7 \times 40 \times 8 = 1{,}371$ man-hours

where:

30/7 = The number of weeks in the month

40 = The number of hours of straight time worked per man per week

8 = The number of men

(2) The hours of overtime required per month at several annual volumes for each size crew then were determined by subtracting the monthly man-hours of straight time in (1) from the required man-hours. The sum of the positive remainders for each annual volume was the hours of overtime required per year.

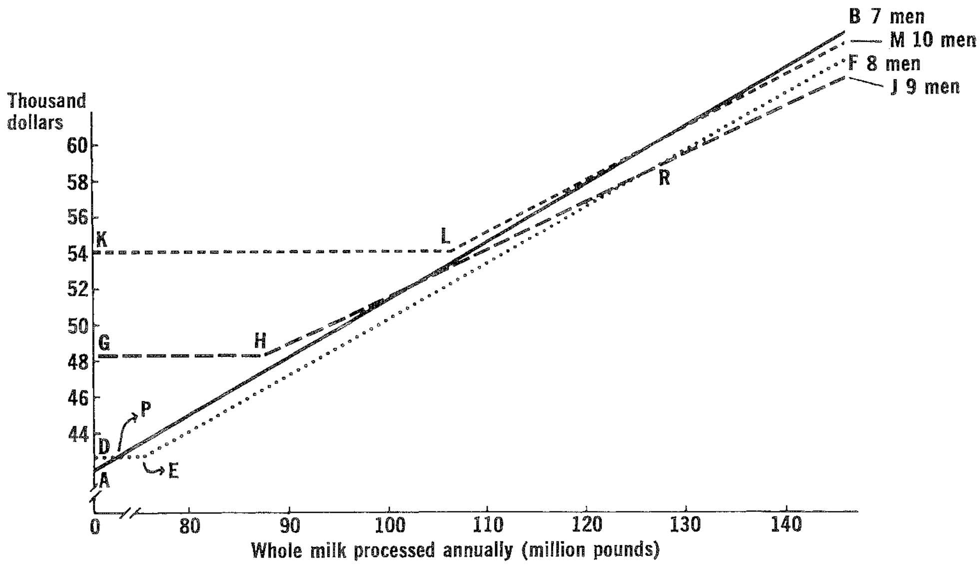


Figure 6. Illustration of results of procedure for determining minimum annual cost of hourly labor using creamery labor of plant I as an example.

(3) The annual cost for each size crew at each annual volume was the sum of the cost of the annual straight time hours plus the cost of the annual overtime hours.

The costs derived in (3), using the creamery labor of plant I as an example, are plotted in figure 6. The annual costs of four crew sizes at milk volumes ranging from 70 to 140.9 million pounds are shown. Line AB represents the total annual cost of hourly creamery labor when seven men are used for the full range of annual volumes. The cost of an eight-man crew is represented by DEF, a nine-man crew is represented by GHJ, and a ten-man crew is represented by KLM. Line segments DP, GH, and KL cover the ranges of annual volumes that can be processed with 0 overtime hours when eight, nine, and ten men, respectively, are used. These volumes can be processed with each man working a maximum of 8 hours per day and 5 days per week during the peak month. When seven men are used, some overtime hours are required for the full range of annual volumes covered in the graph.

The line segments AP, PE, ER, and RJ in figure 6 represent the minimum annual cost creamery labor organizations for the respective annual volumes. These costs are the labor costs shown in subsequent tables.

Hours of labor were not recorded in payroll records for employees paid fixed monthly salaries. These employees were treated as fixed annual costs or as costs that did not change as annual milk volume changed. Employees included in this classification were production supervisors, the general manager, office employees, and some of the plant engineers and maintenance men.

Utility Estimates

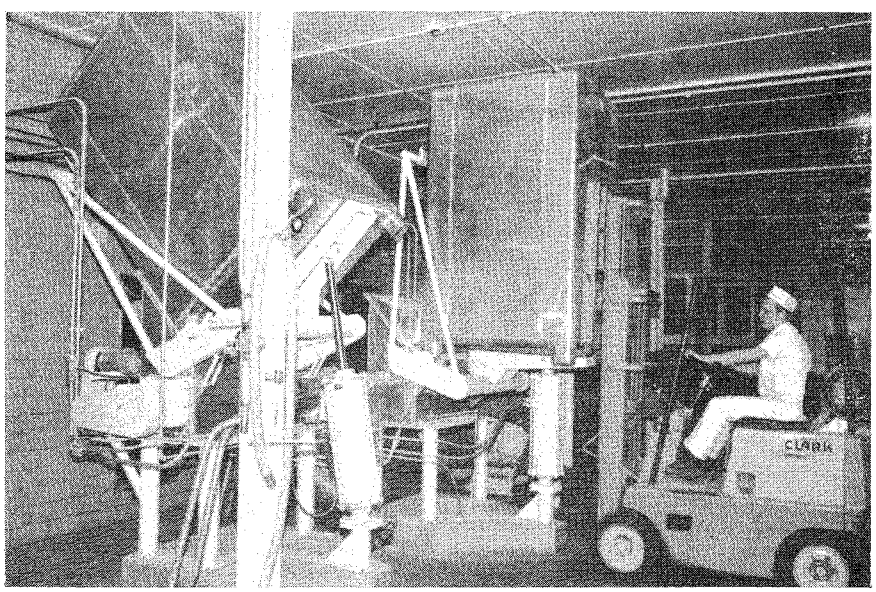
The utilities classification included both fuel and electricity costs. Using monthly data, regression techniques were used to estimate physical fuel and electricity requirements for plants I and II. Estimates of annual costs at standard prices were based on these regression estimates.

No relationships between fuel and milk processed or electricity and milk processed were developed for plants III and IV. Some of the electricity used by these plants was generated within the plants by steam-powered generators, meaning that part of their fuel was transformed into electricity. No meaningful relationships could be developed between fuel costs and quantities of milk processed because plant records did not differentiate between steam used to generate electricity and steam used to process milk. Also, figures on the amounts of electricity generated were not on record. For these reasons, relationships were developed only between the total costs of utilities and the amount of milk processed for plants III and IV.

The relationships were determined by first calculating the total cost of the fuel and electricity actually used, adjusted to a whole milk basis. These relationships were determined on a monthly basis at standard prices. These monthly cost figures and the monthly amounts of milk processed then were used to estimate regression equations that provided estimates of utility costs for any amount of product processed per month.

No adjustments were made in fuel usage to account for heating a plant in winter. Plant managers indicated that there was no detectable increase in fuel used per unit of product during cold weather, as most building heat is derived from low pressure steam that is otherwise wasted.

Tote bins filled with dry milk being hoisted and emptied preparatory to packaging.



The fuel costs estimated in this study reflect the use of the interruptible plan for natural gas service. This plan enables large commercial customers to obtain gas at relatively low rates in exchange for accepting curtailment of service on a few hours notice during cold weather when the demands of small users increase to certain levels. This plan necessitates the use of standby fuels, which were propane and No. 6 fuel oil in all four plants. These fuels are more expensive per unit of usable heat than natural gas. Interruptible service was accounted for in the cost estimates by adding 7 percent to what fuel costs would be if natural gas were used the year around. Seven percent was the average extra cost of standby fuels used in the plants studied.

The standard natural gas rates used were the rates charged by a major supplier in 1966. For interruptible service when the demand was greater than 20,000 MCF (thousand cubic feet) per month for at least 6 months of the year, the rate was 33 cents per MCF; when the demand was less, the rate was 35 cents per MCF. The rate was 35 cents per MCF for plants I and II and 33 cents for plants III and IV at all volumes considered in the shortrun cost estimates.

In determining the standard adjustment in fuel costs to account for interruptible service, the standard 1966 prices charged by a Minneapolis supplier for fuel oil and propane gas were used. (These prices were applicable to points about 50 miles from Minneapolis.) The delivered prices were 9.27 cents per gallon for No. 6 fuel oil and 5.367 cents per gallon for propane gas.

Standard charges also were determined for electricity. The charges for electrical service typically include two components: an energy charge and a demand charge. The energy charge is based on the total number of kilowatt hours (KWH) used during the billing period. The rate schedule for the energy charge used for estimating annual costs is in table 2.

The electricity demand charge usually is based on the maximum electricity usage during any 15-minute period of the billing period. The total number of KWH of electricity used during the peak production month was used to estimate a standard demand charge for each plant. This charge was 0.3567 cent per KWH used during the peak production month at the maximum annual volume. This figure was obtained by dividing the actual demand charge of plant II by the number of KWH it used during a month when it operated at maximum daily capacity.

Table 2. Standard rate schedule for the electrical energy charge in butter-NFDM plants

Kilowatt hours per month*	Cost per kilowatt hour
	cents
First 20,000	1.55
Next 30,000	1.20
Next 50,000	1.05
Next 400,000	0.94

* None of the plants studied purchased more than 500,000 kilowatt hours per month.

This procedure for estimating the demand charge for the other plants is valid for the following reason. The number of KWH used per month is mainly a function of: (1) The number of production runs per month, (2) The number of hours of operation per month, and (3) The amount of electricity used per hour of operation. Regardless of size, (1) and (2) are constants for plants at maximum daily capacity, so (3) is the main source of any differences in the number of KWH used per month. So, at maximum monthly capacity, the KWH used per month by an individual plant provide an estimate of the relative maximum rates at which electricity is consumed by the other plants.

COST ESTIMATES

The costs estimated in this study fit into two broad classifications: costs for which fixed and variable elements were separated and costs for which this separation was not required. Labor and utilities were the only costs included in the first classification. The components of the latter classification were packaging supplies, butter salt, repairs and maintenance, plant supplies and miscellaneous, depreciation, administrative salaries, administrative and general expenses, and local taxes.

The differentiation of costs into fixed and variable elements was accomplished by first estimating weekly, biweekly, or monthy efficiency and cost relationships and then converting these to annual bases. The annual costs of the second classification were estimated directly from annual data or, as in the case of packaging supplies and butter salt, directly from supply prices and product yield coefficients.

Labor

The estimated annual standard labor costs for plant I at several annual whole milk volumes are shown in table 3. The costs represented include wages, benefits, and payroll taxes. Estimates of the minimum annual cost of labor paid on an hourly basis appear in the columns labeled "Creamery" and "Skim milk and warehouse." The other costs in the table represent personnel who received fixed annual salaries.

The number of man-hours of labor represented in the two hourly labor columns were estimated with two regression equations.[4] The previously

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[4] $L^w_c = 186 + \underset{(.0147)}{.085294}\, W^w$ $\qquad r^2 = .401 \qquad n = 52$

$L^w_s = 113 + \underset{(.0085)}{.105643}\, W^w$ $\qquad r^2 = .755$

where:

L^w_c = The number of man-hours of hourly creamery labor required per week

W^w = The amount of whole milk processed per week, thousand pound units

L^w_s = The number of man-hours of hourly skim milk and warehouse labor required per week

r^2 = The coefficient of determination

The numbers in parentheses are the standard errors of the regression coefficients.

Table 3. Standard annual labor cost, including benefits and payroll taxes, at several annual volumes, plant I

Annual whole milk volume, thousand pounds	Hourly labor: Creamery*	Hourly labor: Skim milk and warehouse*	Salaried plant labor	Total plant labor	Administrative costs†
	dollars				
70,000	42,565	36,621	22,489	101,675	22,800
80,000	44,676	39,166	22,489	106,331	22,800
90,000	47,220	42,729	22,489	112,438	22,800
100,000	49,764	46,507	22,489	118,760	22,800
110,000	52,308	50,285	22,489	125,082	22,800
120,000	54,852	53,981	22,489	131,322	22,800
130,000	57,182	57,234	22,489	136,905	22,800
140,000	59,247	60,487	22,489	142,223	22,800
140,900	59,433	60,780	22,489	142,702	22,800

* Hours were estimated by regression equations; costs were determined by the minimum cost procedure.
† General manager and two office employees.

Table 4. Standard annual labor cost, including benefits and payroll taxes, at several annual volumes, plant II

Annual whole milk volume, thousand pounds	Hourly labor: Creamery*	Hourly labor: Skim milk and warehouse*	Salaried plant labor	Total plant labor	Administrative costs†
	dollars				
100,000	53,209	60,632	51,180	165,021	30,312
120,000	55,607	63,995	51,180	170,782	30,312
140,000	58,005	67,491	51,180	176,676	30,312
160,000	60,008	70,752	51,180	181,940	30,312
180,000	61,966	73,588	51,180	186,734	30,312
200,000	63,512	76,424	51,180	191,116	30,312
211,263	64,228	78,021	51,180	193,429	30,312

* Hours were estimated by regression equations; costs were determined by the minimum cost procedure.
† General manager and three office employees.

described procedure for determining the minimum annual cost of hourly labor was then applied in conjunction with these two regression equations.

The estimated annual standard labor costs for plant II are shown in table 4. The procedure used to obtain these cost estimates was the same as that used for plant I, with the exception that the regression equations were based on 2-week rather than 1-week periods.[5]

The estimated annual standard labor costs for plant III are shown in table 5. The procedures for estimating these costs were similar to those used for plant I, with the exception that the regression equations were estimated for three hourly labor classifications: creamery, skim milk, and warehouse.[6]

The cost of hourly creamery and skim milk labor was estimated for plant IV with a single monthly regression equation that indicated monthly cost estimates directly.[7] This equation was converted to an annual basis, and the resulting equation was used to estimate the labor costs for plant IV. These costs are shown in table 6.[8]

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[5] $L^{2w}_{c} = 608 + \underset{(.0041)}{.036690}\ W^{2w}$ $r^2 = .761$ $n = 26$

$L^{2w}_{s} = 695 + \underset{(.0100)}{.048000}\ W^{2w}$ $r^2 = .478$

where:

L^{2w}_{c} = The number of man-hours of hourly creamery labor required per 2-week period

W^{2w} = The amount of whole milk processed per 2-week period, thousand pound units

L^{2w}_{s} = The number of man-hours of hourly skim milk and warehouse labor required per 2-week period

[6] $L^{w}_{c} = 94 + \underset{(.0041)}{.060860}\ W^{w}$ $r^2 = .732$ $n = 52$

$L^{w}_{s} = 588 + \underset{(.0038)}{.054523}\ W^{w}$ $r^2 = .808$

$L^{w}_{w} = 70 + \underset{(.0015)}{.012638}\ W^{w}$ $r^2 = .595$

where:

L^{w}_{c} = W^{w} and L^{w}_{s} are defined as in footnote 4

L^{w}_{w} = The number of man-hours of hourly warehouse labor required per week

[7] $C^{m}_{L} = 28{,}036 + \underset{(.0243)}{.253924}\ W^{m}$ $r^2 = .525$ $n = 52$

where:

C^{m}_{L} = Cost of plant labor per month

W^{m} = The amount of whole milk processed per month, thousand pound units

[8] $C^{a}_{L} = (12)\ (28{,}036) + .253924\ W^{a}$
$= 336{,}432 + .253924\ W^{a}$

where:

C^{a}_{L} = Cost of plant labor per year

W^{a} = The amount of whole milk processed yer year, thousand pound units

Table 5. Standard annual labor cost, including benefits and payroll taxes, at several annual volumes, plant III

Annual whole milk volume, thousand pounds	Hourly labor			Salaried plant labor	Total plant labor	Administrative costs†
	Creamery*	Skim milk*	Warehouse*			
	dollars					
200,000	48,386	113,243	16,790	86,520	264,939	35,768
220,000	52,714	117,099	17,660	86,520	273,993	35,768
240,000	57,042	120,955	18,530	86,520	283,047	35,768
260,000	61,370	124,811	19,400	86,520	292,101	35,768
280,000	65,280	128,667	20,270	86,520	300,737	35,768
300,000	69,081	132,213	21,140	86,520	308,954	35,768
320,000	72,693	135,591	22,010	86,520	316,814	35,768
340,000	76,155	138,950	22,880	86,520	324,505	35,768
355,791	78,888	141,372	23,567	86,520	330,347	35,768

* Hours were estimated by regression equations; costs were determined by the minimum cost procedure.
† General manager and three office employees.

Table 6. Standard annual total cost of plant labor at various annual whole milk volumes, four butter-NFDM plants

Annual whole milk volume, thousand pounds	Plant I	Plant II	Plant III	Plant IV
	dollars			
70,000	101,675	......	......	......
80,000	106,331	......	......	......
90,000	112,438	......	......	......
100,000	118,760	165,021	......	......
110,000	125,082	......	......	......
120,000	131,322	170,782	......	......
130,000	136,905	......	......	......
140,000	142,223	176,674	......	......
140,900	142,702	......	......	......
160,000	......	181,940	......	......
180,000	......	186,734	......	......
200,000	......	191,116	264,939	......
211,263	......	193,429	......	......
220,000	......	......	273,993	......
240,000	......	......	283,047	......
260,000	......	......	292,101	......
270,000	......	......	......	404,991
280,000	......	......	300,738	......
290,000	......	......	......	410,070
300,000	......	......	308,954	......
310,000	......	......	......	415,148
320,000	......	......	316,814	......
330,000	......	......	......	420,227
340,000	......	......	324,505	......
350,000	......	......	......	425,305
355,791	......	......	330,347	......
370,000	......	......	......	430,384
390,000	......	......	......	435,462
410,000	......	......	......	440,541
430,000	......	......	......	445,619
450,000	......	......	......	450,698
470,000	......	......	......	455,776
470,633	......	......	......	455,937

The estimated total annual costs of plant labor at various annual volumes for the four plants are listed in table 6 and plotted in figure 7. These costs include payments to all plant employees, with the exception of the general manager and the office staff. They represent the standard wage rates and salaries shown in table 1 and include payroll taxes, vacation pay, and employee insurance.

The additional, or marginal, labor cost due to the processing of an additional unit of whole milk is a concept useful for describing and comparing plant labor costs. This additional cost averaged about $579 per million pounds of whole milk for plant I, $256 for plant II, $419 for plant III, and $254 for plant IV.

With the exception of plant II, the additional labor cost required to process an additional unit of whole milk generally decreased as plant capacity decreased. This generalization indicates that, as the hourly ca-

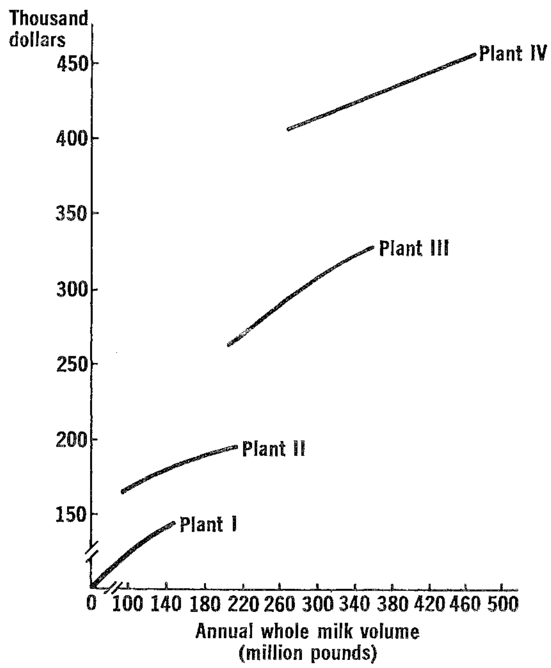


Figure 7. Standard annual total costs of plant labor, four butter-NFDM plants.

pacity of a plant increases, labor need not be increased proportionally. This reasoning seems valid, since a crew that can tend a particular piece or complex of equipment with a given hourly capacity most likely could tend similar equipment designed for other hourly capacities.

Plant II conformed with the above generalization in its relationship to plant I, but not in its relationship to plants III and IV. One reason may be found in the way in which capacity was increased. Plants I and II both had single dryers, so the greater capacity of plant II over plant I

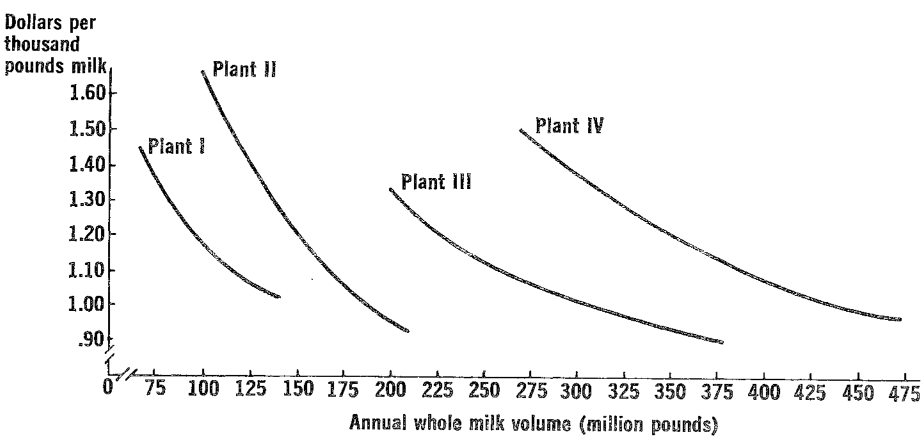


Figure 8. Relationship between annual average cost of plant labor and annual volume of whole milk, four butter-NFDM plants.

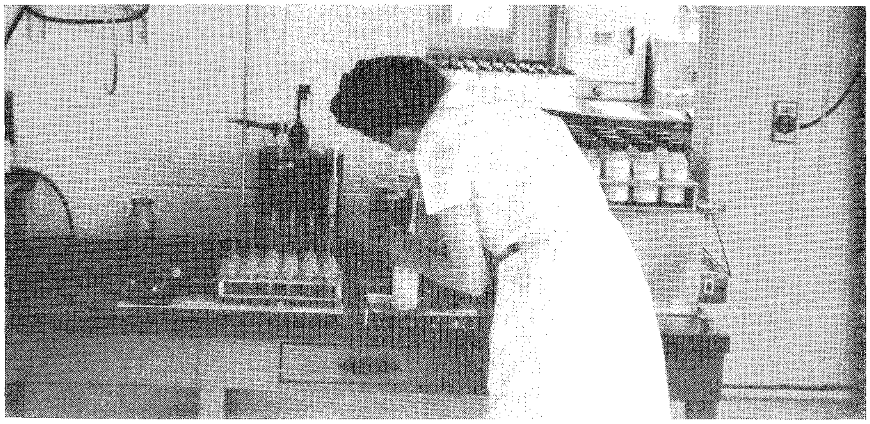
Table 7. Standard annual average cost of plant labor at various annual whole milk volumes, four plants*

Annual whole milk volume, thousand pounds	Plant I	Plant II	Plant III	Plant IV
		dollars		
70,000	1.45	...	...	...
80,000	1.33	...	...	...
90,000	1.25	...	...	...
100,000	1.19	1.65	...	...
110,000	1.14	...	...	...
120,000	1.09	1.42	...	...
130,000	1.05	...	...	...
140,000	1.02	1.26	...	...
140,900	1.01	...	...	...
160,000	...	1.14	...	...
180,000	...	1.04	...	...
200,000	...	.96	1.32	...
211,263	...	.92	...	...
220,000	...	...	1.24	...
240,000	...	...	1.18	...
260,000	...	...	1.12	...
270,000	...	...	...	1.50
280,000	...	...	1.07	...
290,000	...	...	...	1.41
300,000	...	...	1.03	...
310,000	...	...	...	1.34
320,000	...	...	.99	...
330,000	...	...	...	1.27
340,000	...	...	.95	...
350,000	...	...	...	1.21
355,791	...	...	.93	...
370,000	...	...	...	1.16
390,000	...	...	...	1.12
410,000	...	...	...	1.07
430,000	...	...	...	1.04
450,000	...	...	...	1.00
470,000	...	...	...	.97
470,633	...	...	...	.97

* Average cost per thousand pounds of whole milk.

was due to a larger dryer and evaporator. On the other hand, the greater capacity of plants III and IV over plant II was due to multiple dryers and evaporators. Plants III and IV each had three dryers, all smaller than the one used in plant II. Also, plant II had just one evaporator, while plant III had two and plant IV had three of them. The point is that when hourly capacity is increased by duplicating existing equipment, additional labor may be needed. But, when hourly capacity is increased by replacing smaller equipment with larger equipment the same crew may suffice.

The average annual costs of plant labor at several annual whole milk volumes for the four plants appear in table 7. These costs are plotted in figure 8. The lowest average annual labor cost, $0.92 per thousand pounds of whole milk, was obtained by plant II. The lowest labor costs achieved by the other plants were $0.93 for plant III, $0.97 for plant IV, and $1.01 for plant I.



Milk and milk products are tested frequently to determine composition and for quality control.

Utilities

The standard annual average costs of utilities for the four plants at varying annual volumes are shown in table 8. These costs include the cost of fuel and electricity. All are based upon regression equations estimated from historical plant data that were adjusted to reflect whole milk processing.[9] The fuel costs reflect plants using natural gas with inter-

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[9] Plant I:

$G^m_b = 1{,}067 + \underset{(.0130)}{.466529}\ W^m \qquad r^2 = .995$

$G^m_d = 119 + \underset{(.0123)}{.251676}\ W^m \qquad r^2 = .986$

$E^m = 14{,}270 + \underset{(1.810)}{10.901571}\ W^m \qquad r^2 = .972$

Plant II:

$G^m_b = 710 + \underset{(.0197)}{.7790}\ W^m \qquad r^2 = .951$

$G^m_d = 531 + \underset{(.0310)}{.259448}\ W^m \qquad r^2 = .905$

$E^m = 32{,}300 + \underset{(.6600)}{5.312440}\ W^m \qquad r^2 = .886$

Plant III:

$C^m_u = 4{,}150 + \underset{(.0416)}{.282833}\ W^m \qquad r^2 = .939$

Plant IV:

$C^m_u = 4{,}600 + \underset{(.0204)}{.326668}\ W^m \qquad r^2 = .963$

where:

G^m_b = Natural gas used by the boiler per month, thousand cubic feet units

G^m_d = Natural gas used by the dryer per month, thousand cubic feet units

E^m = Electricity used by the entire plant per month, kilowatt hours

C^m_u = Cost of utilities per month, dollars

W^m = Whole milk processed per month, thousand pounds

Table 8. Annual costs of utilities, total and average, four plants

Whole milk volume, thousand pounds	Plant I Total	Plant I Average*	Plant II Total	Plant II Average*	Plant III Total	Plant III Average*	Plant IV Total	Plant IV Average*
	- - - - - - - -	- - - - - - - -	- - - - - - - -	dollars	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
70,000	42,597	.608	......	...	......	...	......	...
80,000	46,351	.579	......	...	......	...	......	...
90,000	50,070	.558	......	...	......	...	......	...
100,000	53,767	.538	61,723	.617	......	...	......	...
110,000	57,460	.522	......	...	......	...	......	...
120,000	61,150	.510	70,566	.588	......	...	......	...
130,000	64,830	.499	......	...	......	...	......	...
140,000	68,504	.489	79,356	.567	......	...	......	...
140,900	68,835	.488	......	...	......	...	......	...
160,000	......	...	88,121	.551	......	...	......	...
180,000	......	...	96,774	.538	......	...	......	...
200,000	......	...	105,625	.528	106,367	.532	......	...
211,263	......	...	110,547	.523	......	...	......	...
220,000	......	...	......	...	112,023	.509	......	...
240,000	......	...	......	...	117,680	.490	......	...
260,000	......	...	......	...	123,336	.474	......	...
270,000	......	...	......	...	......	...	143,400	.531
280,000	......	...	......	...	128,993	.461	......	...

* Average cost per thousand pounds of whole milk.

Table 8 is continued on the following page.

Table 8 (continued). Annual costs of utilities, total and average, four plants

Whole milk volume, thousand pounds	Plant I		Plant II		Plant III		Plant IV	
	Total	Average*	Total	Average*	Total	Average*	Total	Average*
	dollars							
290,000	......	...	......	...	......	...	149,934	.517
300,000	......	...	......	...	134,650	.449	......	...
310,000	......	...	......	...	......	...	156,467	.505
320,000	......	...	......	...	140,306	.438	......	...
330,000	......	...	......	...	......	...	163,000	.494
340,000	......	...	......	...	145,963	.429	......	...
350,000	......	...	......	...	......	...	169,534	.484
355,791	......	...	......	...	150,429	.423	......	...
370,000	......	...	......	...	......	...	176,067	.476
390,000	......	...	......	...	......	...	182,600	.468
410,000	......	...	......	...	......	...	189,134	.461
430,000	......	...	......	...	......	...	195,667	.455
450,000	......	...	......	...	......	...	202,201	.449
470,000	......	...	......	...	......	...	208,734	.444
470,633	......	...	......	...	......	...	208,941	.444

* Average cost per thousand pounds of whole milk.

Table 9. Average fuel costs per thousand pounds of whole milk, plants I and II

Annual whole milk volume, thousand pounds	Plant I	Plant II
	..........dollars..........	
80,000	.336	...
100,000	.322	.445
120,000	.313	.435
140,000	.307	.429
160,000	...	.424
180,000	...	.420
211,263	...	.415

ruptible service. Included are adjustments for the cost of standby fuels used during periods when natural gas service is curtailed. The electricity costs in table 8 reflect the standard rate schedule and the standard demand charge.

The average utility costs per thousand pounds of whole milk at maximum annual volumes were $.488 for plant I, $.523 for plant II, $.423 for plant III, and $.444 for plant IV. Average utility costs for plant II were particularly high: They were about 7 percent higher than those for plant I and about 24 percent higher than those for plant III. In an attempt to explain these differences, some comparisons were made between plants I and II.

First, the fuel costs of the two plants were analyzed. Average fuel costs for these two plants at several annual volumes are shown in table 9. At maximum annual capacity, this cost was 30.7 cents per thousand pounds of whole milk for plant I and 41.5 cents for plant II, indicating that fuel costs were nearly 40 percent greater in plant II than in plant I. This difference obviously was the source of plant II's higher utility costs.

An additional question then arose: Why were plant II's fuel costs so high? To answer it, fuel usages in the two plants were differentiated into fuel used by the dryers and fuel used by the boilers. The original data obtained from the two plants enabled making this differentiation. The dryer in plant I required about 252 cubic feet of natural gas per thousand pounds of whole milk, while plant II's dryer used about 259 cubic feet per thousand pounds. Obviously, the dryer was not the source of plant II's high fuel costs.

Next, the fuel used by the boilers in the two plants was investigated. The boiler in plant I used about 467 cubic feet of natural gas per thousand pounds of whole milk, while the boiler in plant II used about 779 cubic feet per thousand pounds — nearly a 70 percent difference in fuel requirements. Though this difference obviously was the cause of plant II's high fuel costs, the reason for it was not determined. One possible explanation was poor boiler maintenance or some other source of inefficiency in plant II.

Further comparison of plants I and II revealed that plant I used about 60 percent more electricity than plant II: Plant I used 11.3 kilowatt hours per thousand pounds of whole milk, while plant II used only 7.1 KWH.

Table 10. Average electricity costs per thousand pounds of whole milk, plants I and II

Annual whole milk volume, thousand pounds	Plant I	Plant II
	dollars	
80,000	.244	...
100,000	.215	.172
120,000	.196	.153
140,000	.182	.138
160,000	...	.127
180,000	...	.118
211,263	...	.108

The electricity costs shown in table 10 indicate that the average cost of electricity for plant I at maximum annual capacity was 18.2 cents per thousand pounds of whole milk, compared with 10.8 cents for plant II. This difference (7.4 cents) partially offset the advantage of 10.8 cents that plant I had in fuel usage.

The main source of this difference in electricity usage probably was the evaporator-dryer complex. The total connected horsepower of the evaporator-dryer complex in plant I was nearly the same as that in plant II, but the hourly output of plant II was about 50 percent greater, suggesting that plant I used about 50 percent more electricity to dry milk than plant II.

In summary, plant II's high utility costs were due to fuel used by the boiler. The high costs were partly offset by greater efficiency in electricity usage for plant II.

Plants III and IV both were efficient users of utilities, judging from their relatively low costs of $.423 and $.444 per thousand pounds of whole milk at maximum annual capacities.

Packaging Supplies

The cost of packaging supplies was treated as a constant cost per thousand pounds of whole milk. This cost, 36.5 cents per thousand pounds of whole milk for all plants, was based on bulk packaging of both butter and NFDM. It represented butter packed in 68 pound corrugated paper boxes priced at 19.8 cents per box, including parchment box liners and gummed tape for sealing the boxes. The NFDM package represented in this cost was a 100 pound paper bag, suitable for government sale, priced at 30 cents per bag, including the thread and tape for sealing the bag. The product yields assumed were 43 pounds of butter and 80 pounds of NFDM per thousand pounds of whole milk.

Butter Salt

Butter salt was a minor cost item treated as constant per thousand pounds of whole milk. This cost was 1.63 cents per thousand pounds of whole milk, assuming the use of 1.03 pounds of salt per thousand pounds of whole milk and a salt price of $1.58 per hundred pounds.

Repairs and Maintenance

The cost of repairs and maintenance was treated as a constant average cost within particular plants, but the average differed among plants. The average annual cost per thousand pounds of whole milk used for each plant was that actually experienced during the fiscal year studied. These averages were $.1176 for plant I, $.1320 for plant II, $1019 for plant III, and $.1458 for plant IV.

Plant Supplies and Miscellaneous

The cost of plant supplies and miscellaneous items was treated as an annual cost fixed with respect to changes in annual volume of whole milk processed. These costs included cleaning and laboratory supplies, tools, laundry and uniform expense, purchased water, license fees, butter and powder grading fees, and miscellaneous items. The total annual cost in this category was $19,368 for plant I, $24,600 for plant II, $56,097 for plant III, and $84,960 for plant IV.

Depreciation

The annual cost of plant and equipment depreciation included in the cost estimates was the cost actually charged by the respective plants in the year covered by the data. This alternative was chosen over the common procedure of applying depreciation rates to current replacement costs of plant and equipment for the following reason. The efficiency and cost estimates were based on plants using equipment of various ages. Applying depreciation rates to the current replacement costs of buildings and equipment would, in effect, have resulted in the depreciation charges for new plants. Likewise, the cost and efficiency relationships of these new plants most likely were different from those of the older plants. It therefore seemed unrealistic to use the efficiency and cost relationships of older plants while using the depreciation charges of new ones. Annual depreciation charges were $55,094; $51,912; $114,120; and $114,180 for plants I, II, III, and IV, respectively.

Administrative Salaries

Included in administrative salaries were the standard salaries, benefits, and payroll taxes of the general manager and the office staff. Salaries for plant managers were $12,000 per year for plants I and II and $17,000 per year for plants III and IV. The office staff consisted of two employees in plant I and three in plants II, III, and IV. Standard salaries for individual office employees were commensurate with their responsibilities. The total annual cost of administrative salaries was $22,800 for plant I, $30,312 for plant II, $35,768 for plant III, and $34,008 for plant IV.

Administrative and General Expense

Annual administrative and general expenses were those actually experienced by the plants during the year covered by the data. These items are listed in table 11. The total cost for each plant was $18,694 for plant I, $19,368 for plant II, $39,658 for plant III, and $28,680 for plant IV.

Local Taxes

Local taxes consisted of real estate and personal property taxes. When estimating the shortrun cost curves, the tax cost was standardized by expressing it as a constant cost per dollar of depreciation. This alternative was selected because real estate and personal property taxes are related to the market value of land, plants, and equipment. Depreciation charges, while not reflecting land value, were the best available indicators of the market value of the plants and equipment for the four plants studied. The figure selected as the standard cost of local taxes per dollar of depreciation approximated those figures actually experienced by two of the four plants. The standard annual costs of local taxes were $9,917 for plant I, $9,344 for plant II, $20,508 for plant III, and $20,552 for plant IV.

SHORTRUN COSTS

In the following section, shortrun costs are considered in a way that relates directly to the objectives and theory discussed earlier.

The estimated shortrun (annual) costs for plants I, II, III, and IV at varying annual volumes are listed in tables 12, 13, 14, and 15, respectively. The total costs for each plant are plotted in figure 9.

Table 11. Annual cost of administrative and general expenses, four plants

Expense item	Plant I	Plant II	Plant III	Plant IV
	dollars			
Office supplies	1,767	2,592	1,731	3,292
Telephone	825	1,522	1,805	4,529
Auditing and legal	1,086	737	1,185	1,561
Travel	900	678	2,075	694
Insurance	4,456	6,203	11,014	10,696
Advertising and annual meeting	5,020	2,390	2,397	3,533
Unclassified	4,640	5,246	19,451	4,375
Total	18,694	19,368	39,658	28,680

Table 12. Total annual costs at varying annual volumes, plant I

Whole milk volume, thousand pounds	Plant labor	Fuel	Electricity	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	dollars							
70,000	101,675	24,157	18,440	25,550	1,141	8,232	125,873	305,068
80,000	106,331	26,847	19,504	29,200	1,304	9,408	125,873	318,467
90,000	112,438	29,537	20,533	32,850	1,467	10,584	125,873	333,282
100,000	118,760	32,226	21,541	36,500	1,630	11,760	125,873	348,290
110,000	125,082	34,916	22,544	40,150	1,793	12,936	125,878	363,294
120,000	131,322	37,606	23,544	43,800	1,956	14,112	125,873	378,213
130,000	136,905	40,295	24,535	47,450	2,119	15,288	125,873	382,465
140,000	142,223	42,985	25,519	51,100	2,282	16,464	125,873	406,446
140,900†	142,702	43,227	25,608	51,428	2,297	16,570	125,873	407,705

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.
† Maximum annual capacity.

Table 13. Total annual costs at varying annual volumes, plant II

Whole milk volume, thousand pounds	Plant labor	Fuel	Electricity	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	dollars							
100,000	165,021	44,467	17,256	36,500	1,630	13,200	135,536	413,610
120,000	170,782	52,245	18,321	43,800	1,956	15,840	135,536	438,480
140,000	176,674	60,023	19,333	51,100	2,282	18,480	135,536	463,428
160,000	181,940	67,801	20,320	58,400	2,608	21,120	135,536	487,725
180,000	186,734	75,579	21,195	65,700	2,934	23,760	135,536	511,438
200,000	191,116	83,357	22,268	73,000	3,260	26,400	135,536	534,937
211,263†	193,429	87,737	22,810	77,111	3,444	27,887	135,536	547,954

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.
† Maximum annual capacity.

Table 14. Total annual costs at varying annual volumes, plant III

Whole milk volume, thousand pounds	Plant labor	Utilities (fuel and electricity)	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	. . . .	. . . .	. . . .	dollars	. . . .	. . . .	. . . .
200,000	264,939	106,367	73,000	3,260	20,384	266,151	734,101
220,000	273,993	112,023	80,300	3,586	22,422	266,151	758,475
240,000	283,047	117,680	87,600	3,912	24,461	266,151	782,851
260,000	292,101	123,336	94,900	4,238	26,499	266,151	807,225
280,000	300,738	128,993	102,200	4,564	28,538	266,151	831,184
300,000	308,954	134,650	109,500	4,890	30,576	266,151	854,721
320,000	316,814	140,306	116,800	5,216	32,614	266,151	877,901
340,000	324,505	145,963	124,100	5,542	34,653	266,151	900,914
355,791†	330,347	150,429	129,864	5,799	36,262	266,151	918,852

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.
† Maximum annual capacity.

Table 15. Total annual costs at varying annual volumes, plant IV

Whole milk volume, thousand pounds	Plant labor	Utilities (fuel and electricity)	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	. . . .	. . . .	. . . .	dollars	. . . .	. . . .	. . . .
270,000	404,991	143,400	98,550	4,401	39,366	282,380	973,088
290,000	410,070	149,934	105,850	4,727	42,282	282,380	995,243
310,000	415,148	156,467	113,150	5,053	45,198	282,380	1,017,396
330,000	420,227	163,000	120,450	5,379	48,114	282,380	1,039,550
350,000	425,305	169,534	127,750	5,705	51,030	282,380	1,061,704
370,000	430,384	176,067	135,050	6,031	53,946	282,380	1,083,858
390,000	435,462	182,600	142,350	6,357	56,862	282,380	1,106,011
410,000	440,541	189,134	149,650	6,683	59,778	282,380	1,128,166
430,000	445,619	195,667	156,950	7,009	62,694	282,380	1,150,319
450,000	450,698	202,201	164,250	7,335	65,610	282,380	1,172,474
470,000	455,776	208,734	171,550	7,661	68,256	282,380	1,194,627
470,633†	455,937	208,941	171,781	7,671	68,618	282,380	1,195,328

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.
† Maximum annual capacity.

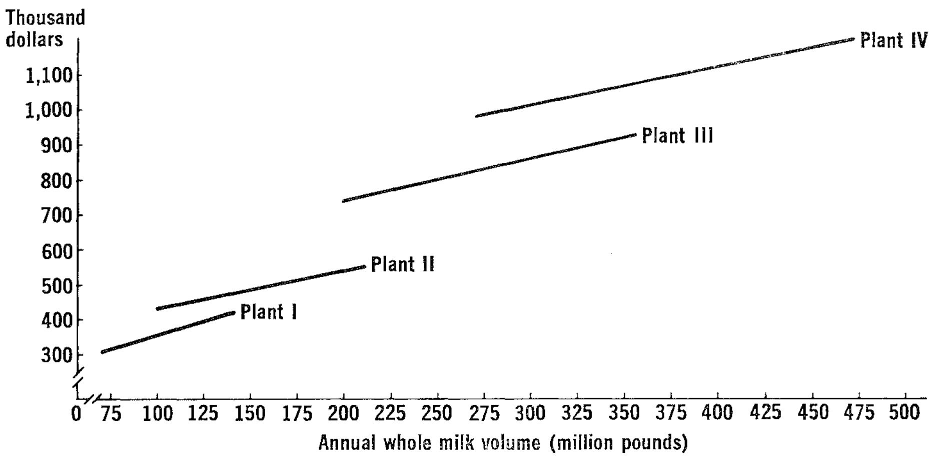


Figure 9. Relationship between total annual costs and annual whole milk volume, four butter-NFDM plants.

Fixed costs were $204,000 per year for plant I, $294,500 for plant II, $499,000 for plant III, and $674,000 for plant IV. Annual fixed costs increase as plant size increases, an expected result, since large plants require greater capital investment and more fuel and electricity to start, clean, and maintain their larger and more numerous equipment items.

Total variable cost is the difference between total cost and fixed cost at any given annual volume. Average variable cost per unit of milk is the total variable cost divided by the number of units processed. A characteristic of the total cost-volume relationships estimated in this study is that average variable cost for any given plant is the same regardless of the amount of milk processed. This fact indicates that the change in variable cost as an additional unit of milk is added is the same at all levels of milk input. Changes in variable cost for each plant are represented by the slopes of the respective lines in figure 9. The steeper the slope of a line, the greater is the average variable cost per unit of milk. Average variable costs were about $1.45, $1.21, $1.19, and $1.11 per thousand pounds of whole milk for plants I, II, III, and IV, respectively. These costs were for additional labor, fuel, electricity, packaging supplies, and other items required to process an additional thousand pounds of milk.

Average variable costs decreased as plant size increased. This result also was consistent with prior expectations because, using the labor input as an example, one man or crew may be required to operate a given machine or complex of machines, regardless of hourly capacity. Also, a machine with twice the hourly capacity of another probably would require less than twice as large a utility cost per hour.

The estimated average annual costs per thousand pounds of whole milk are shown in tables 16, 17, 18, and 19 for plants I, II, III, and IV, respectively. The shortrun average cost curves (average total annual cost curves) for the four plants are plotted in figure 10. This cost declined as annual volume increased within the full range of volumes studied for

Table 16. Average annual costs per thousand pounds of whole milk at varying annual volumes, plant I

Whole milk volume, thousand pounds	Plant labor	Fuel	Electricity	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	dollars							
70,000	1.452	.345	.263	.365	.016	.118	1.798	4.357
80,000	1.329	.336	.244	.365	.016	.118	1.574	3.982
90,000	1.249	.328	.228	.365	.016	.118	1.399	3.703
100,000	1.188	.322	.215	.365	.016	.118	1.259	3.483
110,000	1.137	.317	.205	.365	.016	.118	1.144	3.302
120,000	1.094	.313	.196	.365	.016	.118	1.049	3.151
130,000	1.053	.309	.189	.365	.016	.118	0.968	3.018
140,000	1.016	.307	.182	.365	.016	.118	0.899	2.903
140,900	1.013	.307	.182	.365	.016	.118	0.893	2.894

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.

Table 17. Average annual costs per thousand pounds of whole milk at varying annual volumes, plant II

Whole milk volume, thousand pounds	Plant labor	Fuel	Electricity	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	dollars							
100,000	1.650	.445	.172	.365	.016	.132	1.355	4.135
120,000	1.423	.435	.153	.365	.016	.132	1.130	3.654
140,000	1.262	.429	.138	.365	.016	.132	0.968	3.310
160,000	1.137	.424	.127	.365	.016	.132	0.847	3.043
180,000	1.038	.420	.118	.365	.016	.132	0.753	2.842
200,000	.956	.417	.111	.365	.016	.132	0.678	2.675
211,263	.916	.415	.108	.365	.016	.132	0.642	2.594

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.

Table 18. Average annual costs per thousand pounds of whole milk at varying annual volumes, plant III

Whole milk volume, thousand pounds	Plant labor	Utilities (fuel and electricity)	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	dollars						
200,000	1.325	.532	.365	.016	.102	1.331	3.671
220,000	1.246	.509	.365	.016	.102	1.210	3.448
240,000	1.179	.490	.365	.016	.102	1.109	3.261
260,000	1.123	.474	.365	.016	.102	1.024	3.104
280,000	1.098	.461	.365	.016	.102	.951	2.993
300,000	1.030	.449	.365	.016	.102	.887	2.849
320,000	0.990	.438	.365	.016	.102	.832	2.743
340,000	0.955	.429	.365	.016	.102	.783	2.650
355,791	0.928	.423	.365	.016	.102	.748	2.585

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.

Table 19. Average annual costs per thousand pounds of whole milk at varying annual volumes, plant IV

Whole milk volume, thousand pounds	Plant labor	Utilities (fuel and electricity)	Packaging	Butter salt	Repairs and maintenance	Fixed overhead*	Total
	dollars						
270,000	1.500	.531	.365	.016	.146	1.046	3.604
290,000	1.414	.517	.365	016	.146	0.974	3.432
310,000	1.339	.505	.365	.016	.146	0.911	3.282
330,000	1.274	.494	.365	.016	.146	0.856	3.151
350,000	1.215	.484	.365	.016	.146	0.807	3.033
370,000	1.163	.476	.365	.016	.146	0.763	2.929
390,000	1.117	.468	.365	.016	.146	0.724	2.836
410,000	1.074	.461	.365	.016	.146	0.689	2.751
430,000	1.036	.455	.365	.016	.146	0.657	2.675
450,000	1.002	.449	.365	.016	.146	0.628	2.606
470,000	.970	.444	.365	.016	.146	0.601	2.542
470,633	.969	.444	.365	.016	.146	0.600	2.540

* Includes administrative salaries, plant supplies and miscellaneous, depreciation, administrative and general expenses, and local taxes.

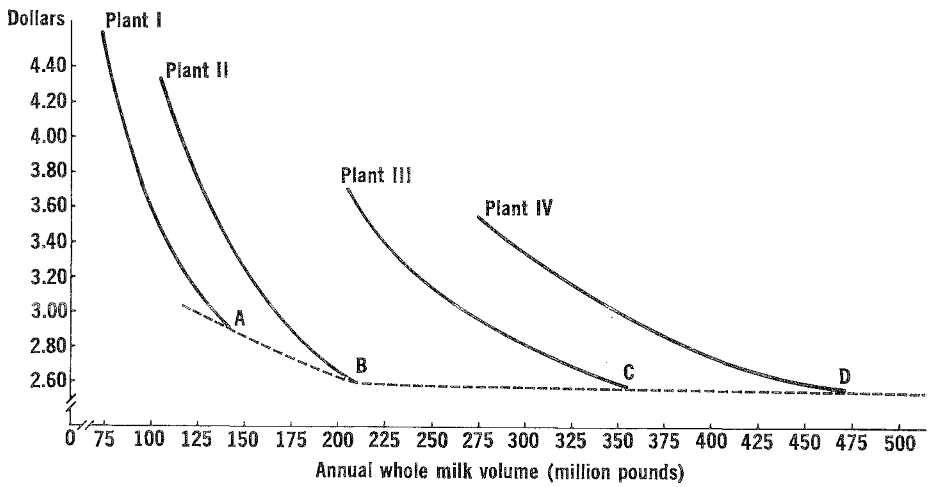


Figure 10. Shortrun and longrun average cost curves, four butter-NFDM plants.

each plant. The decline was due almost entirely to the spreading of fixed costs over larger annual volumes. A second very minor source of declining average costs was quantity discounts on electricity.

The estimated minimum average total annual costs were $2.89, $2.59, $2.58, and $2.54 per thousand pounds of whole milk for plants I, II, III, and IV, respectively. This cost differed by not more than 5 cents among the three largest plants, while plant I's lowest total average cost was 35 cents greater than that of plant IV.

Relationship Between Processing Cost and Size

The relationships between processing costs and plant size were a primary concern of this study. Two important questions arise when evaluating plants of different sizes:

(1) What are the average costs obtained by plants of different sizes when they are used to process alternative amounts of whole milk?

(2) Which plant size, given some annual milk volume, will yield the lowest attainable average cost for processing that volume?

The first question is significant because milk processors cannot always expect to operate at full capacity. Therefore, they want to know what happens to costs when plants are operated at lower levels. The second question is important for long range planning of processing facilities; it will be discussed in the section on longrun costs.

The average annual costs for each of the four plants at five levels of annual milk volume are shown in table 20. At full capacity, the cost for plant I was $2.89 per thousand pounds of whole milk, while at 10 percent below full capacity, it increased to $3.06 and at 20 percent it was

Table 20. Average cost per thousand pounds of whole milk at several percentage levels below annual plant capacity, four plants

Percentage below annual capacity	Plant I	Plant II	Plant III	Plant IV
	dollars			
0	2.89	2.59	2.58	2.54
10	3.06	2.76	2.74	2.70
20	3.26	2.96	2.96	2.90
30	3.50	3.20	3.19	3.15
40	3.85	3.54	3.52	3.50

$3.26. When volume dropped to 30 percent below full capacity, the cost for plant I increased to $3.50 and became $3.85 at 40 percent. The costs for all four plants at various percentage levels below full capacity are plotted in figure 11.

The four curves in figure 11 are nearly parallel, indicating that the cost differences among plants did not change significantly as milk volume dropped by equal percentages below capacity. For example, within the range of full capacity to 40 percent below capacity, the average total annual costs per thousand pounds of whole milk changed from $2.89 to $3.85 in plant I, from $2.59 to $3.54 in plant II, from $2.58 to $3.52 in plant III, and from $2.54 to $3.50 in plant IV. These figures represent cost changes of 96 cents, 95 cents, 94 cents, and 96 cents for plants I,

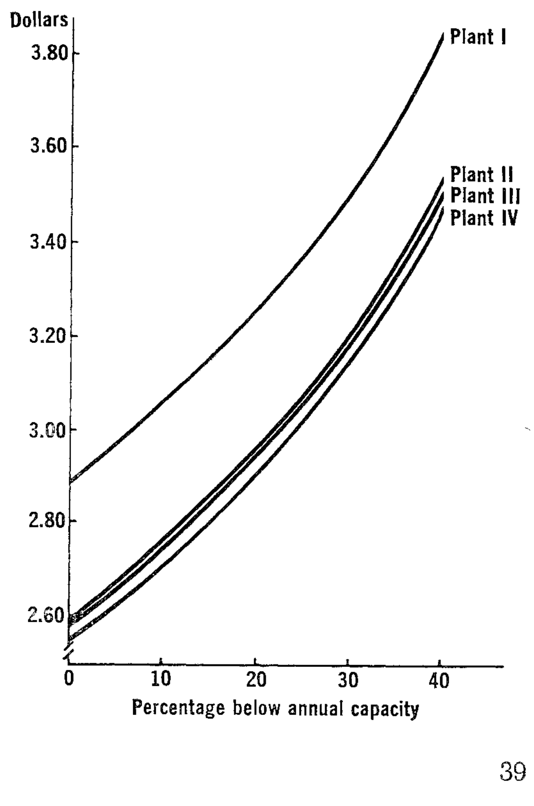


Figure 11. Average cost per thousand pounds of whole milk at indicated percentages below annual plant capacity, four butter-NFDM plants.

Table 21. Average cost per thousand pounds of whole milk at several absolute quantities below annual plant capacities, four plants

Amount below annual capacity, million pounds	Plant I	Plant II	Plant III	Plant IV
	dollars			
0	2.89	2.59	2.58	2.54
20	3.14	2.75	2.67	2.61
40	3.46	2.94	2.76	2.67
60	3.96	3.17	2.88	2.75
80	4.41	3.47	3.01	2.83
100	...	3.89	3.14	2.92
120	...	4.37	3.30	3.03
140	...	...	3.49	3.14

II, III, and IV, respectively. The similarity of these cost changes indicates that no single plant gained an appreciable cost advantage over the others when annual volume decreased.

Cost behavior when a plant's level of operation drops from maximum annual capacity by equal absolute amounts of whole milk is discussed below. The costs for each plant at maximum annual capacity, as well as at 20, 40, 60, and 80 million pounds below capacity are shown in table 21 and in figure 12.

When plant I's annual volume dropped from full capacity by 80 million pounds, the average processing cost per thousand pounds of whole milk increased by $1.52. The same drop in volume caused cost increases of $.88, $.43, and $.29 in plants II, III, and IV, respectively. These cost increases decreased as plant size increased; therefore, the cost differential between the larger and smaller plants increased as a result of these decreases in volume. For example, at maximum capacity, plant II's cost was

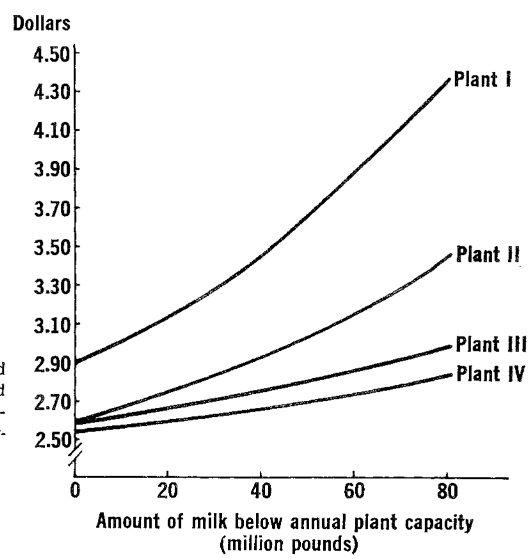


Figure 12. Average cost per thousand pounds of whole milk at indicated absolute quantities of milk below annual plant capacities, four butter-NFDM plants.

only 1 cent greater than plant III's, but when volume dropped by 80 million pounds, this differential increased to 46 cents per thousand pounds of whole milk. This result is shown in figure 12 where the curves of plants II and III depart from one another as volume drops.

In all cases, when any two plants are compared, the average costs in smaller plants increase faster than in larger plants when volume drops from maximum capacity by equal absolute amounts. An implication of this result is that smaller plants are more vulnerable to "raiding" of their milk supplies by neighboring plants. To illustrate this point, assume that plants II and III both are operating at 40 million pounds below annual capacity. As shown in table 21, plant II's cost would be $2.94 and plant III's cost would be $2.76. Now assume that plant III somehow gets 40 million pounds of milk a year away from plant II. Average costs then would be $2.58 for plant III and $3.47 for plant II, a difference of 89 cents. Now assume the original situation, where both plants are at 40 million pounds below capacity, and assume that plant II takes 40 million pounds from plant III. Plant II's cost then would be $2.59 and plant III's would be $3.01, a difference of only 42 cents.

These two differences, 89 cents and 42 cents, show that the cost advantage gained by plant III when it raids plant II's milk supply is greater than the advantage gained by plant II when it raids plant III's supply. This same result occurs when comparing any two of the four plants; that is, the cost advantage gained by a larger plant when it raids a smaller plant's supply is greater than the advantage a smaller plant gains by raiding the larger. This result is significant to the Minnesota dairy processing industry because there are many areas where small and large plants compete for the same milk supply.

In summary, when the three largest plants covered in this study operate at maximum capacity, their average costs differ from one another by only 1 to 5 cents per thousand pounds of whole milk, and the average cost for the smallest plant at maximum capacity differs from the others by 30 to 35 cents. No one plant gains a significant cost advantage over the others as a result of equal percentage decreases from maximum capacities. The smaller plants experience a definite cost disadvantage when annual volumes drop from the maximum by equal absolute amounts of whole milk.

LONGRUN COSTS

The longrun average cost (LRAC) curve for butter-NFDM plants traces the minimum attainable average cost of processing various annual volumes of whole milk. The single plant size represented by a point on the LRAC curve is the one that yields the lowest attainable average cost of processing a particular volume. Estimation of this curve was accomplished by drawing a curve joining the low points of the four estimated shortrun average cost curves. The geometry involved is illustrated in figure 10 where the LRAC curve is a broken line drawn through points A, B, C, and D, the minimum points of the shortrun average cost curves.

Table 22. **Average cost of each cost component per thousand pounds of whole milk at maximum annual volume, four plants***

Cost component	Plant I	Plant II	Plant III	Plant IV
	dollars			
Plant labor	1.013	.916	.928	.969
Fixed overhead	.893	.642	.748	.600
Utilities	.489	.523	.423	.444
Packaging supplies	.365	.365	.365	.365
Repair and maintenance	.118	.132	.102	.146
Butter salt	.016	.016	.016	.016
Total	2.894	2.594	2.582	2.540

* These costs were taken from tables 16, 17, 18, and 19.

The LRAC curve declines as plant size increases, but it becomes increasingly horizontal for plants exceeding about 210 million pounds of annual whole milk capacity. This tendency indicates the existence of cost economies to large-scale plants within the full range of plant sizes studied, with such economies becoming less obvious in the larger plants.

The estimated LRAC curve was determined by using a sample of one plant from each of the four plant sizes. A sample of this size can provide a reliable estimate because one of the major criteria of plants selected for detailed study was that they have histories of relatively low average costs. The selected plants represented four of the optimal plants represented by the LRAC curve.

Why does the estimated LRAC curve slope downward to the right? To answer this, interplant comparisons of the contribution of each cost component to each plant's average cost at maximum annual volume were made. The components of shortrun costs were plant labor, fixed overhead, utilities, packaging supplies, repairs and maintenance, and butter salt. Packaging supplies and butter salt did not contribute to the slope of the LRAC curve because they were treated as constant per unit costs for all plants at all output levels. The average annual costs of all components for the four plants at their respective maximum annual volumes are shown in table 22. The four totals represent points of the estimated LRAC curve.

Plant Labor

Plant labor was the largest cost component for all plants, accounting for 35-38 percent of total costs in each of the four plants.

Table 22 indicates that the average cost of this component at maximum annual volumes dropped by 9.7 cents between plants I and II, increased by 1.2 cents between plants II and III, and increased by 4.1 cents between plants III and IV.

Shown in table 23 are the estimated average costs of fixed and variable labor for the four plants at their respective maximum annual volumes. These data assisted in analyzing the effect that labor exerted on the estimated LRAC curve.

Table 23. Average annual fixed and variable cost of plant labor per thousand pounds of whole milk, four plants at maximum annual volumes

Plant	Labor classification	Average cost Fixed	Variable
		. . . . dollars	
I	Creamery	.261	.206
I	Skim and warehouse	.106	.325
I	Nondepartmental	.114	. . .
	All plant labor	.481	.531
II	Creamery	.328	.064
II	Skim and warehouse	.258	.142
II	Nondepartmental	.124	. . .
	All plant labor	.710	.206
III	Creamery	.083	.173
III	Skim and warehouse	.267	.197
III	Nondepartmental	.208	. . .
	All plant labor	.558	.370
IV	All plant labor	.716	.254

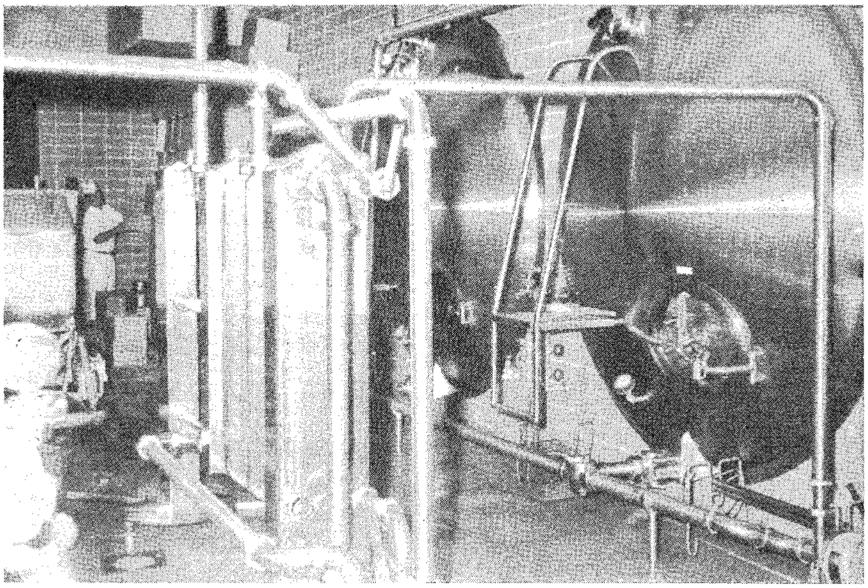
The decline in average cost of plant labor between plants I and II was 9.7 cents per thousand pounds of whole milk. Table 23 indicates that variable labor cost was responsible for this decline. The average cost of variable labor in plant II was 32.5 cents lower than in plant I, while the average cost of fixed labor was 22.9 cents higher in plant II than in plant I with both plants at maximum annual volume.

This combination of lower average variable labor cost and higher average fixed cost for plant II reflected:

1. *A greater proportion of salaried labor relative to hourly labor in plant II than in plant I.* The average cost of salaried labor at maximum annual volume in plant I was 16.0 cents, compared with 24.2 cents in plant II. This difference caused the labor costs of plant II to be less responsive to changes in volume because the salaried workers, while receiving constant monthly salaries, worked varying numbers of hours per month as seasonal variations in milk receipts occurred. For the salaried labor, the payroll data reflected constant monthly salaries rather than the number of hours actually worked each pay period. This factor probably caused plant II's average cost of fixed labor to be higher and its average cost of variable labor to be lower than the analogous costs for plant I.

2. *The greater hourly capacity of plant II's drying equipment complex.* Plant II's larger dryer and evaporator required about the same number of man-hours of labor per hour of operation; therefore, compared with plant I, plant II required fewer man-hours per unit of whole milk equivalent dried.

Table 22 indicates that the average cost of labor increased slightly between plants II and III at their maximum volumes. Table 23 indicates



Whole milk storage and heat exchange equipment in a modern nonfat dry milk plant.

that the difference was due to variable labor cost, which was 16.4 cents greater for plant III than for plant II. This difference was nearly offset by plant II's average fixed labor cost, which was 15.2 cents greater than plant III's. The main source of these differences probably was the greater propensity of plant II toward purchasing labor on a fixed salary basis. Three other possible reasons, which may have offset each other, were: (1) plant II's dryer was larger than any of plant III's, (2) plant III's butter churn was larger than either of plant II's, and (3) one of the two evaporators used by plant III was larger than the one used by plant II.

Average labor cost also increased slightly between plants III and IV at their maximum capacities. The source of this difference was fixed labor, which was 15.8 cents greater in plant IV than in plant III. This difference was partly offset by variable labor, which was 11.6 cents lower in plant IV. The reasons for these differences may have been the same as those cited for the difference in labor costs between plants II and III.

Fixed Overhead

Fixed overhead was the second largest cost component for all four plants, accounting for 24-31 percent of the total costs at the respective maximum annual volumes of the four plants. Table 22 indicates that the average cost of this component dropped by 25.5 cents between plants I and II, increased by 10.8 cents between plants II and III, and dropped by 14.8 cents between plants III and IV. This component caused the estimated LRAC curve to be U-shaped between plant sizes of 140 to 356 million pounds and caused it to slope negatively between 356 and 470 million pounds.

The average annual costs of the several components of overhead costs for the four plants at their maximum annual volumes are shown in table 24. The average cost of only one of these components, administrative salaries, showed an inverse relationship with plant size through the full range of sizes studied. None of these average costs was directly related to plant size through the full range. Supplies and miscellaneous items caused the estimated LRAC curve to be U-shaped within the full range of plant sizes studied, while depreciation, administrative and general expenses, and local taxes caused it to be negatively sloped between 140 and 211 and between 356 and 470, but positively sloped between 211 and 356 million pounds of whole milk per year.

Utilities

The third largest cost component was utilities, accounting for 16-20 percent of total annual costs at the maximum annual volumes of the four plants. The average cost for this component increased by 3 cents between plants I and II, dropped by 10 cents between plants II and III, and increased by 2 cents between plants III and IV. This component caused the LRAC curve to slope upward to the right between plant sizes of 141 to 211 million pounds and caused it to be U-shaped within the range of 211 to 470 million pounds.

The data in table 25 aid in analyzing the effects that utilities exerted on the estimated LRAC curve. Shown in this table are the estimated average costs of fixed and variable utilities for the four plants at their respective maximum annual volumes.

Table 22 indicated that the average cost of utilities increased 3.4 cents between plants I and II at their maximum volumes. Table 25 indicates that the source of this increase was variable utilities, which were 6.8 cents greater in plant II than in plant I. This difference was partly offset by fixed utilities, which were 3.5 cents less in plant II than in plant I. Table 25 indicates that fuel cost was 10.8 cents greater in plant II, while electricity cost was 7.5 cents less in plant II compared with plant I. This suggests the substitution of fuel for electricity.

Table 24. Average annual cost of several components of fixed overhead per thousand pounds of whole milk, four plants at maximum annual volumes

Cost component	Plant I	Plant II	Plant III	Plant IV
	dollars			
Supplies and miscellaneous	.140	.116	.158	.180
Depreciation	.390	.246	.321	.243
Administrative salaries	.162	.143	.100	.072
Administrative-general	.133	.091	.111	.061
Local taxes	.070	.044	.058	.044
Total	.875	.640	.748	.600

Table 25. Average annual fixed and variable cost of utilities per thousand pounds of whole milk, four plants at maximum annual volumes

Plant	Cost classification	Average cost Fixed	Variable
		. . . . . . dollars	. . . . . .
I	Fuel	.038	.269
I	Electricity	.081	.102
	Total utilities	.119	.371
II	Fuel	.026	.389
II	Electricity	.058	.050
	Total utilities	.084	.439
III	Total utilities	.140	.283
IV	Total utilities	.117	.327

Table 22 indicated that the average cost of utilities for plant III was 10 cents lower than for plant II and 2.1 cents lower than for plant IV at maximum annual volumes. Table 25 indicates that variable costs were the source of both of these differences. The average variable utilities cost for plant III was 15.6 cents lower than for plant IV, but the average fixed cost of utilities for plant III was higher than for any of the other three plants. The causes of the low variable and high fixed costs of utilities for plant III were not ascertained.

The average costs of utilities for plants I and IV at maximum volumes were remarkably similar. Table 25 indicates that plant I's average fixed utilities cost was only .2 cent greater than plant IV's while plant I's variable cost was only 4.4 cents greater than plant II's per thousand pounds of whole milk. Perhaps this reflects the fact that the three dryers and evaporators used in plant III were nearly the same size as the single evaporator and dryer used in plant I.

Repairs and Maintenance

Repairs and maintenance accounted for 4-6 percent of the annual costs for the four plants at maximum annual capacity. Table 22 indicated that the average cost of this component increased by 1 cent between plants I and II, decreased by 2 cents between plants II and III, and increased by 4 cents between plants III and IV. This component caused the estimated LRAC curve to slope upward to the right and then to become U-shaped between plant sizes of 210 to 470 million pounds.

In summary, the cost components that caused the estimated LRAC curve to slope downward to the right between plants I and II were plant labor and fixed overhead, while the partially counteracting forces were utilities and repairs and maintenance. The causes of the downward slope between plants II and III were utilities and repairs and maintenance, while the partially offsetting cost components were plant labor and fixed overhead. The sole cause of the downward slope of the LRAC curve between plants III and IV was fixed overhead, which was partly offset by plant labor, utilities, and repairs and maintenance.

SUMMARY AND CONCLUSIONS

The objectives of this study were to estimate the shortrun and longrun average cost curves for Minnesota butter-NFDM plants within the size range of 140 to 470 million pounds of annual whole milk capacity. Relationships between plant size and cost were of primary concern. The costs considered were those incurred from the point of plant intake of whole milk through the loading out of finished products.

The estimated costs represent efficiencies that were actually attained by the four plants selected for intensive study. All cost estimates, with the exception of certain overhead items, represent input prices or price schedules that were standardized among plants. When selecting plants, a major goal was to select plants of several sizes that were achieving maximum efficiency.

Labor was the largest cost component for all plants, accounting for 35-38 percent of the total costs estimated for each plant at maximum annual volume. The lowest average annual cost of labor was estimated for plant II at $0.92 per thousand pounds of whole milk. Labor costs at maximum annual volume averaged $0.93 for plant III, $0.97 for plant IV, and $1.01 for plant I.

The second largest cost component was fixed overhead, accounting for 24-31 percent of the total annual costs for all plants. The average fixed overhead costs at maximum annual volumes were $.89, $.64, $.75, and $.60 for plants I, II, III, and IV, respectively. Included in this component were supplies and miscellaneous, depreciation, administrative salaries, general and administrative expenses, and local taxes. No consistent relationship between plant size and the average cost of this component was obtained.

Utilities, including fuel and electricity, comprised the third largest component, accounting for 16-20 percent of total annual costs for the four plants at their maximum annual volumes. The average utilities costs at maximum volumes were $.49 for plant I, $.52 for plant II, $.42 for plant III, and $.44 for plant IV.

The fixed cost of utilities increased as plant size increased. The fixed costs of utilities for plants III and IV were about three times greater than those of plants I and II. A possible source of this difference was the use of steam-powered electrical generators in plants III and IV.

As plant size increased, the average variable costs decreased, while the total fixed costs increased. The average variable cost per thousand pounds of whole milk was $1.45 for plant I, $1.21 for plant II, $1.18 for plant III, and $1.11 for plant IV. Total fixed costs were $204,000 for plant I, $294,000 for plant II, $499,000 for plant III, and $674,000 for plant IV.

Analysis of the estimated shortrun average cost curves indicated that when the three largest plants in the study operated at maximum annual whole milk capacity, their average costs differed from one another by only 1-5 cents per thousand pounds. At capacity, the average cost for the smallest plant differed from the others by 30-35 cents.

No one plant gained a significant cost advantage over the others as a result of equal percentage decreases in volume from maximum capacities. The smaller plants experienced a definite cost disadvantage when annual volumes dropped from the maximum by equal absolute amounts of whole milk. This disadvantage indicated that smaller plants suffer more severe consequences from decreases in milk receipts than large plants. Thus, when receipts drop due to such factors as reduced emphasis on dairy farming, drought, or raiding by a competing plant, the average costs of smaller plants rise relative to those of larger ones. Smaller plants also would have difficulty protecting their remaining milk supplies from large competitors.

The low points of the four shortrun average cost curves of these plants were used as four points of the longrun average cost (or economies of size) curve. These points were $2.89 per thousand pounds of whole milk at an annual whole milk volume of 141 million pounds, $2.59 at 211 million pounds, $2.58 at 356 million pounds, and $2.54 at 471 million pounds. These points indicated an estimated longrun average cost curve that was downward sloping within its full range, with a very gentle slope beyond 211 million pounds. This curve indicated cost economies to large-size plants, but also indicated that such economies were nearly exhausted beyond 211 million pounds of annual whole milk capacity.

This estimated longrun average cost curve indicates that, considering present technology, butter-NFDM plants should be capable of processing at least 210 million pounds of whole milk annually to compete on the basis of processing costs. Savings in processing costs for plants larger than this are not significant with technologies available at this time.

The results of this study suggest that many of Minnesota's butter-NFDM plants are too small to compete on the basis of processing costs. In 1962, about 34 out of 50 Minnesota butter-NFDM plants had annual milk volumes lower than 200 million pounds of whole milk. This figure corresponded to a daily milk volume of under 700,000 pounds. Only 16 Minnesota butter-NFDM plants were larger than 200 million pounds in that year.

Most of these smaller butter-NFDM plants have relatively high processing costs. This is not to say that such plants should close their doors and divert their milk to larger plants. Some of them are fairly efficient and, in certain cases, the cost of transporting milk to larger plants may more than offset any processing cost advantages. However, this study definitely suggests that the management and farmer-patrons of Minnesota's small butter-NFDM plants should objectively explore the costs and returns of processing milk in larger plants.