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Spray drying costs in low-volume milk plants

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SPRAY DRYING COSTS IN LOW-VOLUME MILK PLANTS

by

Lee Kolmer

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of DOCTOR OF PHILOSOPHY

Major Subject: Agricultural Economics

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1954
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ABSTRACT

Dairy plant managers and boards of directors who contemplate installation of a skimmilk spray drying system need reasonably accurate information on the cost-volume relationships involved in spray-drying processes if they are to make economic investments. The need for this information has increased recently because of changes in dry milk production and consumption patterns. These changes have resulted in an increased demand for non-fat dry milk solids for human food. The increased demand has been reflected in a higher price and increased production.

Increased production has necessitated an increase in processing facilities. In many instances the decision to install drying facilities was made without adequate information about cost-volume relationships. This has resulted in inefficient resource allocation in some plants. The objective of this study is to provide information concerning the cost-volume relationships in low-volume spray-drying plants and thereby assist entrepreneurs in investment decisions. The study is based on a budget analysis of four plants with volumes of 938,200, 1,875,600, 2,817,000 and 3,767,500 pounds of powder produced per year. These volumes of powder production correspond to annual butter volumes in plants producing one, two, three and four 1800 pound churnings per day in the peak season. Several additional cost points
V were budgeted in order to obtain the minimum cost point for each of three equipment combinations. In this budget analysis the physical inputs required were determined and prices were attached to these physical inputs.

The analysis indicates that as volume increases, up to a volume of 3,174,700 pounds of powder per year, unit costs decrease quite rapidly. Beyond this volume costs do not decrease appreciably as volume increases. The processing costs varied from $7.64 per hundredweight in a plant producing 338,200 pounds of powder per year to $5.08 per hundredweight in a plant producing 3,174,700 pounds per year. At a volume of 3,767,500 pounds of powder per year, a volume increase of 582,800 pounds per year, processing costs only decrease $.04 per hundredweight. Therefore for all practical purposes the low cost point is achieved at a volume of 3,174,700 pounds per year. In addition to unit processing costs being reduced, the distribution of costs change as volume increases. The variable costs become relatively more important and the fixed costs relatively less important as volume increases.

The findings of this analysis provide information which may be used as an aid in comparing the relative profitability of each alternative operation available to the plant. In addition to providing information for comparison of the relative profitability of several alternatives, the costs derived in this study provide cost data for
producer payment under a "component" pricing plan.

The general conclusions of this analysis indicate that:

1. Processing costs decrease as volume increases, within the range of this study. Processing costs decrease rather rapidly in the lower portion of the volume range, from $7.64 per hundredweight at a volume of 938,200 pounds per year to $5.08 per hundredweight at a volume of 3,174,700 pounds per year. Beyond this volume, however, costs do not decrease appreciably as volume increases.

2. Skimmilk drying equipment is not utilized most efficiently at volumes of 938,200, 1,875,600, and 2,817,600 pounds of powder produced per year. When volume exceeds three million pounds per year resources are used efficiently and the lowest processing costs are obtained.
INTRODUCTION

In many areas of the United States the milk marketing situation is becoming increasingly acute. Faced with a falling demand for butterfat many producers are seeking to market their entire milk product as fluid milk. This trend has evidenced itself in a reduction of gathered cream production and an increase in fluid milk marketed. In the past several years Grade A milk production, cheese production and non-fat dry milk production have increased. For a majority of producers the Grade A market is the most attractive market. This market, however, is limited, and a large proportion of the milk produced must be used for manufactured products such as cheese and non-fat milk powder.

Since World War II several developments in the marketing situation have given impetus to the shift from cream marketing to fluid milk marketing. The increased demand for non-fat dry milk solids, the government price support policy, and the introduction of drying equipment small enough to make drying feasible for small plants have all had a share in inducing plants to shift from a butter manufacturing operation to a butter-powder operation. The development of small-size drying equipment is perhaps the most important of the factors listed, for if this equipment had not been available, small plants, despite demand and price conditions, would have been excluded from this milk
market. The introduction of this equipment makes another outlet available to new plants or to established plants considering a change in operation.

Before any plant can determine intelligently its most profitable alternative and allocate its investment resources accordingly, it must have a method of determining which alternative will give the greatest long-run return. Therefore, each plant must analyze, in some fashion, the cost and returns of each available alternative. A scientific analysis of the costs and returns of any one of the possible alternatives facing the plant will provide information which can be used as a guide in the decision-making process and thereby reduce the possibility of a plant making an uneconomic investment.

The specific objective of this study is not to develop new methods of analysis but rather to assist plants in investment decision making by analyzing the cost-volume relationship involved in a spray-drying operation at four different volumes. Such information is especially needed for plants at the lower end of the volume range where unit costs are relatively high and where very little information concerning the cost and volume relationship is available.

A plant engaged in the decision making process will have all inputs variable, with the exception of volume. The volume of each plant will be determined by the milk supply available in the plant area. In this study the volume of each plant was fixed by the number of churnings of butter per day in the peak month. In Plant I the volume was fixed at one churning per day or 1800 pounds of butter or 43,200
pounds of milk per day in the peak month. The volume of Plant II is
twice the size; Plant III, three times the size; and Plant IV, four
times the size of Plant I.

This method of volume selection may not be the correct method to
use in multi-product plants. A selection criterion based upon product
allocation may be more useful in such plants. However, if the three
studies currently underway in Project 1169 of the Iowa Agricultural
Experiment Station were to be combined at a later date the identical
volumes in all studies would facilitate combination with a minimum
adjustment of factors such as labor.

In view of the fact that all inputs, except volume, are variable,
the long-run cost curve becomes the appropriate economic model. In
order to obtain points on the long-run cost curve it is first of all
necessary to obtain points on the short-run cost curve. Because of the
restriction of volume the four points obtained in this study are not
minimum cost points for each resource combination, rather they are
minimum cost points for each resource combination at the specific
volume.

Traditionally, the long-run cost curve has been obtained by
connecting the tangency points of many short-run cost curves. This
resulted in a smooth U-shaped curve. Tintner (14), however, cites
studies by Dean (3 and 4), in hosiery and leather mills, and Yntema (16)
in steel mills, that indicate that cost curves are not U-shaped but are
decreasing throughout the volume range. These results seem to contra-
dict the traditional assumption of a U-shaped cost curve. These studies indicate that the short-run cost curve more closely approximates the shape of the curves shown in Chart 2 than the curves shown in Chart 1.

A smooth long-run cost curve can only result in cases where there are no indivisibilities in the input factors. In milk processing there are large indivisibilities in equipment and labor. Therefore the long-run cost curve is not a series of tangency points on short-run cost curves but rather it is a series of connected short-run cost curves. Also, since this study only includes low volume plants it is expected that costs will decrease within the volume range of the study. The curve is, therefore, not a smooth U-shaped curve such as the curve shown in Chart 1 but rather it is shaped like the cost curve shown in Chart 2. The discontinuities in the curve in Chart 2 occur whenever the physical capacity limits are reached for a particular equipment combination. There are smaller discontinuities within each short-run cost curve caused by the indivisibility of labor as an input factor.

The plant volumes used in this study are in the lower areas of the volume range. Because of this it is expected that the cost will decrease as volume increases throughout the volume range. The short-run cost curves have not been fully developed in this study. However, the points obtained do indicate the general direction of the curve and do provide an estimate of the cost volume relationship existing in the areas between the cost points obtained.
METHOD

The method of analysis used to determine the cost-volume relationship was dictated by (a) the purpose of the analysis, and (b) the empirical information available. Since the purpose of this study is to provide information to aid plants in resource allocation for future periods it is necessary that the latest proven technology be used in the plants and that factor pricing be realistic. In order to make factor pricing as realistic as possible, it was assumed that new equipment and building were required and current prices were applied to all inputs.*

Because of the small numbers of plants having spray-drying equipment at the present time and the heterogeneity existing in the operations of plants having such equipment, it was necessary to use the engineering method of determining inputs and apply prices to these inputs to determine individual input cost. The engineering method is a system of cost determination wherein the physical inputs are derived from: (a) engineering performance data such as the efficiency factors for steam generation and electric power output under various conditions, (b) chemical determinations of the characteristics of physical inputs such as fuels and steam, (c) thermodynamic theorems

*Because of the many sources used to procure technical data for the analysis it was impractical to list all references; however the major sources of information have been listed in the citation of literature.
concerning rates of heat transfer through different mediums, (d) institutional arrangements such as labor organization, (e) judgment of technologists and researchers familiar with the area of study under consideration, and (f) research findings of time and motion studies in dairy plants.

The above sources of information are utilized to construct formulae and criteria for the determination of the quantity of physical inputs required to produce a given quantity of output. These derived physical inputs are combined in a resource combination which would be feasible in an actual plant. Hereafter in this analysis these combinations are referred to as model plants. These combinations of inputs are combined in a model plant in a manner which would achieve the lowest cost obtainable under the conditions imposed in this study. Current prices obtained from manufacturers and suppliers are then applied to the inputs of each model plant to obtain the cost of each individual input. By applying the same prices for inputs in all plants, it is possible to compare cost of various specific inputs at different volumes. In this analysis the costs obtained in this fashion were checked whenever possible by observing plants in operation.

Conditions

The following conditions were imposed in the construction of the powder processing section of a plant:
1. The latest techniques and equipment upon which performance data
were available were used in all plants.

2. The equipment and labor organization is the optimum arrived at by a series of trial budgets. It is based upon seasonal production fluctuations and peak requirements.

3. The dryer is operated 7 days per week throughout the year. Seven-day-per-week operation enables a plant to operate with less equipment investment and provides more flexibility of labor organization.

4. The labor schedule is based upon a forty-hour week. Overtime is paid for all work over 40 hours.

5. The yield of powder from 100 pounds of skim milk is estimated at 8.4 pounds per one hundred pounds of fluid skim milk (8, page 483).

6. High heat powder for the wholesale trade will be produced. This restriction excludes the baby food and cottage cheese powder markets, but the majority of plants installing a powder operation will be set up for the wholesale high-heat powder market.

7. The spray powder produced will be acceptable to powder purchasers as extra-grade high-heat powder. In addition to meeting the general conditions for milk powder for human consumption as set up by the American Dry Milk Institute (1 page 5) the following conditions must also be met in order for powder to be classified as extra grade:

   a. Butterfat content not more than 1.25 percent.
b. Moisture content not more than 4 percent.*

c. Titratable acidity** not greater than 0.15 percent.

d. Solubility Index*** not greater than 1.25 ml.

e. Bacterial estimate not greater than 100,000 per gm.

f. Sediment**** not greater than No. 3.

8. It was assumed that the butterfat content of the milk and the production varied seasonally in the following manner:

<table>
<thead>
<tr>
<th>Month</th>
<th>Production</th>
<th>Butterfat content</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>7</td>
<td>3.7</td>
</tr>
<tr>
<td>February</td>
<td>7</td>
<td>3.7</td>
</tr>
<tr>
<td>March</td>
<td>8.5</td>
<td>3.7</td>
</tr>
<tr>
<td>April</td>
<td>9</td>
<td>3.6</td>
</tr>
<tr>
<td>May</td>
<td>10</td>
<td>3.5</td>
</tr>
<tr>
<td>June</td>
<td>11</td>
<td>3.5</td>
</tr>
<tr>
<td>July</td>
<td>10</td>
<td>3.5</td>
</tr>
<tr>
<td>August</td>
<td>9</td>
<td>3.5</td>
</tr>
<tr>
<td>September</td>
<td>8</td>
<td>3.6</td>
</tr>
<tr>
<td>October</td>
<td>7.5</td>
<td>3.6</td>
</tr>
<tr>
<td>November</td>
<td>6.5</td>
<td>3.7</td>
</tr>
<tr>
<td>December</td>
<td>6.5</td>
<td>3.7</td>
</tr>
</tbody>
</table>

The production variation is the approximate annual production fluctuation for Iowa in the years of 1950, 51 and 52, (9)

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*If powder is sold to the Commodity Credit Corporation the moisture content cannot exceed 3.5 percent.

**Determination made upon reliquified sample.
Determination of Inputs

Building

The building materials used in the model plants were chosen on the basis of (a) sanitation, (b) initial cost, including erection time, (c) durability, and (d) ease of future expansion.

With these criteria as a guide the following materials were chosen: Floors and foundation were concrete. The floor in the processing room was covered with red floor brick because of its greater durability and sanitation. The floors in the storage area and boiler room were concrete. The walls material is concrete block struck flush on the inside and pointed on the outside. The interior of the processing room was faced with 1 3/4 inch glazed tile for reasons of sanitation, reduced cleaning time and lower maintenance. The roof was constructed of open truss steel joists, topped with insulated metal roof deck and built-up roofing. No ceiling was provided in any plant. The selected roof materials are more expensive than other roofing materials but the erection cost is lower and the total cost of such roofing is lower than for other roof types of comparable quality. Some thought was given to the use of aluminum panels but the major drawback in using such construction at the present time is the relatively high initial cost, and the lack of general contractors familiar with aluminum alloys required for various
types of construction uses. It does, however, offer a distinct advantage in maintenance cost and in lowered cost of future expansion because of the high re-use rate of aluminum panels. (11)

The building size in each model plant was dictated by the size of equipment installed and the necessary storage area. An attempt was made to keep the building design as nearly square as possible to reduce building costs. The equipment was positioned so as to eliminate undue crowding and still utilize space efficiently. The window area of the drying section is approximately twenty percent of the floor area. The natural light is supplemented by artificial light throughout the drying section.

In order to provide for future expansion at a minimum cost, the drying section was built with two sides away from the remainder of the building, and the basic construction of the storage area was the same as the construction in the processing section. If more processing space were required in the future, the storage area could be converted to a processing room and additional storage space constructed adjoining the present storage space. Large (10 ft. by 12 ft.) tin clad fire doors have been installed in each area in order to provide openings large enough to move processing equipment in and out in case of extensive repair or replacement.

The quantities of materials and labor for each building were determined by using builders' handbooks (12, 13 and 15) and estimating
the quantities for each of the component parts of the building. The
detailed calculations for Plant III are given in Appendix A. The cost
of the building required to house the boiler in each plant was
computed as a part of the boiler cost.

Equipment

The capacity of the various pieces of equipment used in the plants
was selected to allow the equipment combination, as a unit, to operate as
close as possible to hourly capacity. The dryer, the size of which is
determined by plant volume, is the key piece of equipment in this
combination. The dryer capacity (at a specific solids content) is
determined by evaporator size, heater size, boiler size and water
softener size. Even though equipment is selected that will provide
minimum cost at present, excess capacity may exist in a plant because
the equipment is not in operation 24 hours per day. However this
excess capacity exists in all pieces of equipment in the combination
and the volume of the plant can increase without changes in the
equipment combination. By selecting equipment in this manner,
processing costs are kept close to a minimum, flexibility is retained,
and future expansion is possible without prohibitive cost.

The selection of the specific pieces of equipment used in the
combination is based upon the following factors:

1. Sanitation and quality requirements.

2. Operating efficiency.
Sanitation and quality requirements were the first consideration. All equipment specified is of stainless steel construction, both on contact surfaces and exterior surfaces. Discussions with representatives of sales outlets, manufacturers, and users, indicate that there is no significant difference in quality and acceptability of high-heat powder produced by different brands of stainless steel equipment.* All equipment combinations are capable of producing extra-grade powder acceptable to the trade or government. Under these conditions there seems to be no basis for preferring one brand of equipment to another because of sanitation or quality differences.

Insofar as it is possible to determine through observation and discussion with manufacturers and users of various brands of equipment, there is no difference in operating efficiency between brands of the same type. This apparent similarity between various brands of equipment reduced the selection problem to choosing that type of equipment which operated most efficiently.

The different brands of dryers available all have the same basic thermodynamic principle underlying their operation. The drying process

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*High-heat powder only. Low-heat powder requires lower heat in evaporation, reducing efficiency somewhat.
is carried on in a turbulent mixture of heated air and milk at a relatively high velocity. The drying process itself is regulated by the thermodynamic laws of heat transfer between vapors and fluids. The efficiency of the dryer and the hourly capacity is, however, affected by the design of the component parts of the dryer. Countercurrent dryers, in which the milk and air enter from opposite sides of the dryer, heat the milk to a higher temperature and do not dry the milk particles as rapidly as in a parallel flow system. All dryers on the market at the present time use the parallel current system of drying.

The design of the powder-air separators also influences the capacity and efficiency of the dryer. Dryers using single large diameter separators cannot operate at as high a temperature and velocity as dryers using a series of small diameter separators. This occurs because as the diameter of the separator increases the exhaust velocity increases, the smaller particles of powder are then carried out the exhaust stack. In order to avoid excessive powder losses, it is therefore necessary to install cloth powder collectors in drying systems using large diameter powder-air separators. These cloth collectors sift out the entrained powder in the exhaust air. Powder collected in this cloth collector cannot be sold for human consumption. If the size of the individual separator is decreased, the exhaust velocity from each separator is decreased and the velocity of the entering drying air may be increased without loss of powder.
This increase in velocity in the entering air reduces the time the milk particles remain in this drying chamber and because of this reduction in time in the chamber the air heat may be increased without damaging the milk protein in the powder, also, drying systems using small diameter powder-air separators do not require cloth powder collectors to sift out the entrained powder in the exhaust air.

These differences in dryer design result in differences in space requirements for various brands of dryers. Dryers using a vertical drying tube, large powder-air separators and cloth collectors require from 12 to 20 feet more ceiling height than horizontal tube dryers using multiclone collectors. The Buflovak dryer uses a horizontal drying tube and multiclone powder-air separator coupled with increased air velocity. By this means Buflovak achieves a reduction in initial cost and in operating cost because the equipment requires a smaller floor area.

Several types of evaporation equipment are available. The common types of evaporation equipment in use in the dairy industry at present are the single, double, and triple effect evaporators. The principle involved in these evaporators is essentially that of heating milk under vacuum, which reduces the boiling point, and separates, condenses and withdraws milk vapors. In the single effect evaporator the steam is used once in the heating process. In the double effect evaporator the milk enters the first effect and is heated to approximately 160° F. It then enters the second effect, where the vacuum is
greater and the temperature lower and there it is heated by the same vapor as was used in the first effect. The same process is used in the triple effect evaporator as in the double effect except that the steam is used three times and temperature in the first effect is higher. For a further discussion of evaporation systems, see Farrall (5) pages 319 to 328.

In recent years a low temperature ammonia system of evaporation and a recompression system have been introduced. The low temperature system is used quite extensively in the processing of concentrated fruit juices where very low temperatures are required to reduce the possibility of heat damage. At present no performance data are available on such equipment in use in the milk industry. The recompression system of evaporation compresses the vapors used in evaporation. This raises the heat of the vapor, and the vapor is then recirculated and used again for evaporating. This system reduces the fuel and water requirements necessary for evaporation. Relatively few of these recompression systems are in use in the milk industry at present and no performance data are available for comparison with systems in common use. Because of these considerations the low temperature ammonia system and the recompression system were not considered suitable for this study.

The selection of evaporation equipment was therefore reduced to a selection of either a single, double or triple effect evaporator. The single effect evaporator has the lowest initial cost. Since the steam
is only used once, however, the operating cost is greater. The double effect evaporator reduces the steam and water requirements by about one half, and the triple effect reduces the fuel and water cost by about 2/3. The possible savings in fuel and water requirements would dictate that triple effect evaporators be installed in all sizes of plants in this study. However, triple effect evaporators necessitate unduly high milk temperatures in the first effect; and this greatly increases the possibility of heat damage to the milk protein. Double effect evaporators were therefore installed in all plants in the study.

The operating cost of equipment is a function of all the inputs which are necessary to operate efficiently. Several of these have been discussed in preceding paragraphs and in all cases the equipment was selected for the lowest possible operating cost in light of necessary requirements of operation stemming from other criteria used in selection.

The initial cost of different brands of equipment varied considerably. Since for all practical purposes the quality of product and operating efficiency of all brands were equal, the lowest priced equipment combination for a specific volume was chosen. There may be differences in service available which may account in part for the differences in price, but insofar as is known, these have not developed into major criteria for selection of a specific brand of equipment.

1Wherever it was possible and did not result in a higher operating
cost, the equipment which would provide the greatest excess capacity was chosen. This was considered desirable in view of the fact that milk plants, if they are successful, tend to increase their volume rather than remain at the initial volume. By providing excess capacity at no higher cost at the time of construction, the plant can increase its volume in the future without large expenditures for equipment and building replacement or additions.

Fuel and Boiler

The quantity of fuel required for generating steam and drying milk is one of the major inputs in a drying operation. In areas where natural gas is available, it is the most economical source of energy. However, since natural gas is not available in all areas, the quantity of fuel required was computed using propane gas for drying and fuel oil for heating and evaporation.

A direct method of dryer heating using propane gas was selected because of (a) higher heat transfer efficiency of such firing, (b) lower initial dryer cost and (c) lower boiler requirements. Oil fuel was selected for heating and evaporation, even though coal may be more economical, because of the greater cleanliness of oil over coal and the greater degree of automatic control possible with such fuel. In addition, the thermal efficiency of oil in automatically fired boilers is greater than that of coal fired boilers.
The use of an oil or gas fired boiler also eliminates the need for a smoke stack because of the forced draft on the burner. A vent to carry off residual gases in all that is required.

The burner chosen for installation on the boiler is a gas-oil combination burner. This will give the plant a standby source of fuel in case of emergencies and allow plants to take advantage of the off-peak gas rate for industrial gas users if natural gas is used.

The required boiler capacity was determined by the equation:

\[
\frac{a}{(33,479)(0.8)} = \text{boiler horsepower required},
\]

where

- \(a\) = total B.T.U. required for evaporation and heating
- 33,479 = B.T.U. developed by one boiler horsepower in one hour
- 0.8 = thermal efficiency of automatic oil fired boilers.

The size of the boiler installed in each plant was the closest size available above the horsepower requirement.

A water softener was installed in all plants. Softeners were installed to reduce the encrustation of boiler tubes due to the use of hard water, and thereby to reduce the resultant loss of efficiency. It is possible to reduce water hardness by direct water treatment in the boiler. This method, however, is not as effective as a softening unit, and requires periodic shut down periods in order to clean the sludge from the boiler.

Fuel requirements for drying were determined by using the heat balance system given in Farrall (5, page 334-335). In this method,
B.T.U. inputs from fuel balance the B.T.U. requirements for converting milk to powder, after adjustments for heat losses are made. In addition to these drying requirements, radiation losses from the building and temperature differences between the exhaust air and the surrounding intake air were included in the heat requirements. The B.T.U. requirements thus obtained were converted to gallons of propane gas. The conversion factors used were 21,300 B.T.U. per pound of liquid propane (5, page 127) and 4.214 pounds per gallon of propane gas. If natural gas is used the conversion factors would be 1,000 B.T.U. per cubic foot of Texas gas.

Fuel requirements for evaporation and heating were computed in the same manner. In this case, however, the B.T.U. requirements were converted to gallons of fuel oil. The conversion factors used were 19,000 B.T.U. per pound of No. 5 oil and 7.428 pounds per gallon (7, page 1129).

Labor

The labor required for the drying operation varies as equipment size and volume varies. It does not, however, vary proportionally but rather increases in discrete steps as dryer capacity or volume passes a certain magnitude. Only one man is needed to operate the dryer and evaporator on dryers with capacities up to 750 pounds per hour. At this volume or greater it becomes necessary to add a helper to barrel and store the powder. Such labor is added in 40 hour units.
volume increases, labor cost will decrease up to the point where the volume becomes large enough to require an additional shift in order to operate the plant.

Because of the indivisibility of labor resulting from the 40 hour week, the operating labor cost per hundredweight will decrease as volume increases until dryers of 750 pounds per hour capacity are needed or the volume becomes great enough to necessitate hiring an additional shift.

The labor requirement in a milk drying operation is partly fixed and partly variable. The cleaning time is a fixed portion of the labor requirement each day the dryer and evaporator are operated. It remains constant regardless of volume during the day. The type of equipment, however, will affect how much labor is required in the cleaning operation. If an equipment combination using a vertical drying tube is installed, the entire cleaning time for all equipment in the combination is ten man-hours per day. This cleaning time was observed in three plants. Some manufacturers of vertical tube dryers claim less cleaning time than the observed time. These claims, however, have not been substantiated in a commercial setting. If a horizontal tube dryer is installed the cleaning time is reduced to six man hours per day. This factor was taken into consideration when selecting the equipment combination.

The labor organization for all plants is as follows:

a. It was assumed that key personnel, such as the dryer and evaporator op-
erator would be retained throughout the entire year. Unskilled labor, needed in the large plants for barrelling and storing powder, was hired and released as seasonal labor requirements fluctuated. Additional labor was added in forty hour units and all workers were guaranteed a forty-hour work week with time and one-half for all work over forty hours; the labor schedule was designed with no more than a six-day week in the flush season and a five-day week in the slack season. These restrictions were imposed so that the employment policy of plants in this study approximated the employment conditions of plants employing union labor. The labor schedules of all plants are given in Appendix F.

b. A flat charge of $1500 for managerial services was assessed against the drying operation in each plant. A flat charge was applied because the managerial requirements in a plant, within the volume range of this study, are not a function of volume but rather are a function of the type of operation carried on in the plant.

c. Plant superintendent services responsible for boiler operation, equipment maintenance and general plant supervision were provided in appropriate amounts in all plants.

d. Appropriate laboratory and bookkeeping charges were assessed in all plants.
Electricity

The electricity requirements for the plants were computed on the basis of size, efficiency and length of operation of all motors necessary for processing. Three-cycle 440 volt power wiring was installed in each plant. The following formula was used:

\[
\frac{(746)(.85)(a)(b)}{1,000} = \text{KWH}
\]

where

- \(746\) = theoretical watts per horsepower hour
- \(.85\) = motor efficiency
- \(a\) = number of horsepower used
- \(b\) = length of operation in hours.

Water and Sewage

Large quantities of water are used in a milk drying operation. The major use of water in the drying process is in condensing the milk vapors in the evaporator. Approximately 18 pounds of water are required for every pound of vapor condensed (8, page 79). The temperature of evaporation, the temperature of the water supply, the temperature of the discharge water and the type of condenser will all influence the quantity of water required for evaporation.

In this study it was assumed that:

1. Milk will be condensed under 26 inches of vacuum (125° F. milk dis-
charge temperature) in the second effect, which means that the first effect will have a temperature of 160° F. at 21 inches of vacuum.

2. A parallel-current external condenser with a 15° F. temperature differential between the evaporator and discharge water will be used (8, page 79).

3. The temperature of the water supply is 60° F.

The formula used to compute the water consumption in condensing is as follows, (8, page 79):

\[
\frac{(a) - \sqrt{(b-c)}}{d-e} \times 327 = \text{Pounds of water required to condense one pound of vapor,}
\]

where

\[a = \text{total B.T.U. contained in vapor at the temperature of the evaporator}\]
\[b = \text{temperature of the evaporator}\]
\[c = \text{temperature differential between evaporator temperature and water discharge temperature}\]
\[d = \text{water discharge temperature}\]
\[e = \text{temperature of water supply.}\]

The above calculation will give the pounds of water required to condense one pound of vapor. The annual water requirement is computed by determining the pounds of vapor condensed per hour in a particular evaporator and the hours of operation per year.

The boiler requires four gallons of water per horsepower hour.
The annual requirement is obtained by determining the hours of opera-
tion per year for the boiler and multiplying.

The water requirement for cleaning was derived from a cleaning
manual published by a cleaning supply firm (10). This water consump-
tion is not a function of volume, as the two above are, but will
only vary if the equipment is taken out of use.

Insurance and Taxes

Appropriate charges for insurance and taxes were made in all
plants. The building and equipment in all plants was insured against
loss from fire and extended coverage of 80% of cost was provided in
all cases. The boilers in all plants were insured against loss from
explosion in addition to the insurance mentioned above. The rates
per $100 valuation are discussed in a following section.

Packaging

The plants in this study were designed to produce high-heat
powder for the wholesale market. The common containers for wholesale
bulk sale are either fiber bags lined with a polyethylene liner or
hardboard barrels lined with fiber bags and polyethylene liners.
Powder sold to the government must be packed in 220 pound barrels;
requirements for other sales outlets will depend upon the wishes of
the purchaser. In this analysis all powder was packaged in barrels
because at the present time this type of packaging is the most
prevalent and powder packaged in barrels will reduce the hazards involved in storing. The barrels and liners are usually purchased in lots of one thousand at a price of $3.00 per barrel and liners.

Storage and Selling

The selling costs incurred in plants will vary as selling policies differ between plants. In this study we have assumed that only high-heat powder for the wholesale trade will be produced. Under this assumption there are no market development costs, such as advertising or promotion, incurred. This assumption excludes the baby food market and other low-heat markets for plants but it is realistic in that the bulk of the powder produced in small plants is produced for high-heat powder markets. In addition this assumption reduces selling cost variation between plants for purposes of analysis. Under these conditions the following selling costs will be incurred in marketing powder, (a) insurance, (b) lumber required for packing powder in railroad cars, (c) labor required for loading powder, (d) equipment and (e) brokerage fees.

These costs, with the exception of insurance and equipment costs, vary directly with volume. The insurance costs vary with output but not in direct proportion; therefore the unit costs will decrease as volume increases. The equipment cost per unit will decrease as volume increases.
The selling cost per hundredweight has been computed in the following manner:

a. Insurance

\[ \frac{\text{value of inventory and equipment} \times \text{insurance rate}}{\text{annual volume}} = \text{cost per hundredweight} \]

b. Lumber required and cost of lumber per carload of powder

\[ \frac{a}{1,000} \times b = \frac{c}{400.00} = \text{cost per hundredweight}, \]

where

- \(a\) = board feet of lumber required
- \(b\) = price of lumber per thousand board feet
- \(c\) = total cost of lumber per carload of powder
- 400.00 = number of hundredweight per carload of powder.

c. Brokerage is $0.50 per hundredweight of powder. This is the brokerage fee charged by one of the major marketing organizations in this area. (State Brand Creameries of Mason City, Iowa)

d. Labor

During the peak season it will be necessary to pay labor overtime rates for car loading operations. The labor rate for car-loading labor was therefore set at $1.88 per hour, which is one and one half times the regular rate for common labor. The unit cost of labor was computed as follows:
\[ a(1.88) = \frac{b}{440.00} \text{ cost per hundredweight,} \]

where

\( a \) = numbers of hours required to load one car
\( b \) = total labor cost per carload
\( 1.88 \) = overtime rate for common labor
\( 440 \) = number of hundredweight per car load.

e. Equipment

Fork lift truck, estimated life 5 years
Depreciation \( a(0.20) \) = depreciation cost
Maintenance \( a(0.05) \) = maintenance cost
Interest \( \frac{a}{2}(0.05) \) = interest cost

where \( a \) = initial cost of the fork lift truck.

Pallets for stacking barrels, estimated life 5 years.
Pallets are assembled during the slack season by plant labor not required for processing. Each pallet contains 35 board feet of rough sawed lumber.
Depreciation \( c(0.20) \) = depreciation cost
Maintenance \( c(0.05) \) = maintenance cost
Interest \( \frac{c}{2}(0.05) \) = interest cost

where \( c \) = initial cost of pallets.

f. Financing

Powder is in storage approximately two months after the powder is produced; therefore it is necessary to provide working capital by securing a bank loan for an average
two months production. The financing cost is computed as follows:

\[ a(\$1.15) = b \]
\[ b(0.035) = c \]
\[ \frac{c}{d} = e \]

where

- \( a \) = average production for two months
- \( b \) = value of powder in storage
- \( c \) = annual interest charge
- \( d \) = annual production
- \( e \) = cost per hundredweight
- \$1.15 = wholesale price of powder
- 0.035 = interest rate for short term loans.

If a plant produces powder for special markets the selling costs will vary from those given above. The selling costs incurred in these situations will depend upon the shipping and loading specifications of the purchaser and to some extent upon the periodicity of shipment. These special markets are a possible source of increased revenue for some plants. However, small plants, such as the plants in this study, will more likely produce powder for the bulk wholesale market and market their product through a marketing organization such as State Brand Creameries in Iowa. Special market development often involves too great an initial expense to make it profitable for small plants. By marketing through a large organization, the selling costs for
individual plants are reduced because the development and marketing service costs are dispersed among many plants.
PRICES OF INPUTS

Before any entrepreneur makes a decision affecting future operations, he must, in some fashion, discount future costs and returns back to the present. This is not difficult in the case of fixed costs because if the entrepreneur decides to operate, the present commitments continue into the future at the same rate at which they occur at present. In this study such charges would be building, equipment, managerial services, taxes and insurance. Except for small amounts of depreciation due to use, these charges will remain the same irrespective of volume variation or price variation.

The variable input prices and product prices, however, will fluctuate over a period of time. The price of labor, fuel, supplies, water, electricity and power will vary from one period to another. Therefore, in order to determine the profitability of future operation it is necessary to anticipate these prices and discount them back to the present.

This is a very difficult process, because the farther the future periods are removed from the present the less basis one has for forecasting and the larger the possible error. Recently, this discounting process has been especially difficult. The unstable world conditions, the threat of war (or peace) and the uncertain future of foreign aid, defense and support programs have made price forecasting extremely
The prices of inputs, as stated previously, will fluctuate, but they will not fluctuate at the same rate, because of differences which exist in the market organization for the various factors. This difference in the rate of fluctuation introduces still another problem into the analysis and increases the complexity of the forecasting process. The uncertainty is such that not only is the price variation unknown, but anticipations of price variations are held with less certainty.

In view of the problems involved in price forecasting, future costs and returns have not been discounted back to the present in this study. For purposes of this analysis it was assumed that present prices would continue into the future. This assumption grows from the assumption that prices are just as likely to decline as to rise, and by the same amounts. Therefore, assuming the same discount rate is used on all prices and prices are constant over time, if it is profitable to operate at present it will be profitable to operate throughout the period included in the entrepreneur's economic horizon.

The prices attached to inputs in this study are current prices in all cases. They have been obtained from manufacturers, suppliers, contractors and individuals familiar with the various inputs involved. The prices and rates and the source from which they have been obtained are given in Appendix D.
PRICE OF OUTPUT

The general level of the price of skim milk powder has been determined by the support price level for the past few years. According to the provisions of the Agricultural Act of 1949 the price of milk and milk products must be maintained at 75 to 90 percent of parity. This has been accomplished by government purchases of butter, cheese and non-fat dry milk solids. Prior to November 1952 milk prices remained above the designated support levels (90 percent of parity until April 1, 1954). Since that time, however, the government has purchased large quantities of dairy products to maintain the price.

Because of the large quantities of dairy products in storage and the continued increase in milk production, the support price for dairy products was reduced to 75 percent of parity effective April 1, 1954. The support price of non-fat dry milk solids was reduced from sixteen cents per pound to fifteen cents per pound for spray process powder. This decrease in the government support price will cause a decrease in the general price level for spray process powder.

The support price (15 cents per pound at present) does not, however, guarantee that a plant will receive this price for its entire production. Powder which does not qualify as Extra grade will sell at prices below the support level. The portion of the plants' production which is Standard rather than Extra grade will depend upon the quality
standards of the plant. In all plants, however, there will be a small percentage which will not qualify as Extra grade powder. This powder will sell for 1 to 2 cents per pound less than Extra grade powder. It is not possible to determine the exact price or quantity of Standard grade powder. This depends upon market demand and plant conditions at any particular time. Table 1 shows the prices and quantities sold of all grades of skimmilk powder in January 1954.

Table 1. Manufacturers' selling prices for spray process non-fat dry milk solids (F.O.B. Plant, January, 1954)\(^a\)

<table>
<thead>
<tr>
<th>Price (cents per pound)</th>
<th>Quantity sold (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13(\frac{3}{10}) - 14</td>
<td>166,845</td>
</tr>
<tr>
<td>14 - 14(\frac{3}{10})</td>
<td>1,005,295</td>
</tr>
<tr>
<td>14(\frac{3}{10}) - 15</td>
<td>7,627,452</td>
</tr>
<tr>
<td>15 - 15(\frac{3}{10})</td>
<td>16,241,447</td>
</tr>
<tr>
<td>15(\frac{3}{10}) - 16</td>
<td>33,981,621</td>
</tr>
<tr>
<td>16 - 16(\frac{3}{10})</td>
<td>7,303,693</td>
</tr>
<tr>
<td>16(\frac{3}{10}) - 17</td>
<td>560,527</td>
</tr>
<tr>
<td>17 - 17(\frac{3}{10})</td>
<td>2,367,822</td>
</tr>
</tbody>
</table>

\(^a\)Prices and quantities sold obtained from U.S.D.A. Evaporated Condensed and Dry Milk Report. March 1, 1954.

At this time the support price of skimmilk powder was 16 cents per pound.

As yet no market data are available for powder prices prevailing under the lowered support level.

The powder which was sold for less than 15\(\frac{1}{2}\) to 16 cents per pound in Table 1 was in all probability powder which did not classify as
Extra grade and therefore was not acceptable for government purchase. The powder which sold for more than 16 cents per pound was low-heat powder used for special products. Table 1 illustrates that while the government support price determines the general level of skimmilk powder prices, large quantities of powder are sold for prices above and below the government support price.

In this study it was assumed that all plants will manufacture bulk high-heat powder acceptable to the government. Therefore the minimum price for this powder is 15 cents per pound. However, in most plants, approximately 5 percent of the production will not meet government specifications. This powder will be sold at a somewhat lower price (1 to 2 cents per pound less than support price). If this is taken into consideration and the assumption is made that the unacceptable powder will sell for 2 cents per pound less than acceptable powder, the weighted average price for powder to a plant will be 14.9 cents per pound.

In view of the large stocks of powder in storage (470 million pounds in February 1954) it appears unlikely that the general price level will rise above the level set by the current support price. Therefore in this analysis the price of 14.9 cents per pound will be considered the product price.
PROCESSING COSTS IN FOUR MODEL PLANTS

In the following section the processing costs in each of four model plants are discussed. The volume of the drying section of each plant was determined by the volume of the butter section of each plant. In Plant I, one full churning of butter (1800 pounds) is produced each day in the peak season. A plant of this volume receives 43,200 pounds of milk per day in the peak month and produces 3,400 pounds of powder per day in the peak month. Plant II is approximately twice the volume, Plant III three times, and Plant IV four time the volume of Plant I. The costs discussed in the following section are the minimum processing costs, under the conditions stated previously, for each particular volume.

Plant I

Plant I, the smallest plant in the analysis, received 11,536,365 pounds of milk per year. The daily receipts varied from 12,300 pounds per day in the peak production month to 25,000 pounds per day in the low production months. In this plant daily powder production varied from 3,400 pounds per day in June to 2,000 pounds per day in November and December. The plant produced 938,200 pounds of powder at a cost of 7.64 cents per pound. The cost of each input in the four plants is shown in Table 2. The major costs in this plant were equipment, labor,
fuel and packaging. These four inputs account for more than 70 percent of the unit cost. As volume increases, equipment cost, and (within certain volume ranges) labor costs will decrease. Fuel and packaging cost, however, will remain relatively constant as volume increases.

In selecting the optimum equipment combination from all possible combinations the space requirements, labor requirements, initial cost and boiler requirements were considered. A total of ten equipment combinations were worked out which would have been usable in this plant. After all combinations were considered a 500 pound per hour dryer, and evaporation and heating equipment matching this capacity, were installed.

Three of the ten possible combinations included a single effect evaporator. The fuel cost for such an evaporator would have been twice as great as the fuel cost for a double effect evaporator. Five of the seven remaining combinations required ceilings 35 feet high. The additional building cost for the added height would have been $4,500 in initial cost or 4 cents per hundredweight of powder in annual cost. These five combinations also had a lower hourly capacity than the remaining two combinations. This lower capacity would have increased labor costs $3,200 per year or 33 cents per hundredweight. Therefore the building and labor cost would have been 37 cents per hundredweight higher if one of these five combinations had been selected. However, these combinations cost less initially than either of the two remaining combinations. The larger equipment combination
Table 2. Input costs per hundredweight of powder

<table>
<thead>
<tr>
<th></th>
<th>Plant I 938,200#/yr.</th>
<th>Plant II 1,875,600#/yr.</th>
<th>Plant III 2,617,600#/yr.</th>
<th>Plant IV 3,767,500#/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500</td>
<td>650</td>
<td>500</td>
<td>650</td>
</tr>
<tr>
<td>Building</td>
<td>.24</td>
<td>.16</td>
<td>.16</td>
<td>.12</td>
</tr>
<tr>
<td>Equipment</td>
<td>1.34</td>
<td>.69</td>
<td>.69</td>
<td>.46</td>
</tr>
<tr>
<td>Boiler</td>
<td>.35</td>
<td>.24</td>
<td>.18</td>
<td>.15</td>
</tr>
<tr>
<td>Insurance</td>
<td>.16</td>
<td>.09</td>
<td>.09</td>
<td>.06</td>
</tr>
<tr>
<td>Taxes</td>
<td>.16</td>
<td>.09</td>
<td>.09</td>
<td>.06</td>
</tr>
<tr>
<td>Quality control</td>
<td>.01</td>
<td></td>
<td></td>
<td>less than 1 cent per cwt.</td>
</tr>
<tr>
<td>Clerical</td>
<td>.11</td>
<td>.06</td>
<td>.06</td>
<td>.04</td>
</tr>
<tr>
<td>Labor</td>
<td>1.11</td>
<td>.72</td>
<td>.73</td>
<td>.51</td>
</tr>
<tr>
<td>Fuel</td>
<td>1.11</td>
<td>1.11</td>
<td>1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>Electricity</td>
<td>.24</td>
<td>.22</td>
<td>.24</td>
<td>.22</td>
</tr>
<tr>
<td>Water and sewage</td>
<td>.18</td>
<td>.18</td>
<td>.18</td>
<td>.18</td>
</tr>
<tr>
<td>Packaging</td>
<td>1.36</td>
<td>1.36</td>
<td>1.36</td>
<td>1.36</td>
</tr>
<tr>
<td>Supplies</td>
<td>.41</td>
<td>.21</td>
<td>.21</td>
<td>.14</td>
</tr>
<tr>
<td>Selling costs</td>
<td>.86</td>
<td>.80</td>
<td>.80</td>
<td>.80</td>
</tr>
<tr>
<td>Total processing cost</td>
<td>7.64</td>
<td>5.93</td>
<td>5.90</td>
<td>5.21</td>
</tr>
</tbody>
</table>
selected was $14,200 higher in initial investment or 23 cents per
hundredweight on the basis of 10 year depreciation. Also the smaller
equipment required less boiler capacity and the boiler charge per
hundredweight would have been reduced 6 cents. On balance therefore
the larger equipment combination selected cost 8 cents per hundred-
weight less than the lowest price alternative.

In addition to being the lowest cost combination at this volume
the combination selected provides a volume range for possible
expansion. This plant would almost triple its volume before additional
or larger equipment were needed. This could very well become a very
important consideration in future operation.

The fact that excess equipment capacity exists in the plant even
when it is operating at the lowest equipment cost indicates that
resources are not being utilized efficiently. Any plant facing such
a situation should attempt to increase its skimmilk volume. If the
remainder of the physical plant is being utilized to capacity it may
be possible to purchase skimmilk from plants in the surrounding area.
So long as the price of purchased skimmilk and the variable input cost
does not exceed the powder price it will be advantageous for the plant
to purchase and process skimmilk from other supply sources. The
differential existing between the combined purchase price and variable
input cost and the sale price of powder will reduce the unit cost for
fixed expenditures and increase net revenue.

After the equipment combination was selected the space require-
ments for the equipment were computed and a plant layout chart constructed. With this plant layout as a base the building cost was computed under the conditions set out in Section 2.

The labor organization was then designed to fit the equipment combination, and labor cost was computed. The cost of each remaining input was computed according to the method set out in Section 2. The detailed calculations for the physical quantities and cost per hundredweight of each input for Plant III are given in Appendix E.

### Plant II

Plant II, the second largest plant in the study, processed 1,875,000 pounds of powder per year. Daily powder production varied from 6,800 pounds in the peak month to 4,000 pounds in the low production months. Either of two possible resource combinations would permit economical operation in a plant of this volume. The combination selected in any particular instance would be dependent upon the expectations of the individual entrepreneur. If the entrepreneur does not expect plant volume to increase, or expects volume to increase only slightly, the 500 pound dryer combination would be the logical choice. This combination would process skimmilk powder for $5.90 per hundredweight (three cents per hundredweight lower than the next alternative combination, see Table 3). Future expansion, however, would be restricted, for the daily plant volume could not increase by more than 23 percent of the present volume. At this volume the
equipment would be operating at capacity in the peak month and further increases in annual production would not be possible unless the pattern of seasonal production were changed.

If, however, the entrepreneur expects a volume increase of more than 23 percent within the period covered by his economic horizon he would logically select the 650 pound dryer combination. During the period in which volume is less than 2,679,500 pounds of powder per year

Table 3. Processing costs per hundredweight of powder for three equipment and labor organizations

<table>
<thead>
<tr>
<th>Volume Pounds of powder per year</th>
<th>500 pound/hour dryer</th>
<th>650 pound/hour dryer</th>
<th>750 pound/hour dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td>938,200</td>
<td>7.64</td>
<td>5.90</td>
<td>5.28</td>
</tr>
<tr>
<td>1,875,600</td>
<td>5.93</td>
<td>5.21</td>
<td>5.48</td>
</tr>
<tr>
<td>2,679,500</td>
<td>5.30</td>
<td>5.08</td>
<td>5.20</td>
</tr>
<tr>
<td>3,174,700</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,767,500</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(the maximum production possible with a 500 pound dryer combination)

the annual cost in excess of the lowest unit processing cost would range from $563, or 3 cents per hundredweight, at a volume of 1,875,600 pounds per year to zero at a volume of approximately 2,600,000 pounds per year. This additional cost would be cost incurred by having facilities capable of processing products without equipment changes for the volume range of 1,875,600 to 2,679,500 pounds of powder per year.
The selection of the higher cost combination in instances where volume is expected to increase beyond the capacity of the 500 pound dryer combination would, in all probability, result over time in a lower processing cost.

Because it seems more likely that skimmilk supplies will increase, rather than remain constant or decrease, the 650 pound dryer combination would be the most economical investment in a plant of this volume. This probable increase in manufacturing skimmilk supplies is the result of two changes which have been occurring over the past several decades. The rate of utilization of skimmilk for human food has increased from 51 percent in 1924 to 74 percent in 1952, and there has been a continuing trend away from farm separated cream. This trend away from farm separated cream was caused by (a) an increased price for skimmilk at the time when the farmer began to ship fluid milk, (these price increases were partially caused by the increased rate of utilization for human food,) or (b) by a change in personal preferences. These changes away from farm separated cream are diverting more skimmilk from animal feed uses on the farm to marketing channels where it is available for human food uses.

As stated previously, this probable increase in future supplies would make the 650 pound dryer combination the most economical investment over time for most entrepreneurs. The recent experiences of several plants in Iowa substantiates this statement. Several plants,
which began drying operations within the past five years, have been forced to either replace or duplicate their drying facilities because of increases in volume. Such changes have been expensive and these plants would be in a more desirable competitive position at present if these volume changes had been anticipated during the initial planning stage.

Plant III

Plant III, the third largest plant in the study, processed 2,817,600 pounds of powder per year. Daily powder production varied from 10,200 pounds in the peak month to 6,000 pounds in the low production month. At this volume (2,817,600 pounds per year) a 650 pound dryer combination is the low cost combination. The alternative equipment combination for this plant is a 750 pound dryer combination. While the 750 pound dryer combination would provide a much larger volume range for future expansion the present processing cost ($5.48 per hundredweight) would exceed the processing cost of a 650 pound dryer combination by 27 cents per hundredweight. At an annual volume of 2,819,600 pounds this higher cost would result in an additional $7,600 per year processing cost. If the annual volume of Plant III were to increase to the physical capacity limits of the 650 pound dryer combination (3,174,700 pounds per year) the alternative 750 pound dryer combination would still exceed the processing cost of a 650 pound dryer combination by 12 cents (see Table 3).
If in the planning stage of Plant III, the entrepreneur does not expect plant volume to surpass 3,174,700 pounds per year within the first two years, the annual savings possible through selection of the 650 pound dryer combination would, to a large extent, offset the cost of replacement. Also, if a 650 pound dryer combination is chosen, the lower processing cost at present will place the entrepreneur in a more favorable position in the immediate future. This may be of more importance than long-run processing costs if the plant's survival is dependent upon showing a profit from the beginning of the operation period.

In Plant II the higher cost combination was chosen because of probable future volume increases. In the case of Plant II the extra annual cost would be small; it would range only from $563 per year to zero. But in Plant III the extra annual cost would be large. It would range from $7,600 to $3,810 per year in the section of the volume range under consideration (2,817,600 to 3,174,700 pounds per year). Therefore, if it is not expected that annual volume will exceed 3,174,700 pounds per year in the near future, it will be more profitable to install a 650 pound dryer combination and replace it when volume does exceed its capacity.

Plant IV

Plant IV, the largest plant in the study, processed 3,767,500 pounds of powder per year. Powder production varied seasonally from
13,600 pounds per day in the peak month to 8,000 pounds per day in the low production month. At this volume a 750 pound dryer combination achieves the lowest unit processing cost ($5.04 per hundredweight of powder).

In Plant IV the relative importance of fixed and semi-fixed costs, with the exception of labor, continued to decline. Labor cost did not decline but rather increased even though volume increased. This higher labor cost was incurred because it was necessary to employ two men per shift for dryers of 750 pounds per hour or larger capacity. This becomes necessary at these hourly capacities because the time devoted to packaging and storing the powder requires such a large proportion of one man's time that not enough time remains to adequately perform the inspection and adjustment duties required. This additional labor expense accounts for a large part of the discontinuity between the processing costs of the two combinations as shown in Figure 1.

Table 3 shows that at the maximum annual output of a 650 pound dryer (3,174,700 pounds) a 12 cent unit cost differential exists between the 650 and 750 pound dryer combinations. The labor cost differential at this volume accounts for 10 cents of this 12 cent unit cost differential.
EFFECT OF VOLUME ON COSTS AND COST DISTRIBUTION

The method of volume selection for each of the four model plants was discussed in a preceding section. The selection criterion employed was based primarily upon efficiency of equipment utilization in the butter section of each plant. This method of volume selection did not result in volumes which would permit the most efficient drying operation. In order to determine the most efficient level of operation for each equipment combination in the plants, additional cost points have been computed for each equipment combination. The derived cost points for each of three equipment combinations are given in Table 4.

The costs shown in Table 4 indicate that processing costs per unit decreased within the volume range of each equipment combination, as volume increased. Also as volume increased and larger equipment was required, unit costs decreased as volume surpassed the physical capacity of each combination. The rate of cost decline, however, decreased as volume increased. This decrease in the rate of cost decline can be seen in Table 4. The low cost points for the equipment combinations illustrate this decline (Figure 1). Processing costs declined from $5.28 per hundredweight for a 500 pound dryer combination to $5.08 per hundredweight for a 650 pound dryer combination to $5.04 per hundredweight for a 750 pound dryer combination. This decline
Table 4. Input costs per hundredweight of powder at various volumes, and with several equipment combinations

<table>
<thead>
<tr>
<th>Volumes^a</th>
<th>500 pound dryer combination</th>
<th>650 pound dryer combination</th>
<th>750 pound dryer combination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Volumes</td>
<td>9,382</td>
<td>18,756</td>
<td>26,795</td>
</tr>
<tr>
<td>Inputs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building</td>
<td>.24</td>
<td>.16</td>
<td>.11</td>
</tr>
<tr>
<td>Equipment</td>
<td>1.34</td>
<td>.67</td>
<td>.47</td>
</tr>
<tr>
<td>Boiler</td>
<td>.35</td>
<td>.18</td>
<td>.12</td>
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<td>.09</td>
<td>.06</td>
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<td>.09</td>
<td>.06</td>
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<td>less than 1 cent per hundredweight of powder</td>
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<td>.06</td>
<td>.04</td>
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<td>1.36</td>
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<tr>
<td>Total</td>
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<td>5.93</td>
<td>5.30</td>
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^a Hundreds of pounds of powder produced per year.
Fig. 1. Cost of spray drying skim milk with several equipment combinations at various volumes.
represents a 4 percent cost reduction between the 500 and 650 pound dryer combinations and a 0.8 percent reduction between the 650 and 750 pound dryer combination. At the same time the volume increased 18 percent in both instances.

In addition to the decrease in the rate of cost decline, the distribution of various types of costs changed as volume increased. At a volume of 938,200 pounds of powder per year, the fixed costs, which include building, equipment, boiler, insurance and taxes, comprised 30 percent of the total processing cost. Semi-fixed costs—cost items in which part of the input was fixed and part variable, such as supplies, selling costs and labor—comprised 32 percent of the unit cost. Variable costs, which included packaging, water and sewage, electricity, and fuel cost, accounted for the remaining 38 percent of the unit cost. When the volume is increased to 2,679,500 pounds per year (using the same equipment combination) the fixed cost proportion of the processing cost is reduced to 16 percent, the semi-fixed cost proportion is reduced to 27 percent, and the variable cost proportion is increased to 57 percent. This change in the relative importance of the different classes of input costs continued as volume increased. As in the case of unit cost decline, however, the rate of change declined as volume increased.

Table 4 illustrates the importance of efficient resource utilization in any plant. The differences in processing cost within the same equipment combination indicates the net revenue increases
possible through increased efficiency in the utilization of fixed factors. The economies possible through such increased efficiency make the problem of anticipating future volumes one of the most important considerations in the planning stage. Grossly incorrect expectations of future volumes will reduce net revenue through (a) unduly high fixed input costs because of low volumes (b) excessive replacement costs if volume increases beyond the capacity of the installed equipment, or (c) revenue foregone because of inability to process the entire available supply.

In cases where a plant is contemplating changing from a butter operation to a butter-powder operation a first approximation of future volume may be obtained by surveying the present patrons to determine how many patrons will shift from gathered cream to fluid milk production. Further, a survey of all cream producers in the area may provide additional information about future plant volume. Farmers' intentions may change from those given in the survey. The degree and effect of such changes may be evaluated by observing plants in similar situations which have recently installed a fluid milk operation.

In the event that expectations of future volume are incorrect, a plant may have recourse to several courses of action which could reduce its operating cost and thereby increase net revenue. If volume does not increase as expected, the plant may increase its operating efficiency by purchasing fluid skimmilk from surrounding milk plants.
This will be advantageous so long as the net return from such purchased skimmilk solids exceeds the costs of the variable inputs, the variable portion of the semi-fixed inputs, transportation, and the initial cost of the skimmilk solids.

On the other hand, if the errors in expectation result in volumes beyond the physical capacity of the installed equipment, it may be more desirable either to sell the excess skimmilk in another market, if a market is available, or to return the skim to farmers as animal feed rather than install larger equipment.

This would be true when excess supplies are expected to be temporary or when future supplies are not expected to increase. If the latter is the case and no new producers are accepted in the market, selling skimmilk in another market or returning skimmilk to farmers would have to be practiced only until the normal producer turnover eliminates the excess supply. If, however, it is expected that the volume increase will continue into the future, it would probably be more advantageous to increase drying capacity or utilize the excess skimmilk in another product.
The costs computed above were direct charges incurred in the processing and selling of skim milk powder. A butter-powder plant, in which butter and powder are considered joint products, must add to these costs a portion of the receiving and separating costs.* The method of allocation will depend upon the policies and conditions facing individual plants. If, however, the skim milk powder is not considered a joint product but is thought of as an additional product to the butter manufacturing enterprise, the entire costs of the additional receiving and separating equipment, building, power requirements, office expenses, and labor must be added to the processing costs computed in this study before net revenue can be determined.

For example: A butter manufacturing plant may have, at present, $10,000 invested in receiving equipment and have one man operating the equipment. If the plant changes to a fluid milk operation it may require an additional $30,000 in receiving and separating equipment and an additional man to operate the equipment. In this case, where powder is not considered to be a joint product with butter, the additional costs of receiving equipment ($30,000) and the additional labor (1 man) costs must be added to the costs computed above in order

*No attempt was made to determine these costs in this study. These costs are being determined in another study currently underway under Project 1169 of the Iowa Agricultural Experiment Station.
to determine net revenue.

In the case of multi-product plants, in which the receiving and separating equipment is required for other products (no additional inputs are required), the drying operation may be used as an outlet for the plant surplus. In such cases the powder would be considered as an additional product, but the costs incurred in such plants would only be the costs computed in this study—the direct costs. This difference in costs between plants where the powder is considered to be an additional product in both instances occurs because of the differences in plant organization and operation. In both cases the plants are attempting to maximize profit. In the case of butter plants, this maximization is attempted by addition of a product (skim-milk powder) through which the firm hopes to increase its net revenue; the drying operation is a major source of revenue for the plant. But in multi-product plants, the drying section of the plant is used to dispose of skim milk which cannot be sold in higher-use classes. The prime consideration in these plants is to have available facilities which will add flexibility to the overall plant operations and also dispose of surplus skim milk as economically as possible. In these plants the drying operation is used primarily to add flexibility to the overall operation. In many cases the revenue considerations are secondary to flexibility, and while a drying operation may not return the highest net revenue it will add the most flexibility to the plant operations and is therefore the most desirable method of disposal.
If a multi-product plant, where the drying operation is a marginal enterprise, sells its entire output for 14.9 cents per pound (government support price, weighted average of 95 percent of production, and five percent standard grade powder) the net return per pound of skim milk solids is the difference between the processing costs (line a of Figure 2) and the selling price (line b of Figure 2). The return per pound of skim milk solids increases as volume increases. In Table 5 the net return is expressed as the net return per hundredweight of fluid skim milk at various volumes of annual powder production.

In plants where the drying section is considered to be a joint operation with the remainder of the plant, the total drying costs cannot be isolated for purposes of determining the net revenue from skim milk drying. This is not possible because there is no economically sound basis for allocating the joint costs of receiving and separation.
Fig. 2. Net return available for payment of separation, receiving, transportation, and raw material costs (assuming a sale price of $1.149 per pound).
between products.

The costs computed in this study, however, can be used to compare the relative profitability of various alternative operations available to a fluid milk plant. The lack of separation and receiving cost data will not interfere with this comparison because these costs will be incurred and will be identical at any specific volume irrespective of the method of disposal. Thus, it is possible to use the costs computed in this study to compare the relative profitability of processing and selling (a) fluid skimmilk, (b) condensed skimmilk, (c) dried ice cream mix, and (d) cheese if one or several of these markets is available.

As an example, let us assume that a fluid skimmilk market is available, and will continue to be available throughout the foreseeable future. The entrepreneur must then decide at what long-run price of skimmilk it will become more profitable to dry skimmilk rather than dispose of skimmilk in fluid form. In this situation the price of fluid skimmilk, f.o.b. plant, must be equal to or greater than the net return for skimmilk shown in Table 5 before selling skimmilk in fluid form is more advantageous than processing it into powder.

In the case of the remaining alternatives listed, the entrepreneur must have a knowledge of the processing cost in addition to price if a meaningful comparison is to be made.
APPLICATION OF THE COMPUTED COSTS TO MANUFACTURING

MILK PRICING FORMULAE

In several areas of the United States milk producers are being paid for their milk under a "component pricing" plan rather than under the traditional butterfat pricing plan. Briefly, component pricing is a method of determining producer paying prices by determining the quantity of product obtained from 100 pounds of milk (including a deduction for plant losses) on the basis of the butterfat skim milk relationship. The prices of the products, after deducting processing costs, are multiplied by yield and the value thus obtained is available for producer payments.

Clark and Hassler (2) have published suggested formulae to be used for component pricing with various types of operations. The formula for a butter-powder operation is based upon the following relationships:

(a) \[ Q_b = 1.23 F - .123 \]

(b) \[ Q_{nfs} = 7.17 + .141 F, \]

where \( Q_b \) = quantity of butter obtained from 100 pounds of milk
\( F \) = butterfat test
\( .123 \) = fat losses in processing
\( Q_{nfs} \) = quantity of non-fat solids obtained from 100 pounds of milk
\( .141 \) = added pounds of dried non-fat solids obtained from 100
pounds of milk as the butterfat test increases by 1 percent.

With these relationships the value of milk used for butter and powder can be expressed:

\[ V_m = (1.23F - .12)(P_b - C_b) + (7.17 + .141F)(P_{nfs} - C_{nfs}) - C_{rs}, \]

where \( V_m \) = the net value of 100 pounds of whole milk
\( F \) = butterfat test of milk
\( P_b \) = price of butter
\( C_b \) = direct processing costs per pound of butter (including selling costs)
\( P_{nfs} \) = price of non-fat dried milk solids
\( C_{nfs} \) = direct processing and marketing costs
\( C_{rs} \) = cost per hundredweight for receiving and separating milk.

The costs computed in this study are the direct costs for processing and marketing non-fat dried milk solids (\( C_{nfs} \) in the above formula). By selecting the relevant cost for its particular volume, a plant can determine the net value for the non-fat solids in the milk received. The butter processing costs can be obtained from Bulletin 389 of the Iowa Agricultural Experiment Station (6) and information on receiving and separating cost will also be available in the near future. By using these costs in combination with the product prices facing the plant the paying price of whole milk in a butter-powder operation can be determined in a component pricing plan.
LIMITATIONS OF THE STUDY

The application of this type of budget analysis to investment decisions in milk plants can be an effective tool in increasing resource efficiency in the plant. The value of the results obtained by using such a technique is however limited by the following factors:

a. Expectations of future volumes must be reasonably accurate. The least cost combination of input factors cannot be ascertained until some reasonably accurate knowledge of the expected future volume is made available to management.

b. The ability of management to achieve the level of efficiency assumed in the analysis. This may require either replacing present management or assuming lower levels of efficiency in the analysis.

c. Noneconomic factors such as personal preferences for products and individuals may (1) result in resource combinations which are not optimum for a specific volume and (2) prevent resource adjustments to changes in volume.

In addition to the above limitations to the application of this method of analysis in dairy plants, there are further limitations to the application of the results of this study to individual plants in the industry. These limitations exist because of the differences in assumptions and conditions as stated in this analysis and actual
situations facing individual plants.

Any entrepreneur must take these differences into account when attempting to apply the derived costs to particular situations. If the conditions in a plant are different from those set forth in this study the individual factor input requirements and costs must be adjusted before the plant's processing costs can be determined.

The largest area where such differences may occur is in factor pricing. The prices used in this study were prices quoted by manufacturers, suppliers and users. These prices, however, are not necessarily the prices facing each plant. Milk plants purchase equipment and supplies in an imperfectly competitive market. Therefore, individual plants may be able to secure price advantages that are not generally available to all plants. These price advantages may take the form of a reduced price if equipment is purchased from a single manufacturer as a "package deal". It is also possible that individual plants may obtain price advantages in building costs. If a contractor can use the job as a "fill-in" job between larger jobs and thereby reduce his overhead costs he may submit a lower bid than he would ordinarily.

Beside the price advantages which may be available to individual plants, there may be labor economies also, where the drying operation is integrated into the plant as a whole. Labor organization for the whole plant may result in changes in equipment size and changes in labor requirements in the drying section of the plant. These could
result in lower powder-processing cost. Such economies are more likely to occur in the smaller plants where low volumes prevent complete labor specialization for each operation in the plant.

In addition to the foregoing situations other things such as (a) the availability of natural gas, (b) the operation of a waste disposal system, (c) plant-owned water wells, (d) lower or higher wage rates, and (c) lower or higher insurance and tax rates will all influence costs and must be taken into consideration by individual plants when they apply the results of this study to their particular situations.
SUGGESTIONS FOR FURTHER STUDY

The results of this study indicate that the volumes at which butter manufacturing equipment is utilized efficiently do not permit efficient resource utilization in the skimmilk drying section of the plant. Study of the problem of efficiency of resource use within the entire plant would be desirable. Much of the research for such a study has been completed or is currently underway and integration of the results of the butter manufacturing cost study, receiving and separating cost study and the present study would provide information about the processing costs of the entire plant. Such study would also provide information about the optimum resource combination for the plant as a whole and the possible economies of integration of the plant labor organization.

In addition to the above information an integration of the results of these three studies is necessary if information about the costs of volume flexibility is to be provided entrepreneurs. By combining the results and computing costs for various volumes of operation, the differences in plant costs at the various volumes would aid entrepreneurs in selecting the optimum resource combination for their expected future volume.

In addition to integration of processing costs for the entire plant research in developing a method for the determination of future
volumes of milk plants would be useful to entrepreneurs in the planning stage. A more accurate method of approximation of future volumes would enable entrepreneurs to use the results of cost research more effectively and aid in preventing uneconomic resource allocation in the milk industry.
LITERATURE CITED


ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to Dr. Geoffrey Shepherd for his guidance and assistance during the preparation of this thesis. Thanks are also due Professors Henry A. Homme, Verner H. Neilsen and Henry M. Black for their assistance in the technical aspects of the thesis.

The author also wishes to thank the many equipment manufacturers and suppliers, and milk-processing plants who cooperated in providing information which made this study possible.
APPENDIX A

PLANT III. BUILDING COSTS

Plant III. Drying building 57 ft. by 105 ft. by 24 ft. high

Foundation excavation

\[ 400(6)(2) = 4800 \text{ cu. ft.} \]
\[ 240(6)(2) = 2880 \text{ cu. ft.} \]
\[ \frac{2880}{27} = 106.7 \text{ cu. yd.} \]

Trenching with trencher and hand backfilling

\[ 1.30(284) = 369 \]

Machine rental = 265

Total = $634.00

Forms (forms are used twice)

\[ 400(5)(2) = 4000 \text{ sq. ft.} \]
Three board feet of lumber are required per square foot of surface

\[ 4000(3) = 12000 \text{ bd. ft. of lumber} \]
\[ 12000(158) = 1896 \approx 2 \]

Wire and nails cost 1 cent per square foot of form

\[ 12000(.01) = 120.00 \]

Form labor (4000 sq. ft. of forms)

5.1 carpenter hours per 100 sq. ft. of forms for erection and removal

\[ 40(5.1)(2.25) = 459.00 \]

Foundation material

\[ 400(5)(1.33) = 2660 \]
\[ 400(1.33)(2.67) = 1120 \]

\[ \frac{1120}{4000} \text{ cu. ft. of material} \]
Floor 57 ft. by 105 ft. 6 in. concrete
No. 6 reinforcing mesh

(57)(105)(.5) = 2993 cu. ft.

4080 cu. ft. of foundation material
2993 cu. ft. of floor material
7073 cu. ft. or 262 cu. yd. of concrete

Materials

Cement (7.2)(262)(1.15) = $2169.00

Gravel \frac{0.73(262)(27)(165.5)}{2000} (2.25) = 961.00

Sand \frac{.5(262)(27)(165.5)}{2000} (2.35) = 689.00

Reinforcing \frac{57(105)}{100} = 60 squares @ $5.00 per square = 300.00

Labor Use 6-S 1 bag mixer, crew of 13, one foreman

2.5 hours of labor per cu. yd.
2.5(262)(1.25) = 819.00
82(3.00) = 246.00

Wall material

Wall area

(59)(24)(2) = 2832
(105)(24)(2) = 6040
(59)(24) ÷ 2 = 708
8580

Wall openings

23 6 by 8 windows 23(4.8) = 1104
2 10 by 12 doors 2(120) = 240
3 4 by 8 doors 3(32) = 96

8580 total wall area
1140 wall openings
7440 sq. ft. net wall area
Concrete block

Corner 4(24)(12) \div 8 = 144
Jamb 23(2)(12)(12) \div 8 = 828
2(2)(12)(12) \div 8 = 72
3(2)(8)(12) \div 8 = 72

Full jamb 486
Half jamb 486
Half reg. 486

Regular block

\( \frac{7140(144)}{128} - \frac{7144}{2} + \frac{486}{2} + \frac{486}{2} \) = 6917

Total block = 6917 + 1602 = 8519

Block cost

\( 144(31) = \) $45.00
\( 486(31) = \) 151.00
\( 486(16) = \) 78.00
\( 486(15) = \) 73.00
\( 6917(30) = \) 2075.00

Angles for lintels

240(19)(.11) = 502.00

Mortar: 1 pt. cement, 3 pts. sand

600 lb. per 100 block

Sand \( \frac{(85,20)(600)}{2000} \) = \( \frac{3}{4} \) (2.35) = 45.00

Cement \( \frac{1/3(19.2)(2000)}{94} \) = \( \frac{12800}{94} \) = 136(1,15) = 155.00

Interior tile

\( \sqrt{(59)(22)(2)} + \sqrt{(25)(22)(2)} - \sqrt{120} + 288 + 967 = \)

\( \frac{3192(144)}{60} = 7,660(230) = 1762.00 \)
Motor

Cement \((76.6)(1.5)(1.15)\) = $132.00

Sand \((76.6)(3)(165.5)\) \(\frac{2000}{200} = 45.00\)

Floor tile \((59)(25) = 1175\) sq. ft.

\(\frac{1175(144)}{32} = 6638(1.25) = 830.00\)

Mortar

Cement \(14.75(1.5)(1.15)\) = 26.00

\(\frac{(14.75)(3)(165.5)}{2000} = 9.00\)

Labor

Walls 1 mason, 1 helper, lay 115 block per day

\(\frac{8519}{115} = 74\) days

\(74(8)(3.15) = 74(8)(1.25) = 1865.00\)

Cleaning 1 side mason 2.6 hrs. per 100 block

\(2.6(85.2)(3.15) = 698.00\)

Painting 1 side mason 3.3 hrs. per 100 block

\(3.3(85.2)(3.15) = 885.00\)

Helper 3.3 hrs. per 100 block

\(3.3(85.2)(1.25) = 351.00\)

Interior Tile 1 mason, 1 helper, lay 160 tile per day

\(\frac{7660}{160} = 48\)

\(48(8)(3.15) = 1210.00\)

\(48(8)(1.25) = 480.00\)
Floor tile: 3 men (1 man 1/2 time) lay and bed
100 sq. ft. per day

\[
\frac{14.75}{100} = 14.75 \text{ or } 15 \\
15(8)(3.15) = 378.00 \\
15(8)(1.25) = 150.00 \\
15(4)(1.25) = 75.00
\]

Roof open truss steel joists 1\(\frac{1}{4}\) in. joists 4\(\frac{1}{8}\) in. o.c.

\[
15(\frac{1}{4}) = 60 1\frac{1}{4} \text{ in. joists type } 1\frac{1}{4}, 240 \text{ lbs. per joist} \\
240(60) = 14400
\]

\[
\frac{14400}{2000} = 7.2 \text{ T. @ } $190 \text{ per T. } = 1368.00
\]

Roof deck steel (18 ga.) 1\(\frac{1}{8}\) in. with insulation

\[
6000 @ \$1.60 \text{ per sq. ft. } = 2400.00
\]

Roofing 3 plies felt and graveled top

Felt \[32\frac{1}{4}(60 \text{ sq.}) = \frac{1944}{4} = 486 \text{ or } 490\]

490 rolls @ $3.50 per roll = 1720.00

Asphalt

\[
3(30)(60) + 1(65)(60) = \frac{2300}{2000} = \frac{4.65}{2} \text{ T.}
\]

\[
4.65 \text{ T. @ } $50 \text{ per T. } = 233.00
\]

Gravel \[400(60) = \frac{24000}{2000} = 12 \text{ T. @ } $2.25 = 270.00
\]

Labor for roof

Joists 7.2 T. erection cost $50 per T. = 360.00

Roof deck 60.00 sq. @ $11 per sq. = 660.00

Roofing 5 men put on 15 sq. per day

\[
60 = 4 \text{ days}
\]

\[
3(4)(8)(2.75) = 264.00 \\
2(4)(8)(1.25) = 80.00
\]
Sewer materials  two 120 ft. sewer lines

\[2(138) = 276 \text{ ft. of pipe} @ \$1.65 \text{ per ft.} = \$455.00\]

6 tees @ $4.10 per tee = 25.00
2 ells @ $2.55 per ell = 5.00
6 drains @ $4.50 per drain = 27.00

Labor 1 man lays 12 ft. per hour

\[\frac{276}{12} = 23 \text{ hrs.} @ (2.75) \text{ per hr.} = 63.00\]

Steam lines 2(140)(2.00) = 160.00

Insulation 80 ft. pipe 126 sq. ft. @ $0.15 per sq. ft. = 19.00

Labor

Covering steam lines 1 man covers 15 ft. per hour

\[\frac{80}{15} (2.75) = 15.00\]

Plumbing 2 men 3 days

\[2(3)(8)(2.75) = 132.00\]

Windows 23 windows type Ah642414

23 @ $35.00 per window = 805.00

Labor 1 man hangs 200 sq. ft. of window per day

\[\frac{23(48)}{200} = 5.52 \text{ days or 6 days}\]

\[6(8)(2.75) = 132.00\]

Doors tin clad fire doors and 4 ft. by 8 ft. units

a. Fire doors 2(10.67)(12.33) = 26\frac{1}{4} \text{ sq. ft.} @ $2.25 per sq. ft. = 594.00

b. 4 ft. by 8 ft. units 3 units @ $65 per unit = 195.00
Hardware

a. Fire doors = $63.00
b. Steel doors = 129.00

Labor 1 man hangs 4 feet of track in 8 hours

a. $2.5(8)(2.75)(2) = 110.00$

b. 1 man hangs 1 unit per day

$3(8)(2.75) = 66.00$

Wiring = 2500.00

Girders for roof

1/4 in. 30 pound girders
2 girders 59 feet long

$2(59)(30) = 3540$ pounds

$\frac{3540}{2000} = 1.77 \text{ T. @} $220 \text{ per T.} = 389.00$

Labor 1.77 T. @ $50 \text{ per T.} = 89.00$

Material and labor 32885.00
Overhead (20 percent) 6577.00
Profit (15 percent) 5919.00

$45381.00$

or $45500.00$
Boiler building

Boiler dimensions 22 ft. long, 9 ft. wide, 10 ft. high

Softener 60 in. by 108 in.

Building size 36 ft. by 24 ft. by 14 ft. high

8 in. reinforced floor

Foundation excavation

\[
(36)(6)(2) = 432 \text{ cu. ft.} \\
(24)(6)(2) = 288 \text{ cu. ft.} \\
\frac{720}{27} = 27 \text{ cu. yd.}
\]

Labor \( \frac{27}{\frac{7}{5}} = 54 \text{ hrs.} \)

Shoveling \( .9(14) = 13 \text{ hrs.} \)

Backfilling \( .617(13) = 8 \text{ hrs.} \)

Total hrs. = 75 hrs.

Forms \( (60)(5)(2) = 600 \text{ sq. ft.} \)

3 bd. ft. per sq. ft. of form (used twice)

\( 600(3) = 1800 \text{ bd. ft.} \)

Lumber \( .9(158) = 142.00 \)

Wire and nails \( 600(.01) = 6.00 \)

Form labor 5.1 carpenter hours of 100 sq. ft. of form

\( 5.1(6)(2.25) = 69.00 \)

Materials foundation

\( (60)(5)(1.33) = 400 \text{ cu. ft.} \)

\( (60)(1.33)(2.67) = 213 \text{ cu. ft.} \)

\( \frac{1192}{27} = 44 \text{ cu. yd.} \)
Floor 8 in. concrete

\[(2\frac{1}{4})(36)(0.67) = \frac{579}{1192} \text{ cu. ft.}\]

Use 6-3 l bag mixer, crew of 13, 1 foreman

2.5 hours of labor per cu. yd.

\[2.5(\text{hr}) = 110(1.25) = 116 = 138.00\]

\[7(\text{hr}) = 21.00\]

Materials

Cement \[7.2(\text{hr})(1.15) = 365.00\]

Sand \[0.5(\text{hr})(27)(165.5) = (50)(2.35) = 118.00\]

Gravel \[0.73(\text{hr})(27)(165.5) = (62)(2.25) = 162.00\]

Reinforcing 6 in. by 6 in. No. 6 mesh

\[9 \text{ sq. @ 5.00 per sq. } (9)(5) = 45.00\]

Wall material

2 6 ft. by 6 ft. windows = 72 sq. ft.
1 10 ft. by 12 ft. door = 120 sq. ft.

Wall area

\[(2\frac{1}{4})(16) = 381 \text{ sq. ft.}\]
\[(36)(16) = 576 \text{ sq. ft.}\]
\[960 \text{ sq. ft.}\]

Wall openings 172 sq. ft.
\[768 \text{ sq. ft. net wall area}\]

Corner block

\[2(16)(12) \div (8) = 48\]
Jamb block

\[
\begin{align*}
(2)(2)(6)(12) \div (8) = 36 & \quad \text{Full length jamb} \\
2(12)(12) \div (8) = 36 & \quad \text{Half length jamb} \\
\frac{2(12)}{72} & \quad \text{Half length regular}
\end{align*}
\]

Regular block

\[
\frac{768 \times 144}{128} = \frac{\sqrt{18} + 36 + \frac{36}{2}}{2} = 744
\]

\[
\begin{align*}
48(.31) &= 15.00 \\
36(.31) &= 11.00 \\
36(.16) &= 6.00 \\
36(.15) &= 5.00 \\
744(30) &= 223.00
\end{align*}
\]

Angles for lintels

\[
(30)(19 \text{ lb. per ft.})(11) = 63.00
\]

Mortar 3 pt. sand, 1 pt. cement

\[
\begin{align*}
600 \text{ lb. per 100 block} & \quad 852 \text{ total block} \\
\text{Sand} & \quad \frac{8.52(600)}{2000} = \frac{36(2.35)}{} = 5.00 \\
\text{Cement} & \quad \frac{1/3(2)(2000)}{94} = \frac{1320}{94} = 14(1.15) = 16.00
\end{align*}
\]

Labor for walls 1 mason and 1 helper lay 115 block per day

\[
\begin{align*}
\frac{852}{115} = 7.4 & \quad 7.4(8)(3.15) = 148.00 \\
7.4(8)(1.25) = 74.00
\end{align*}
\]

Cleaning mason 2.6(8.52)(3.15) = 70.00

Painting mason 3.3(8.52)(3.15) = 89.00

Helper 3.3(8.52)(1.25) = 35.00

Roof 14 in. open steel truss 250 lbs. per joist 4 ft. o.c.

10 joists

\[
\begin{align*}
250(10) = 2500 \text{ lbs.} & \quad \frac{2500}{2000} = 1.25(190) = 238.00
\end{align*}
\]
Roof deck steel (18 ga.) with insulation

\[(24)(36)(.40) = \$ 346.00\]

Roofing 3 plies felt and asphalt

Felt \[32\frac{1}{4}(9) = \frac{30}{4} \text{ sq.} = 7.25 \text{ or } 8(3.5) = 28.00\]

Asphalt \[3(30)(9) + 1(65)(9) = .67(50) = 34.00\]

Gravel \[400(9) = 3600 \text{ or } 2 \text{ T.(2.25)} = 5.00\]

Labor for roof

Joists 2500 lbs. = 1.25T.(50) = 63.00

Roof Deck 9 sq.(11) = 99.00

Roofing 9 sq., 5 men, .67 days

\[3(.67)(2.75)(8) = \$44.00\]

\[2(.67)(1.25)(8) = 13.00\]

Windows 2 6 ft. by 6 ft. windows @ 23.30 = 47.00

Labor 1 man sets 200 sq. ft. per day

\[\frac{72}{200} = .36(8)(.275) = 8.00\]

Doors 1 tin clad fire door 132 sq. ft. @ 2.25 per sq.ft.

a. \[132(2.25) = 297.00\]

b. One 4 ft. by 8 ft. steel door = 65.00

Hardware

a. Fire door = 63.00

b. Steel door = 65.00
Labor 1 man hangs 4 ft. of door in 8 hrs.

\[ \frac{10}{4} = 2.5(8)(2.75) = \quad \$\ 55.00 \]

1 man hangs one 4 ft. by 8 ft. door in 1 day

\[ 2.75(8) = \quad 20.00 \]

Total materials and labor $3053.00
Overhead (20\%) 610.00
Profit (15\%) 550.00

$4213.00
# APPENDIX B

## PLANT III. EQUIPMENT REQUIREMENTS

### Plant III. Equipment

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryer--650 pounds per hour--Buflovak</td>
<td>$36,650.00</td>
</tr>
<tr>
<td>Evaporator--No. 55 Henzey (double effect)</td>
<td>26,000.00</td>
</tr>
<tr>
<td>Pre-heater--16 x 1.5 x 12 Henzey</td>
<td>4,500.00</td>
</tr>
<tr>
<td>Hi Concentrate Pre-heater--No. 21 Buflovak</td>
<td>2,500.00</td>
</tr>
<tr>
<td>Hotwell--4 x 4 Rogers</td>
<td>13,42.00</td>
</tr>
<tr>
<td>Milk Pump--Tri-Clover</td>
<td>75.00</td>
</tr>
<tr>
<td>Scale--250 pound portable--Toledo</td>
<td>550.00</td>
</tr>
<tr>
<td>Shaker</td>
<td>100.00</td>
</tr>
<tr>
<td>Propane gas equipment</td>
<td>2,000.00</td>
</tr>
</tbody>
</table>

**Total equipment investment** $73,717.00

### Boiler equipment

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler and burner--217 HP. (installed)</td>
<td>$19,400.00</td>
</tr>
<tr>
<td>Water softener</td>
<td>4,500.00</td>
</tr>
</tbody>
</table>

**Total boiler investment** $23,900.00

### Storage equipment

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fork lift truck</td>
<td>$2,850.00</td>
</tr>
<tr>
<td>Pallets</td>
<td>3,125.00</td>
</tr>
</tbody>
</table>

**Total storage investment** $5,975.00

### Drying building

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying building</td>
<td>$30,000.00</td>
</tr>
</tbody>
</table>

**Total building investment** $34,200.00

### Total plant investment

**Total plant investment** $137,800.00
APPENDIX C

PLANT III. HOURS OF OPERATION AND WATER CONSUMPTION FOR EVAPORATION (DOUBLE EFFECT EVAPORATOR)

<table>
<thead>
<tr>
<th>Month</th>
<th>Hrs. per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>310</td>
</tr>
<tr>
<td>February</td>
<td>280</td>
</tr>
<tr>
<td>March</td>
<td>372</td>
</tr>
<tr>
<td>April</td>
<td>385</td>
</tr>
<tr>
<td>May</td>
<td>460</td>
</tr>
<tr>
<td>June</td>
<td>472</td>
</tr>
<tr>
<td>July</td>
<td>460</td>
</tr>
<tr>
<td>August</td>
<td>398</td>
</tr>
<tr>
<td>September</td>
<td>348</td>
</tr>
<tr>
<td>October</td>
<td>330</td>
</tr>
<tr>
<td>November</td>
<td>278</td>
</tr>
<tr>
<td>December</td>
<td>288</td>
</tr>
</tbody>
</table>

4,381 hrs. per year

7738 - 1625 = 6113 lbs. of vapor condensed per hour

6113(20.71) = 126,784 lbs. H₂O used per hour

126784(4381) = 55540704 lbs. H₂O

\[
\frac{55540704}{62.5} = \frac{8887051}{2} = 4,434,352
\]

cu. ft. of water
APPENDIX D

PRICES AND RATES APPLIED TO MODEL PLANTS

Building

Building materials prices were obtained from suppliers and handlers.

Construction labor requirements were obtained from Walkers The Building Estimator's Reference book.

Labor rates are Des Moines union scale for journeyman and common labor.

Depreciation and maintenance rate—5 percent of initial investment.

Interest—5 percent of average investment.

Taxes—30 mills per dollar of average investment obtained from Bul. 389, Iowa Agricultural Experiment Station. 1952.

Insurance rate—Eighty percent co-insurance $1.35 per $100 valuation and $.096 per $100 valuation for extended coverage. Insurance rates obtained from the Iowa Inspection Bureau.

Equipment

Equipment prices, freight and installation charges were obtained from equipment manufacturers and handlers.

Depreciation and obsolescence—10 percent of the investment.

Interest—5 percent of the average investment.

Taxes—30 mills per dollar of average investment.

Insurance rate—Eighty percent co-insurance $1.45 per $100 valuation, and $.096 per $100 valuation for extended coverage.
Boiler

Boiler and softener prices were obtained from handlers.

Building costs, depreciation, and tax rates are the same as for the remainder of the equipment.

The insurance rate on boiler and softener is $.625 per $100 valuation and extended coverage rate of $.062 per $100 valuation.

Boiler efficiency for automatic oil fired boilers obtained from boiler handlers and Professor H. M. Black of the Mechanical Engineering Department of Iowa State College.

Fuel

Heat content of liquid propane--21,300 B.T.U. per pound, obtained from Farrel--Dairy Engineering.

Heat content of mid-continent fuel oil, 19,000 B.T.U. per gallon, obtained from Handbook of Chemistry and Physics.

Fuel prices, $.11 per gallon of propane and $.13 per gallon of fuel oil were obtained from gas and oil suppliers.

Electricity

Motor efficiency obtained from Nilson of the Electrical Engineering Department of Iowa State College.

The price of electricity, 3.2 cents per K.W.H., is an average price of several processing plants observed in this study and in previous studies.

Plant labor

Operators--$1.50 per hour
Helpers--$1.25 per hour
Managerial charge--$1500.00 per year
Plant Superintendent (½ time)--$2250.00 per year

Water

$.10 per 100 cu. ft.
Sewage

$.06 per 100 cu. ft. of water discharged into the sewage system

These rates were obtained from municipalities selling water to milk plants.

Supplies

Organic acid--$2.94 per gallon
Alkali cleaner--$.162 per pound
Salt--$.01 per pound delivered

These prices were obtained from plants and individuals using these products.
APPENDIX E

PLANT III. INPUT COSTS

Input costs 650 pound dryer 2,817,600 pounds of powder per year.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per cwt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>$ .12</td>
</tr>
<tr>
<td>Equipment</td>
<td>$.46</td>
</tr>
<tr>
<td>Insurance</td>
<td>$.06</td>
</tr>
<tr>
<td>Taxes</td>
<td>$.06</td>
</tr>
<tr>
<td>Boiler</td>
<td>.15 (includes building, softener, boiler, burner, insurance and taxes)</td>
</tr>
<tr>
<td>Labor</td>
<td>.51</td>
</tr>
<tr>
<td>Packaging</td>
<td>1.36</td>
</tr>
<tr>
<td>Electricity</td>
<td>.22</td>
</tr>
<tr>
<td>Fuel</td>
<td>1.11</td>
</tr>
<tr>
<td>Water and sewage</td>
<td>.18</td>
</tr>
<tr>
<td>Supplies</td>
<td>.16</td>
</tr>
<tr>
<td>Clerical</td>
<td>.04</td>
</tr>
<tr>
<td>Quality control</td>
<td>(less than 1¢ per cwt.)</td>
</tr>
<tr>
<td>Selling costs</td>
<td>.76</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$ 5.21</strong></td>
</tr>
</tbody>
</table>

Calculation of individual input costs of Plant III.

Building:

Depreciation and maintenance \( \frac{45500(.05)}{2} = \) $ 2275.00

Interest \( \frac{45500}{2} (.05) = \) $ 1136.00

\( \frac{3413}{28176} = \$ .12 \) per hundredweight
Equipment

Depreciation 73717(.10) = $7372.00
Maintenance 73717(.05) = 1813.00
Interest $\frac{73717}{2}(.05) =$ 3686.00

\frac{12901}{28176} = $.46 per hundredweight

Insurance

Building 455.00(1.35) = $611.00
Contents 737.17(1.45) = 1069.00
Extended Coverage 1192.00(.096) = 114.00

\frac{1797}{28176} = $.06 per hundredweight

Taxes

\frac{1192}{2} (30) = 1788  \quad  \frac{1788}{28176} = $.06 per hundredweight

Labor

Plant labor = $10568.00
Plant superintendent = 2250.00
Manager = 1500.00
Workmen compensation = 133.00
Payroll tax = 329.00

\frac{14780}{28176} = $.52 per hundredweight

Packaging $1.36 per hundredweight
Electricity

Dryer 4.0 HP.
Take off pump 2.
Milk pump 1.
Pan pump 1.0
Turbine pump 7.5
Shaker 0.5

(1 HP. 1/3 time) 52.0

\[
\frac{7h6(52)(4381)}{2} = 28176 = 7(3.2) = 0.22 \text{ per hundredweight}
\]

Water

Evaporation \(1,443,526 \text{ cu. ft.}\)
Cleaning \(120,500 \text{ cu. ft.}\)
Boiler \(1,232,212 \text{ cu. ft.}\)

\(4,987,238 \text{ cu. ft.} @ 0.10 \text{ per 100 cu. ft.}\)

\(4,987,238(0.10) = 498.700\)

Sewage \(120,500(0.06) = 72.00\)

\(5059 \cdot 28176 = 0.18 \text{ per hundredweight}\)

Supplies

730 gal. of acid per year \(2.94 \text{ per gallon} = 2146.00\)
9125 lbs. alkali per year \(18.2 \text{ per pound} = 166.00\)
75000 lbs salt @ \$.01 per pound = 750.00

\(4557 \cdot 28176 = 0.16 \text{ per hundredweight}\)

Clerical \(\frac{1}{2} \text{ time bookkeeper}\)

\(1040 \cdot 28176 = 0.04 \text{ per hundredweight}\)
Quality control

\[
\frac{132}{28176} \leq 0.01 \text{ per hundredweight}
\]

Boiler cost

- Building = \$4000.00
- Boiler = \$17517.00
- Depreciation and maintenance = \$200.00
- Interest = \$100.00

Boiler and softener

- Depreciation = \$2162.00
- Maintenance = \$1081.00
- Interest = \$540.00

Insurance

- Building = \$54.00
- Contents = \$114.00
- Extended coverage = \$11.00

Taxes

\[
\frac{26517}{2}(30) = \frac{4292}{28176} = 0.15 \text{ per hundredweight}
\]

Fuel requirements (650 pound dryer produces 650 pounds per hour)
Evaporation

\[ 7738(0.93^a)(125 - 50) = 539,700 \text{ B.T.U.} \]
\[ 6113(1022) = 6,247,486 \text{ B.T.U.} \]
\[ 6113(52) = 317,876 \text{ B.T.U.} \]

Evaporator is \( 7,105,062 \text{ B.T.U.} \)
90 percent efficient \( 710,506 \text{ B.T.U.} \)

\[ \frac{7815568}{2} = 3907784 \text{ B.T.U.} \text{ needed for evaporation} \]

Drying \( \frac{650}{60}(830)(60) = 539500 \text{ cu. ft. of air per hour} \)

\[ 539500(0.0506) = 27245 \text{ pounds per hour} \]

Input

\[ (27245)(0.243^b)(325 - 180) = 959,900 \text{ B.T.U.} \]
\[ (15)(0.85)(2515) = 32,449 \text{ B.T.U.} \]
\[ \frac{1}{8}(0.85)(2515) = 1,082 \text{ B.T.U.} \]
\[ 2000(0.7632^c)(190 - 125) = 80,600 \text{ B.T.U.} \]

Total = \( 1,071,031 \text{ B.T.U.} \)

Output

\[ 975(212 - 190) = 21,450 \text{ B.T.U.} \]
\[ 975(970.4^d) = 946,140 \text{ B.T.U.} \]
\[ 650(0.4381^e)(190 - 130) = 17,100 \text{ B.T.U.} \]
\[ 1200(\frac{3}{12})(0.04^f)(330 - 130) = 12,000 \text{ B.T.U.} \]
\[ 333(\frac{125}{12})(25^g)(180 - 130) = 1,041,040 \text{ B.T.U.} \]

\( ^a \) Specific heat of skimmilk
\( ^b \) Specific heat of air
\( ^c \) Specific heat of 40 percent solids skimmilk
\( ^d \) Latent heat of vaporization of water at 212° F.
\( ^e \) Specific heat of skimmilk powder
\( ^f \) Conductivity factor for rock wool insulation
\( ^g \) Conductivity factor for stainless steel
Heat losses

Walls = 20,592 B.T.U.
Windows = 166,153 B.T.U.
Doors = 2,060 B.T.U.
Total 188,805 B.T.U.

Heat exhausted into surrounding air

2724.5 pounds of air per hour
2724.5(0.243)(180 - 50°F) = 860,730 B.T.U. per hour

Total heat required for drying

Dryer = 1,074,031 B.T.U.
Heat losses from building = 188,805 B.T.U.
Heat lost in exhaust = 860,730 B.T.U.
Total 2,135,666 B.T.U. per hour

2,123,566 = 100 lbs. of propane

Cost of fuel for drying

\[ \frac{100}{4.24^\circ} = 24 \text{ gallons} @ \$1.1 \text{ per gallon} = \$2.64 \text{ per hour} \]

Cost of fuel for evaporation

\[ \frac{3907.78\text{ B.T.U.}}{1900^\circ} = 257.5 \text{ pounds of oil} \]

\[ \frac{257.5}{7.128^\circ} = 35 \text{ gallons} @ \$1.13 \text{ per gallon} = 4.55 \text{ per hour} \]

---

aAnnual mean temperature of Iowa
bHeat content of one pound of propane gas
cWeight of one gallon of propane gas
dThermal efficiency of boiler
eHeat content of one pound of fuel oil
fWeight of one gallon of fuel oil
Fuel cost per pound of powder

650 pounds of powder produced per hour

\[ 264 + 4.55 = 7.19 \]

\[ \frac{7.19}{6.5} = 1.11 \text{ per hundred pounds of powder produced} \]

Boiler requirement

\[ \frac{3884730}{33179^a} = 146 \text{ horsepower} \]

\(^a\text{B.T.U. generated per hour per boiler horsepower}\)
Storage and selling costs

Equipment

Pallets will be required for two months production. Each pallet is large enough to hold four barrels.

Cost per pallet

5 ft. by 5 ft. pallets
1 in. by 4 in. face and back lumber 67 percent of pallet area covered
3 2 in. by 4 in. centers

Board feet required

\[
\sqrt{(5)(5)(2/3)} \cdot \sqrt{((2/3)(5)(3)^2} = 43 \text{ bd. ft. per pallet}
\]

Lumber cost @ $100 per M.

\[
.043(100) = 4.30
\]

Nails 1¢ per board feet of lumber in pallet face and back

\[
33(.01) = .33
\]

Pallet cost $4.63 per pallet

Pallet cost per hundredweight

Two months production in the peak season = 564,000 pounds

\[
\frac{564,000}{220} = 2564 \text{ barrels}
\]

\[
\frac{2564}{4} = 641 \text{ pallets}
\]

641(4.63) = $2968.00 total pallet investment
Depreciation 2968.00 (.20) = $594.00
Maintenance 2968.00 (.05) = 148.00
Interest 2968.00 (.05) = 74.00

$816.00

Fork lift truck

Stand up lift truck 1 Ton capacity
12 ft. high lift
Initial cost $2850.00
Estimated life 5 years

Depreciation 2850.00 (.20) = $570.00
Maintenance 2850.00 (.05) = 143.00
Interest \[\frac{2850.00}{2} (.05) = 72.00\]

Annual cost of lift truck = $785.00

\[\frac{785}{28176} = .03 \text{ per hundredweight}\]

Insurance cost

Fork lift truck $2850.00
Pallets 2968.00
Powder in storage 76258.00

$76258.00

$76258(1.45) = $1106.00 annual insurance cost

\[\frac{1106}{28176} = .04 \text{ per hundredweight}\]

Taxes cost

$76258.00 invested in equipment and product

\[\frac{76258.00}{2} (30) = 1144.00 \text{ annual tax cost}\]

\[\frac{1144}{28176} = .04 \text{ per hundredweight}\]
Financing Cost

Powder is usually in storage two months before payment is received. A bank loan equal in value to an average two months production will be required throughout the year to provide working capital.

Average two months production in Plant III 469,000 pounds

\[ 469,600(\$0.15) = \$70,440.00 \]

\[ 70,440(0.035) = \$2,465.00 \]

\[ \frac{2465.00}{28176} = \$0.09 \text{ per hundredweight} \]

Lumber cost

One carload contains 41,000 pounds or 200 barrels of powder. One half of cars shipped out will require 67 board feet of bracing lumber @ \$0.10 per board foot.

\[ \frac{67}{2}(\$0.10) = \$3.35 \]

All cars will require 142 board feet of lumber for spacing between barrels and for door bracing.

\[ 142(\$0.10) = \$14.20 \]

Total lumber cost per car = \$17.55

\[ \frac{18}{440} = \$0.04 \text{ per hundredweight} \]
Labor cost

Load 200 barrels per car

Tying and stenciling barrels (2 men 2 hours each)
Loading and bracing (2 men 2 hours each)

2 men 4 hours each @ $1.88 per hour = $15.04

\[ \frac{15}{100} = .04 \]

Total storage and selling cost per hundredweight $ .80
APPENDIX F

WORK SCHEDULES FOR MODEL PLANTS

Plant I. Annual Production 938,200 Pounds of Powder

June  Operation and cleaning time 12 hours 15 minutes per day
      Operation time 6 hours 15 minutes, cleaning time 6 hours

<table>
<thead>
<tr>
<th>Men</th>
<th>S</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>Hours worked per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>12:15</td>
<td>12:15</td>
<td>12:15</td>
<td>6:10</td>
<td></td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>2.</td>
<td>6:10</td>
<td>12:15</td>
<td>12:15</td>
<td>12:15</td>
<td></td>
<td></td>
<td></td>
<td>43</td>
</tr>
</tbody>
</table>

May  Operation and cleaning time 11 hours 40 minutes per day

<table>
<thead>
<tr>
<th>Men</th>
<th>S</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>Hours worked per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>11:40</td>
<td>11:40</td>
<td>11:40</td>
<td>5:50</td>
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<td></td>
<td></td>
<td>41</td>
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<tr>
<td>2.</td>
<td>5:50</td>
<td>11:40</td>
<td>11:40</td>
<td>11:40</td>
<td></td>
<td></td>
<td></td>
<td>41</td>
</tr>
</tbody>
</table>

July  Operation and cleaning time is the same as for May, the labor scheduling is the same as the May schedule.
      During the remainder of the year two men operate the drying section with no overtime.
Total labor requirements and costs

Two men, 52 weeks @ $1.50 per hour or $60 per week = $6240.00

Overtime
- June 6 hrs. per week
- July 2 hrs. per week
- May 2 hrs. per week

10 hrs. for 4.33 weeks (average number of weeks per month) at $2.25 per hour.

10(4.33)(2.25) = 197.00

Total operation labor = $6337.00
Managerial charge = 1500.00
Plant superintendent (½ time) = 2250.00
Plant labor expense = $10087.00
Workmen's compensation = 94.00
Payroll tax = 232.00
Total labor expense = $10413.00
Plant II. Annual Production 1,875,600 Pounds of Powder

June Operation and cleaning time 18 hours 20 minutes.

Operation time 12 hours 20 minutes, cleaning time 6 hours.

<table>
<thead>
<tr>
<th>Men</th>
<th>S</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>Hours worked per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>9:10</td>
<td>9:10</td>
<td>9:10</td>
<td>9:10</td>
<td>6:10</td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>2.</td>
<td>9:10</td>
<td></td>
<td>9:10</td>
<td>9:10</td>
<td>6:10</td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>9:10</td>
<td>9:10</td>
<td>9:10</td>
<td>6:10</td>
<td></td>
<td></td>
<td>43</td>
</tr>
</tbody>
</table>

May and July Operation time 11 hours 15 minutes cleaning time 6 hours

<table>
<thead>
<tr>
<th>Men</th>
<th>S</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>Hours worked per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>8:40</td>
<td>8:40</td>
<td>8:40</td>
<td></td>
<td>5:45</td>
<td></td>
<td>40:30</td>
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</tbody>
</table>

The labor schedule remains the same throughout the remainder of the year, except for fluctuations in weekly hours worked. There is no overtime throughout the remainder of the year.

Labor requirements

- Plant labor $3(60)(52) = $9360.00
- Overtime $13(4.33)(2.25) = 127.00
- Manager = 1500.00
- Plant superintendent ($\frac{1}{2}$ time) = 2250.00
- Workmen's compensation insurance = 123.00
- Payroll tax 2.3 percent = 304.00

Total labor cost $13664.00
Plant III. Annual Production 2,817,600 Pounds of Powder

June
Operation and cleaning time 22 hours per day
Operation time 16 hours, cleaning time 6 hours

<table>
<thead>
<tr>
<th>Men</th>
<th>S</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>Hours worked per week</th>
</tr>
</thead>
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</table>

May and July
Operation time 15 hours per day, cleaning time 6 hours per day

<table>
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<td>49</td>
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</tbody>
</table>

April and August
Operation time 12.83 hours per day, cleaning time 6 hours per day

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<th>S</th>
<th>Hours worked per week</th>
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</thead>
</table>
March and September

Operation time 12 hours per day, cleaning time 6 hours per day

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<thead>
<tr>
<th>Men</th>
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</table>

During the remainder of the year no worker works more than 40 hours per week.

Total labor requirements and costs:

Three men 52 weeks @ $1.50 per hour or $60.00 per week = $9360.00

Overtime
- June 3 1/4 hrs. per week
- July 27 hrs. per week
- May 27 hrs. per week
- Apr. 12 hrs. per week
- Aug. 12 hrs. per week
- March 6 hrs. per week
- Sept. 6 hrs. per week

121/4 hrs. for 4.33 weeks (average number of weeks per month) at $2.25

\[
12\frac{1}{4}(4.33)(2.25) = 1208.00
\]

Total operation labor = $10568.00

Plant superintendent (1/2 time) = 2250.00

Managerial charge = 1500.00

Plant labor expense = $11318.00

Workmen's compensation = 133.00

Payroll tax = 329.00

Total labor cost = $11780.00
Plant IV. Annual Production 3,767,500 Pounds of Powder

June  Operation and cleaning time 20 hours

Operation time 17 hours, cleaning time 2 men 3 hours each
Three shifts of two men each

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</table>

March, April, May, July and August have the same organization as June (3 shifts of 2 men); the hours worked per week will fluctuate as seasonal production fluctuates.
September

Operation and cleaning time 15 hours 20 minutes

Operation time 9 hours 20 minutes, cleaning time 6 hours

Two shifts of two men and one relief man

<table>
<thead>
<tr>
<th>Men</th>
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<td>43</td>
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</tbody>
</table>

October, November, December, January and February have the same organization as September (two shifts of two men each and one relief man); the hours worked per week will fluctuate as production fluctuates seasonally.

Labor requirements and costs

Plant labor 3 operators @ $1.50 per hour

\[ 3 \times (40 \times 1.50) \times 52 = \] $9360.00

2 helpers @ $1.25 per hour

\[ 2 \times (40 \times 1.25) \times 52 = \] $5200.00

1 helper @ $1.25 per hour

\[ 1 \times (40 \times 1.25) \times 26 = \] $1300.00
<table>
<thead>
<tr>
<th></th>
<th>Overtime</th>
<th>Operators</th>
<th>Helpers</th>
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<tbody>
<tr>
<td>January</td>
<td>17.33 hrs</td>
<td>8.67 hrs</td>
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<tr>
<td>February</td>
<td>17.33 hrs</td>
<td>8.67 hrs</td>
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<td>March</td>
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<tr>
<td>August</td>
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<tr>
<td>September</td>
<td>39.00 hrs</td>
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<td>November</td>
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<td>December</td>
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<table>
<thead>
<tr>
<th></th>
<th>Total hrs. overtime</th>
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<tbody>
<tr>
<td>Operators</td>
<td>223.67(2.25) =</td>
<td>$ 503.00</td>
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<tr>
<td>Helpers</td>
<td>193.33(1.88) =</td>
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</tbody>
</table>

Managerial charge = 1500.00
Plant superintendent = 2250.00
Workmen's compensation $.93 per $100 payroll = 190.00
Payroll tax = 471.00
Total labor cost = $21137.00