SPRAY DRYING COSTS IN
LOW-VOLUME MILK PLANTS

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Spray Drying Costs in Low-Volume Milk Plants[1]

BY LEE KOLMER, HENRY A. HOMME AND GEORGE W. LADD

Since World War II several developments have given impetus to a shift from marketing farm-separated cream to marketing whole milk. The increased consumer demand for nonfat dry milk, the government price-support program, the introduction of drying equipment small enough to make drying feasible for small plants, and farmers preferences have all had a share in inducing plants to shift from a butter manufacturing operation to a butter-powder operation.

Before the management of any plant can determine its most profitable product and direct its investment funds accordingly, it must have a method of determining which alternative product will give the greatest long-run return. A scientific analysis of the costs and returns of the possible alternatives will provide information which can be used as a guide in the decision-making process.

The specific objective of this study is to provide information by analyzing the cost-volume relationship involved in a spray-drying operation at six different volumes of production. Such information is especially needed for plants at the lower end of the volume range where unit costs are relatively high and where little information concerning the cost and volume relationship is available. Previous studies by Walker *et al.* (16), Butz and Koller (2) and Juers and Koller (10) have dealt with larger volume plants. This study also provides a budgeting technique which can be used by a plant to determine its individual input costs.

METHOD

The method of analysis used to determine the cost-volume relationship was dictated by the purpose of the analysis and the empirical information available. Since the purpose of this study is to provide information to aid managers in planning for future periods, it is necessary that the latest accepted technology be used in the plants and that factor pricing be realistic. To make prices of inputs realistic, it was assumed that new equipment and building were required, and current prices were applied to all inputs.[2]

The engineering method was used to determine inputs. The engineering method is a system of cost determination in which the physical amounts of 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 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.

Information from these sources is used to construct formulas and standards for the determination of the quantity of physical inputs required to produce a given quantity of output. These derived physical inputs are used in combinations which would be feasible in an actual plant. These are referred to as model plants, and the inputs are combined in a model plant in a manner which would achieve the lowest cost obtainable under the conditions imposed. Current prices obtained from manufacturers and suppliers are then applied to the individual inputs of each model plant to obtain costs. By applying the same prices for inputs in all plants, it is possible to determine how variations in quantity of output affect costs. The costs thus obtained in this study were checked when possible by observing plants in operation.

CONDITIONS

The following conditions were imposed in the construction of the nonfat dry milk processing section of a plant:

1. The latest techniques and equipment upon which performance data are available are used in all plants.

2. The equipment and labor organization is the optimum arrived at by a series of trial budgets. It is based on 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 a smaller equipment investment and provides more flexibility of labor organization.

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

1 Project 1169 of the Iowa Agricultural Experiment Station. Acknowledgments are due to Geoffrey Shepherd, V. H. Nielsen and the milk plants cooperating in the study.

2 Because of the many sources used to procure technical data for the analysis it is impractical to list all references; however, the major sources of information are listed in the citations of literature.

5. The yield of nonfat dry milk from 100 pounds of skimmilk is estimated at 8.6 pounds (8, page 425).

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

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

a. Flavor and odor (applies equally to the reliquified form): sweet, and has not more than slight cooked flavors and odors.
b. Physical appearances: white or light cream color; free from lumps that do not break up under slight pressure; and practically free from brown and black scorched particles.
c. Butterfat content: not more than 1.25 percent.
d. Moisture content: not more than 4 percent.[3]
e. Titratable acidity: not greater than 0.15 percent.[4]
f. Solubility index: not greater than 1.25 ml.[5]
g. Bacterial estimate: not greater than 50,000 per gm.
h. Scorched particle content: not more than 15.00 mg.

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

	Production (percent of annual production)	Butterfat content (percent)
January	7	3.7
February	7	3.7
March	8.5	3.7
April	9	3.6
May	10	3.5
June	11	3.5
July	10	3.5
August	9	3.5
September	8	3.6
October	7.5	3.6
November	6.5	3.7
December	6.5	3.7

The production variation is the approximate annual production fluctuation for Iowa in the years 1950 through 1952 (9).

9. A price of 15.85 cents per pound is used as the output price. This price is based on the present support price of 16 cents per pound for extra grade nonfat dry milk with a 5-percent allowance for rejected nonfat dry milk which will move into commercial channels as standard grade at a price of 13 cents per pound.

DETERMINATION OF INPUTS

BUILDING

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

With these criteria as guides, the following materials were chosen: Floors and foundation are concrete—except that the floor in the processing room is covered with red floor brick because of its greater durability and sanitation. The wall material is concrete block, struck flush on the inside and pointed on the outside. The interior of the processing room is faced with 1¾-inch glazed tile for sanitation, reduced cleaning time and lower maintenance cost.

The roof is constructed of open-truss steel joists topped with insulated metal roof deck and built-up roofing. No ceiling is provided in any plant. 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 construction uses. Aluminum panels do, however, offer a distinct advantage in maintenance cost and in lowered cost of expansion because of their high re-use rate (13).

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 minimize building costs. The equipment was positioned to eliminate undue crowding and still use space efficiently. The window area of the drying section is approximately 20 percent of the floor area, and the natural light is supplemented by artificial light throughout.

The basic construction of the storage area is 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.) metal-sheathed fire doors have been installed in each area to provide openings large enough to move processing equipment in and out in case of extensive repair or replacement. The Appendix shows the floor plan for one of the model plants.

The quantities of materials and labor used for each building were determined by using builders' handbooks (13, 14 and 15) and estimating the quantities required for each part of the building.

Plant operators can determine building costs for their particular situation by obtaining estimates of costs from contractors for structures designed to meet their specifications.

EQUIPMENT

The dryer, the size of which is determined by plant volume, is the key piece of the equipment combination. The dryer capacity (at a specific solids content of the fluid skimmilk) is determined by evaporator size, heater size, boiler size and water softener size. Even though equipment is selected that will provide minimum cost at a certain volume, unused capacity may exist in a plant because the equipment is not in operation 24 hours per day. However, this unused capacity exists in all pieces of equipment in the combination, and the volume of the plant can increase without changes in the equipment combination.

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

4 Determination made upon reliquified sample.

5 See footnote 4.

Selection of the specific pieces of equipment used in the combination was based on the following factors: (a) sanitation and quality requirements, (b) operating efficiency, (c) space requirements, (d) operating cost, (e) initial cost and (f) future expansion.

Plant operators may obtain information from manufacturers concerning costs of various sizes of equipment combinations designed to meet their particular needs. Equipment manufacturers can also provide information about steam, fuel and water requirements for their equipment.

FUEL AND BOILER

The 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.

The propane gas uses a direct method of heating rather than steam coils because of its higher heat transfer efficiency, lower initial dryer cost and lower boiler requirements. Oil was selected for heating and evaporation. Coal is more economical as a source of heat; however, oil is cleaner and a greater degree of automatic control is possible with it. 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 is all that is required. This results in a lower building cost.

The burner chosen for installation on the boiler is a gas-oil combination burner. This gives the plant a standby source of fuel in case of emergencies. It also allows 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 evapotion and heating,

33,479 = b.t.u. developed by 1 boiler horsepower in 1 hour, and

0.8 = thermal efficiency of automatic oil-fired boilers.

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

A water softener was installed in each plant to reduce the encrustation of boiler tubes from the use of hard water and the resultant loss of efficiency. While it is possible to reduce water hardness by direct water treatment in the boiler, this method is not as effective as a softening unit and requires periodic shutdowns to clean sludge from the boiler.

Fuel requirements for drying were determined by using the heat balance system given by Farrall (5, page 334-335). In this method, b.t.u. inputs from fuel balance the b.t.u. requirements for converting fluid milk to nonfat dry milk, after adjustments are made for heat losses. Radiation losses from the building and temperature differences between the exhaust air and the surrounding intake air are included in the heat requirements. The b.t.u. requirements thus obtained were converted to gallons of propane gas. The conversion factors used were 21,600 b.t.u. per pound of liquid propane (5, page 127) and 4.244 pounds per gallon of propane gas. If natural gas is used, the conversion factor is 1,000 b.t.u. per cubic foot of Texas gas.

Fuel requirements for evaporation and heating were computed in the same manner. Here, 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 (3, page 1,429).

LABOR

The labor required for the drying operation varies as equipment size and volume vary. It does not, however, vary proportionally but increases in discrete steps as dryer capacity or volume passes certain magnitudes.

With any dryer, the operating labor cost per hundredweight of nonfat dry milk declines as volume increases until volume becomes great enough to require another labor shift. Only one man is needed to operate the dryer and evaporator on dryers having capacities of less than 750 pounds per hour. At this volume and larger ones, it is necessary to add a helper to barrel and store the nonfat dry milk. Because labor is hired in units of 40 hours, the labor cost per unit of output increases sharply as new labor shifts are added with a particular dryer or as a plant changes from a smaller dryer to a dryer with a capacity of 750 pounds per hour.

The labor requirement in a milk drying operation is partly fixed and partly variable. Cleaning requires a fixed number of hours each day that the dryer and evaporator are operated.

The labor organization for all model plants is as follows:

a. Key personnel, such as the dryer and evaporator operator are retained through the entire year. Unskilled labor, needed in the large plants for barrelling and storing nonfat dry milk, is hired and released as seasonal labor requirements fluctuate. Additional labor is added in 40-hour units, and all workers are guaranteed a 40-hour work week with time-and-one-half for all work over 40 hours; the labor schedule is designed so that the work week is no more than 6 days in the peak season and 5 days in the slack season. Under these restrictions, the employment policy of plants in this study approximates the employment conditions of plants hiring union labor.

b. A flat charge of $1,500 for managerial services is assessed against the drying operation in each plant. A flat charge is 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 are provided in appropriate amounts in all plants.

d. Appropriate laboratory and bookkeeping charges are 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:

$$\frac{746ab}{(0.85)\ 1{,}000} = \text{kwh}$$

where

746 = theoretical watts per horsepower hour,
0.85 = motor efficiency,
a = number of horsepower used and
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 milk vapors in the evaporator. Approximately 21 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 all influence the quantity of water required for evaporation.

In this study it was assumed that:

1. Milk is to be condensed under 26 inches of vacuum (125° F. milk discharge temperature) in the second effect, which means that the first effect has 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 is to 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, pp. 78-79 contains the information upon which the formulas are based):

$$\frac{a - b + c + 32}{d - e} = \text{Pounds of water required to condense 1 pound of vapor} = y$$

and

$$\frac{(f - g)\ (y)\ (h)}{(62.5)\ (2)} = \text{cu. ft. of water required per year}$$

where

a = total b.t.u. contained in vapor at the temperature of the evaporator,
b = temperature of the evaporator,
c = temperature differential between evaporator temperature and water discharge temperature,
d = water discharge temperature,
e = temperature of water supply,
f = pounds of skimmilk condensed per hour,
g = pounds of nonfat dry milk produced per hour,
h = number of hours of operation per year,
62.5 = weight of 1 cubic foot of water and
2 = double effect evaporator.

The boiler requires 4 gallons of water per horsepower hour. The annual requirement is obtained by determining the hours of operation per year for the boiler and multiplying.

The water requirement for cleaning was derived from a cleaning manual published by a cleaning supply firm (11). Cleaning water consumption is a fixed requirement each day a plant is in operation.

INSURANCE AND TAXES

Appropriate charges for insurance and taxes were made in all plants. The building and equipment in all plants is insured against loss from fire; extended coverage of 80 percent of cost is provided in all cases, and boilers in all plants are insured against loss from explosion. The rates per $100 valuation are given in the Appendix.

PACKAGING

The common containers for wholesale bulk sale are either fiber bags lined with polyethylene liner or hardboard barrels lined with fiber bags and polyethylene liners. Nonfat dry milk sold to the government must be packed in 220-pound barrels; requirements for other sales outlets depend on the wishes of the purchaser. In this analysis, all nonfat dry milk is packaged in barrels; this type of packaging is the most prevalent at the present time, and packing in barrels reduces the hazards involved in storing. The barrels and liners are usually purchased in lots of 1,000 at a price of $3 per barrel and liner.

STORAGE AND SELLING

Selling costs differ among plants as selling policies differ. In this study it was assumed that only high-heat nonfat dry milk for the wholesale trade will be produced. Under this assumption there are no market development costs—such as for advertising or promotion. This assumption eliminates selling cost variation among plants for purposes of analysis. Under these conditions the following selling costs are incurred in marketing: (a) insurance, (b) lumber required for packing powder in railroad cars, (c) labor required for loading, (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 decrease as volume increases. The equipment cost per unit decreases as volume increases.

The selling cost per hundredweight has been computed in the following manner:

(a) Insurance cost per hundredweight =

$$\frac{\text{value of inventory and equipment x insurance rates}}{\text{annual volume}}$$

(b) Lumber cost per hundredweight =

$$\frac{ab}{1{,}000 \times 440}$$

where

a = board feet of lumber required,
b = price of lumber per 1,000 board feet and
440 = number of hundredweights per carload of powder.

(c) Brokerage fee per hundredweight = 50 cents. This is the brokerage fee charged by one of the major marketing organizations in this area.

(d) Labor cost per hundredweight = $\frac{\$1.88a}{440}$

where

a = numbers of hours required to load one car,
\$1.88 = overtime rate for common labor and
440 = number of hundredweights per carload.

During the peak season it is necessary to pay labor overtime rates for carloading operations. The labor rate for carloading labor was therefore set at \$1.88 per hour, which is 1½ times the regular rate for common labor.

(e) Equipment cost per hundredweight =

$$(a + b)\ (0.20 + 0.05 + \frac{0.05}{2})$$

where

a = initial cost of fork lift truck with an estimated life of 5 years,
b = initial cost of pallet also with an estimated life of 5 years,
0.20 = annual depreciation rate,
0.05 = annual maintenance rate and
$\frac{0.05}{2}$ = average annual interest rate.

Pallets are assembled during the slack season by plant labor not required for processing.

(f) Financing cost per hundredweight = (\$0.16) (0.035) a

where

a = one-sixth of plant's annual volume,
\$0.16 = wholesale price of nonfat dry milk and
0.035 = interest rate for short-time loans.

Nonfat dry milk is in storage approximately 2 months after it is produced; therefore, it is necessary to provide working capital by securing a bank loan for an average production of 2 months.

If a plant produces nonfat dry milk for special markets, the selling costs will vary from those given above. The selling costs incurred in these special situations will depend on the shipping and loading specifications of the purchaser and, to some extent, on the frequency 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, are more likely to produce nonfat dry milk for the bulk wholesale market and to sell their product through a market organization. Special market development often involves such a large initial expense that it is unprofitable 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.

PROCESSING COSTS IN THE MODEL PLANTS

The costs presented in this section are the minimum processing costs attainable under the conditions stated for the plants studied. An example of the calculation of these processing costs can be obtained from the Department of Economics and Sociology, Iowa State College, Ames. Table 1 and fig. 1 present the unit costs of producing various volumes in each plant.

Plant I, the smallest plant analyzed, has a 500-pound-per-hour dryer with the necessary auxiliary equipment. When producing 959,000 pounds annually, it receives 11,536,365 pounds of whole milk per year. At this annual volume its daily receipts of whole milk vary from 42,300 pounds in June to 25,000 pounds in November and December, and its daily production of nonfat dry milk varies from 3,800 pounds in June to 2,200 pounds in November and December.

Plant II consists of a 650-pound-per-hour dryer and the corresponding auxiliary equipment. At annual volumes of less than 2,560,000 pounds of nonfat dry milk, Plant I has lower unit costs than Plant II; at greater volumes, Plant II has lower unit costs.

Plant III consists of the 750-pound-per-hour equipment combination. At annual volumes up to 3,174,700 pounds (which is the maximum possible output of a 650-pound dryer combination), Plant III has higher costs than Plant II. A large part of this cost differential arises because it is necessary to employ two men per shift to operate dryers of 750-pounds-per-hour capacity whereas one man can operate the smaller dryers.

TABLE 1. INPUT COSTS PER HUNDREDWEIGHT OF NONFAT DRY MILK AT VARIOUS VOLUMES IN PLANTS I, II AND III.

	Plant I			Plant II				Plant III		
	9,590 cwt.	19,170 cwt.	26,795 cwt.	19,170 cwt.	26,795 cwt.	28,794 cwt.	31,747 cwt.	28,794 cwt.	31,747 cwt.	38,500 cwt.
Inputs	$	$	$	$	$	$	$	$	$	$
Building	0.23	0.11	0.11	0.15	0.11	0.12	0.11	0.12	0.11	0.10
Equipment	1.31	0.65	0.47	0.67	0.48	0.45	0.41	0.50	0.43	0.36
Boiler	0.35	0.17	0.12	0.24	0.17	0.15	0.14	0.18	0.16	0.13
Insurance	0.16	0.09	0.06	0.09	0.06	0.06	0.06	0.06	0.06	0.05
Taxes	0.16	0.09	0.06	0.09	0.06	0.06	0.06	0.06	0.06	0.05
Quality control equipment	0.01	Less than 1 cent per hundredweight of powder								
Clerical labor	0.11	0.05	0.04	0.05	0.04	0.04	0.03	0.04	0.03	0.03
Plant labor	1.09	0.71	0.60	0.71	0.54	0.51	0.48	0.71	0.58	0.55
Fuel	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.07	1.07	1.07
Electricity	0.24	0.24	0.24	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Water and sewage	0.18	0.18	0.18	0.18	0.18	0.17	0.18	0.18	0.18	0.17
Packaging	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Supplies	0.40	0.21	0.15	0.21	0.15	0.16	0.13	0.15	0.13	0.11
Selling cost	0.86	0.80	0.80	0.80	0.80	0.80	0.79	0.80	0.79	0.79
Total	7.45	5.75	5.28	5.86	5.26	5.20	5.06	5.44	5.18	4.99

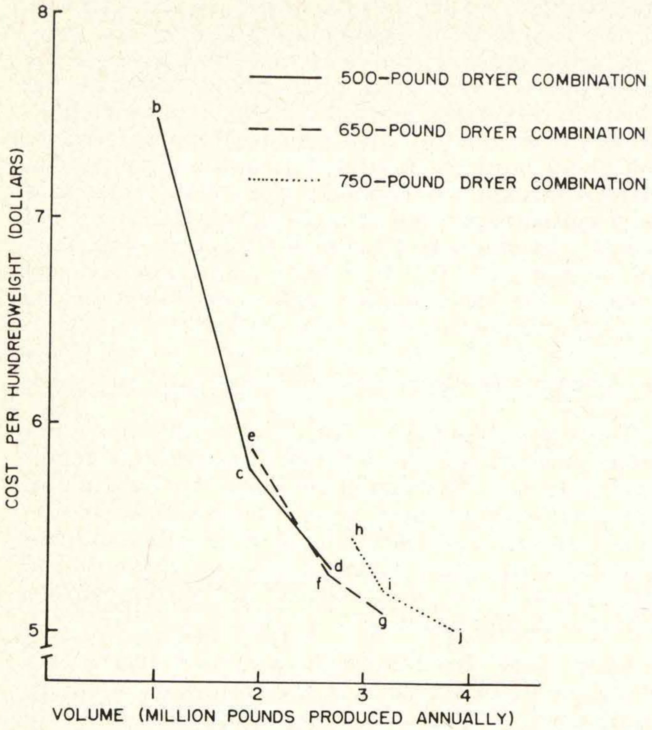


Fig. 1. Cost of spray drying skimmilk with several equipment combinations at various volumes.

Table 1 indicates that processing costs per unit decrease within the volume range of each equipment combination as volume increases. Each equipment combination, when operated at its optimum (lowest unit cost) volume, has a lower unit cost than a smaller equipment combination operated at its optimum volume. The rate of cost decline, however, decreases as volume increases. This decrease can be seen in table 1 and fig. 1. Processing costs decline from $5.28 per hundredweight for a 500-pound dryer combination to $5.06 per hundredweight for a 650-pound dryer combination to $4.99 per hundredweight for a 750-pound dryer combination. This decline represents a 4-percent cost reduction between the 500- and 650-pound dryer combinations and an 0.8-percent reduction between the 650- and 750-pound dryer combinations. The volume increases 18 percent in both instances.

Table 1 illustrates the importance of efficient use of inputs in any plant. The differences in processing costs within the same equipment combination indicate the net revenue increases possible through increased efficiency in the use of fixed inputs.

The economies possible through such increased efficiency make the problem of anticipating future volumes one of the most important considerations in the planning and building stage. Grossly incorrect expectations of future volumes will reduce net revenue through (a) unduly high fixed input costs because of low volumes relative to plant capacity, (b) excessive replacement costs if volume increases beyond the capacity of the equipment installed or (c) revenue foregone because of inability to process the entire available supply.

Figure 1 shows the cost of spray drying skimmilk with three different equipment combinations. In the planning stage, an operator can select any combination of equipment, building and labor. Each of these available combinations will have its own cost curve, and the operator can select the cost curve most suitable for his operation. For example, in fig. 1, the operator can select curve *bcd, efg* or *hij*. However, after the building and equipment are installed, the operator is restricted in his production to points on the cost curve he previously selected. If, for example, he had selected the Plant I combination, he cannot move from curve *bcd* to curve *efg* or *hij* but can operate only at different cost points on curve *bcd*.

VOLUMES IN A BUTTER-POWDER PLANT

Plant managers and boards of directors considering a butter-powder operation can use the costs presented here in connection with the costs of manufacturing butter in a whole milk plant. Using engineering methods similar to those used in the present study, Frazer *et al.* (6) estimated these costs for four different plants.

Usually, if a butter plant is operating at its optimum (lowest unit cost) volume, the available fluid skimmilk is not sufficient to permit a drying plant to operate at its optimum volume. Conversely, if a drying plant operates at its lowest unit cost the amount of cream available will not permit a butter plant to operate at its lowest unit cost. The data presented in table 2 show that the two types of plants do not achieve their optimum outputs from the same volume of whole milk receipts.

This indicates that, in cases in which several plants in an area are considering butter-powder operations and no one plant has sufficient skimmilk to operate a drying plant at its optimum volume, it might be more profitable for them to build a central dryer. Even if each plant did have sufficient skimmilk, it might still be more profitable to build a central dryer since a large plant operated at its optimum volume has lower unit costs than a smaller plant operated at its optimum volume.

VARYING PLANT VOLUME TO INCREASE NET REVENUE

If changing from a butter operation to a butter-powder operation is contemplated, an estimate of future volume may be obtained by surveying the present patrons to determine how many will shift

TABLE 2. UNIT COSTS AT SELECTED VOLUMES IN WHOLE-MILK BUTTER PLANTS AND IN NONFAT DRY MILK SOLIDS PLANTS.

Required volumes of whole milk (thousands of pounds)	Butter Plant No.	Butter Volume (thousands of pounds)	Butter Unit cost (cents)	Nonfat dry milk Plant No.	Nonfat dry milk Volume (cwt.)	Nonfat dry milk Unit cost (dollars)
11,536	I	500*	9.42	I	9,590	7.45
23,072	II	1,000*	7.18	I	19,180	5.75
30,916	III	1,340	6.75	I	25,625	5.35
32,300	III	1,400	6.49	I	26,795*	5.28
34,608	III	1,500*	6.26	II	28,770	5.20
30,916	III	1,340	6.75	II	25,625	5.35
38,184	IV	1,655	6.59	II	31,747*	5.06
46,144	IV	2,000	5.62	III	38,500*	4.99
50,758	IV	2,200*	5.21		42,196	

* Optimum output in the indicated plant.
Source: Nonfat dry milk data from table 1. Butter data from Frazer et al. (6), tables 1, 2, 3 and 4.

from gathered cream to whole milk delivery. In addition, a survey of all cream producers in the area may provide additional information about future plant volume. However, 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.

Whenever a plant's actual volume is well below its optimum volume, the plant may be able to increase its net revenue by purchasing fluid skimmilk from surrounding milk plants. This will be advantageous as long as the total return from purchased skimmilk solids exceeds the initial cost of the skimmilk, the cost of transportation, the costs of the variable inputs [6] and the variable portion of the semifixed inputs [7] used to dry this milk.

When the available supply of milk exceeds the physical capacity of the installed equipment, it may be more desirable to sell the excess skimmilk in another market, if available, or to return the skimmilk to farmers as animal feed rather than to install larger equipment. This would be true when excess supplies are expected to be temporary or when drying the skimmilk is not expected to contribute as much to net revenue as either of the previous methods of disposal. If, however, it is expected that the volume increase is permanent and drying will be profitable, it would be advantageous to increase drying capacity or to use the excess skimmilk in an even more profitable product.

RETURNS FROM SPRAY DRYING SKIMMILK

The foregoing costs are direct charges incurred in the processing and selling of nonfat dry milk. If a butter manufacturing enterprise adds nonfat dry milk as an alternative product, 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 from nonfat dry milk can be determined.

If a multi-product plant, in which the receiving and separating equipment is required for other products (no additional inputs are required), adds nonfat dry milk, the costs charged to it would be only the costs computed in this study—the direct costs. This difference between plants, where the nonfat dry milk is an additional product in both instances, occurs because of the differences in plant organization and operation before the addition of nonfat dry milk as an alternative product. In multi-product plants the only increase in costs from adding nonfat dry milk would be the direct costs computed in this study. In a butter plant, the costs would increase by the amount of these direct costs plus the amount of those listed in the preceding paragraph.

In each situation, in determining the attractiveness of the additional product, the revenue that will be derived from its sale is compared with the costs that will be incurred because of its production.

6 Variable inputs are packaging, water and sewage, electricity and fuel.

7 Semifixed inputs are supplies, selling costs and labor.

When the addition of nonfat dry milk to a butter plant is considered, the drying operation is expected to be a major source of revenue. When its addition to a multi-product plant is planned, the drying operation may not be expected to be a major source of revenue but rather a source of flexibility.

Future market conditions are not known with certainty. There may be periods when nonfat dry milk will be a more profitable product than some other uses of skimmilk. Or, there may be periods when the plant outlets for other products shrink, and a drying section can be used to take up the slack in total revenues. Under such conditions a multi-product plant may install drying equipment even though it does not at present contribute materially to the net revenue of the plant.

In a multi-product plant, the net return per pound of skimmilk solids is the difference between the processing costs (from table 1) and the selling price. On the other hand, if a plant changes from a gathered cream to a whole milk operation, the net revenue per pound of skimmilk solids is the difference between the selling price and the sum of (a) the processing costs (from table 1), (b) the costs of separating and storing the fluid skimmilk and (c) the excess of the costs of receiving whole milk over the costs of receiving cream. In table 3 the net return is expressed as the net return per hundredweight of fluid skimmilk at various volumes of annual nonfat dry milk production. The return per pound of skimmilk solids increases as volume increases.

The costs computed in this study, and the price used, may be compared with costs and prices of various alternatives products available to a fluid milk plant to determine the relative profitability of different products. 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, regardless of the method of disposal.

As an example, suppose that a fluid skimmilk market is available and will continue to be available throughout the foreseeable future. The operator must then decide at what long-run price of skimmilk it will become more profitable to dry skimmilk than to dispose of skimmilk in fluid form. In this situation, the net return from fluid skimmilk must be equal to or greater than the net return for nonfat dry milk (shown in table 3) before selling skimmilk in fluid form is more advantageous than processing.

TABLE 3. RETURN PER HUNDREDWEIGHT OF FLUID SKIMMILK AT VARIOUS ANNUAL VOLUMES OF NONFAT DRY MILK PRODUCTION.

Pounds of nonfat dry milk produced annually	Net return per hundredweight of fluid skimmilk*: In plant already receiving and separating whole milk	In plant receiving cream before adding drying equipment
959,000	$0.72	$0.50
1,917,000	0.87	0.69
2,679,500	0.91	0.77
2,879,400	0.92	0.78
3,174,700	0.93	0.80
3,850,000	0.94	0.82

* Hauling costs must be paid out of this return.

APPLICATION OF THE COMPUTED COSTS TO MANUFACTURING MILK PRICING FORMULAS

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 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-skimmilk relationship. The prices of the products, after deducting processing costs, are multiplied by yield, and the value thus obtained is available for producer payment.

Clark and Hassler (4) have published suggested formulas 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) $Qb = 1.23\ F - 0.123$

(b) $Qnfs = 7.17 + 0.441\ F,$

where Qb = quantity of butter obtained from 100 pounds of milk,

F = butterfat test,

0.123 = fat losses in processing,

Qnfs = quantity of nonfat dry milk obtained from 100 pounds of milk and

0.441 = added pounds of nonfat dry milk 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 nonfat dry milk can be expressed:

$$Vm = (1.23F - 0.123)\ (Pb - Cb) + (7.17 + 0.441F)\ (Pnfs - Cnfs) - Crs,$$

where Vm = the net value of 100 pounds of whole milk,

F = butterfat test of milk,

Pb = price of butter,

Cb = direct processing costs per pound of butter (including selling costs),

Pnfs = price of nonfat dry milk,

Cnfs = direct processing and marketing costs per pound of nonfat dry milk and

Crs = cost of receiving and separating 100 pounds of whole milk.

The costs computed in this study are the direct costs for processing and marketing nonfat dry milk (Cnfs in the formula). By selecting the relevant cost for its particular volume, a plant can determine the net value for the nonfat solids in the milk received. The direct butter processing costs can be obtained from Frazer *et al.* (7). At present, reliable receiving and separating costs based on engineering determinations are not available. However, receiving and separating costs have been roughly estimated to vary from 15 cents per hundredweight of whole milk at annual volumes of 46 million pounds and over to 35 cents per hundredweight at annual volumes of 11.5 million pounds. By using these costs in combination with the product prices facing the plant, the producer price for whole milk in a butter-powder operation can be determined in a component pricing plan.

LIMITATIONS OF THE STUDY

The results of this type of budget analysis can be an effective tool in reducing costs and thereby increasing profits. The value of the results obtained by using budgeting is, however, limited by the following factors:

(a) The accuracy of estimates of future volumes. The least-cost combination of inputs cannot be determined until management has some reasonably accurate estimate of future volumes.

(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 of individuals for products. These may result in resource combinations which do not give the lowest cost for a specific volume and prevent adjustments of inputs to changes in volume.

(d) Differences between conditions assumed in this analysis and actual conditions facing individual plants. Any operator must take 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 prices of inputs. 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. Individual plants may be able to secure price advantages that are not generally available to all plants.

(e) Possible labor economies present 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 nonfat dry milk processing costs. 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, other things such as the availability of natural gas, the operation of a waste disposal system, plant-owned water wells, and lower or higher wage, insurance and tax rates will all influence costs and must be considered in applying the results of this study to individual plants.

SUMMARY

To make the most profitable investments, dairy plant managers and directors need reasonably accurate information on cost-volume relationships when considering the installation of new equipment.

Recent developments in dry milk production and purchases have resulted in higher prices for nonfat dry milk and in increased production facilities and output. Some inefficient investments have occurred where a decision has been made to install drying facilities without adequate information on cost-volume relationships. The objective of this study is to provide this information for low-volume spray-drying plants to assist in investment decisions.

The study is based on budget analysis which determined the physical inputs needed to produce given volumes and attached prices to them. Costs per unit of production decrease as volume increases within the ranges considered. Processing costs vary from $7.45 per hundredweight at a volume of 959,000 pounds per year to $4.99 per hundredweight at 3,850,000 pounds per year. The distribution of costs also changes as volume increases; variable costs become relatively more important, fixed costs relatively less important.

This analysis also provides information which may be used in comparing the relative profitability of various products. The costs derived also provide data for payments to producers under a "component" pricing plan.

APPENDIX

PLANT II. EQUIPMENT REQUIREMENTS

Dryer—650 pounds per hour	$36,650
Evaporator (double effect)	26,000
Preheater	4,500
Hi Concentrate Preheater	2,500
Hotwell	1,342
Milk pump	75
Scale—250-pound portable	550
Shaker	100
Propane gas equipment	2,000
Total equipment investment	$73,717
Boiler	
Boiler and burner—217 hp (installed)	$19,400
Water softener	4,500
Total boiler investment	$23,900
Storage	
Fork lift truck	$ 2,850
Pallets	3,125
Total storage investment	$ 5,975
Drying building	$45,500
Boiler building	4,200
Total building investment	$49,700
Total plant investment	$158,692

PLANT II. HOURS OF OPERATION AND WATER CONSUMPTION FOR EVAPORATION AT AN ANNUAL VOLUME OF 2,879,400 POUNDS

	Hours per month
January	310
February	280
March	372
April	385
May	460
June	472
July	460
August	398
September	348
October	330
November	278
December	288
Total hours per year	4,381

$$\frac{(1{,}115.1) - 125 + 15 + 32}{110 - 60} = \frac{1{,}037.1}{50} = 20.74$$ pounds of water required to condense 1 pound vapor.

7,558 pounds of fluid skimmilk are condensed into 1,625 pounds of concentrated skimmilk per hour.

5,993 pounds of water are evaporated per hour.

7,558 - 1,625 = 5,993 pounds of vapor condensed per hour.

5,993 (20.74) = 124,295 pounds of water used per hour.

124,295 (4,381) = 544,536,395 pounds of water used per year.

$$\frac{544{,}536{,}395}{62.5} = 8{,}712{,}582$$ cubic feet of water used per year.

8,712,582 cu. ft. divided by 2 because of the double effect evaporator = 4,356,291 cubic feet of water used per year.

PRICES AND RATES APPLIED TO MODEL PLANTS

Building

—Building materials prices were obtained from suppliers and handlers.

—Construction labor requirements were obtained from Walker's, The Building Estimator's Reference Book (15).

—Labor rates are Des Moines union scale for journeymen and common laborers.

—Depreciation and maintenance rate is 5 percent of the initial investment.

—Interest is 5 percent of average investment (i.e., half of original cost).

—Taxes are 30 mills per dollar of average investment, obtained from Frazer, Nielsen and Nord (7).

—Insurance rates for 80 percent co-insurance are $1.35 per $100 valuation and $0.096 per $100 valuation for extended coverage. Insurance rates were obtained from the Iowa Inspection Bureau.

Equipment

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

—Depreciation and obsolesence were computed as 10 percent of the investment.

—Interest is 5 percent of the average investment (half of the original investment).

—Taxes are 30 mills per dollar of average investment.

—Insurance rates for 80 percent co-insurance are $1.45 per $100 valuation and $0.096 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 $0.625 per $100 valuation, and the extended coverage rate is $0.062 per $100 valuation.

—Boiler efficiency for automatic oil fired boilers (0.8) was obtained from boiler handlers and Professor H. M. Black of the Mechanical Engineering Department of Iowa State College.

Fuel

—Heat content of liquid propane, 21,600 b.t.u. per pound, obtained from Farrall (5).

—Heat content of mid-continent fuel oil, 19,000 b.t.u. per gallon, obtained from Handbook of Chemistry and Physics (3).

—Fuel prices of $0.11 per gallon of propane and $0.13 per gallon of fuel oil were obtained from gas and oil suppliers.

Electricity

—Motor efficiency (0.85) was obtained from James W. Nilsson of the Electrical Engineering Department of Iowa State College.

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

Plant labor pay scale

Operators: $1.50 per hour
Helpers: $1.35 per hour
Managerial charge: $1,500.00 per year
Plant Superintendent (half time): $2,250.00 per year.

Water rate is $0.10 per 100 cubic feet.

Sewage rate

—Sewage rate is $0.06 per 100 cubic feet of water discharged into the sewage system.

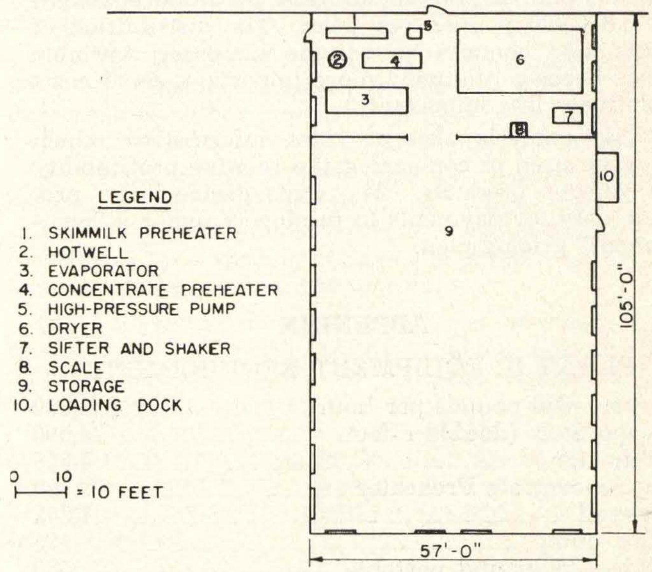
—These rates were obtained from municipalities selling water to milk plants.

Supplies

Organic acid—$2.94 per gallon
Alkali cleaner—$0.182 per pound
Salt—$0.01 per pound delivered

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

PLANT II FLOOR PLAN



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