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ULTRA-HIGH-TEMPERATURE FLUID MILK PROCESSING COSTS

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The use of company names and their registered trade marks in this study does not imply recommendation or endorsement of these companies or their products.

ABSTRACT

The Ultra-high-temperature (UHT) processing and aseptic packaging of fluid milk products greatly extends product shelf life. This technology has been used in Europe for many years but has been introduced only recently into the United States. The economic feasibility of UHT products depend in part on processing costs. This study specifies four model UHT processing plants and develops engineering cost estimates for these plants. The costs of UHT processing are compared with conventional pasteurization costs.

Keywords: Fluid milk processing costs, ultra-high-temperature milk processing, aseptic packaging, engineering cost estimates.

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INTRODUCTION

Conventionally processed and packaged fluid milk products have a short shelf life of approximately 21 days under refrigeration (McGarrahan, 1979). This perishability of beverage milk is responsible for product losses because of spoilage and imposes added distribution costs in the form of more frequent delivery schedules and refrigerated distribution and storage. Technology exists to process and package fluid milk with an unrefrigerated shelf-life of six months or longer if the package is unopened. This technology is referred to as ultra-high-temperature (UHT) processing and aseptic packaging (Burton, 1979).

Under UHT processing raw milk is heated to at least 280 degrees Fahrenheit (^{o}F) for a minimum of two seconds, whereas conventional pasteurization by the high temperature short time (HTST) method heats raw milk to a minimum of 161^{o}F for 15 seconds. Both heat treatments kill pathogenic bacteria present in milk, but some non-pathogenic bacteria survive the HTST heat treatment and cause the spoiling or off-flavors that result in a shorter shelf life. The UHT processing effectively destroys all bacteria. To achieve a longer shelf life without refrigeration, the UHT processed milk must be aseptically packaged to prevent recontamination after the heat treatment. The packaging material also must provide an effective barrier against the entry of microorganisms. Conventional packaging of HTST processed fluid milk permits recontamination of the milk after pasteurization (McGarrahan, 1979).

The UHT process is not new; UHT processed fluid milk products were available in the 1920s. Technological advances in processing and packaging since the early 1960s led to the development of commercially successful UHT fluid milk products in Western Europe. By 1975 UHT processed milk had captured 45 percent of the fluid milk market in Italy, 38 percent in West Germany, 35 percent in Switzerland and 18 percent in France (MMB, 1976). UHT milk was first produced commercially in Canada in 1975 and in the United States in 1982.

If UHT milk is to be commercially successful in the United States, then major changes are likely in processing, distribution, retail merchandizing and consumer purchasing patterns for fluid milk (OMMB, 1976; Drews and Longuet, 1981). These changes could affect the entire dairy industry. The technical aspects of UHT processing are well developed (Proceedings, 1979) and, as noted above, UHT milk has attained a substantial share of the fluid milk market in several European countries. However, it cannot be inferred from the European experience that UHT milk will be a commercial success in the United States because there are marked differences in economic, social and regulatory conditions. Therefore, an evaluation of the economic feasibility of UHT milk products in the United States is of interest to potential processors and distributors of UHT milk, competing firms and others interested or involved in the dairy industry.

The commercial success of UHT fluid milk products depends on consumer acceptance on the one hand and production and marketing costs on the other. The combination of producer and consumer factors will determine the market price for UHT milk and the total volume produced.

The quantity of UHT milk products a consumer is willing to purchase depends on several factors, including individual tastes and preferences, price of the UHT product, prices of other commodities including substitutes such as HTST milk products, and income. The "Law of Demand" states that, provided a consumer's income does not change and the prices of other goods remain the same, an individual will buy less of a given commodity at a higher price and more at a lower price. This inverse relationship between prices and quantity purchased is an individual's demand schedule. The total market demand schedule is simply the sum of the quantities purchased by all consumers at each level of prices. It represents the total market available to present or would-be producers of that product.

UHT processed milk is nutritionally equivalent to HTST processed milk (Renner, 1979) but differs in a number of characteristics. The extended shelf life without refrigeration provides the convenience and cost savings associated with less frequent purchases of milk. Also, UHT milk can be used as a "back-up" to HTST supplies in place of dried milk powder. UHT milk can be used in situations when HTST milk might spoil, such as recreational activities, vending machine sales and military uses (OMMB, 1976).

Not all UHT milk characteristics are positive, however. Taste test panels have evaluated the flavor of freshly processed UHT milk as markedly inferior to that of HTST processed milk, and there is more variability in flavor. However, the flavor of UHT milk improves with storage, and flavor scores can be achieved that are only slightly inferior to those of HTST milk (Hansen, 1979). The aseptic package design differs from the widely used conventional packages and is limited to half-pint and quart sizes. The package is more difficult to open because of its multiple-layer construction and spillage occurs easily because the container is completely filled with milk (OMMB, 1976).

These characteristics suggest that UHT milk will compete with HTST milk primarily in the major fluid milk markets and with non-milk beverages in some new or expanded markets. As with any new product, market research is required to predict consumer demand, both in total and for a specific firm's product(s).

The price at which UHT milk can be profitably offered for sale will depend on the production, distribution and retail marketing costs. The production and distribution costs are interdependant. Production costs normally exhibit economies of scale; that is, average production costs per unit fall as the size of plant increases. Reasons include specialization in labor and management, efficient use of equipment, and the ability to obtain volume discounts on input purchases. At some point these economies might be offset by managerial diseconomies arising from the complexities of managing a large-scale operation. Also, a larger plant size implies a proportionate increase in the market area and, therefore, in the average cost per unit of distributing that plant's output (Scherer, 1980).

Economies of scale are important to potential entrants into UHT processing because they are likely to be a major determinant both of the structure of the industry and of the level of product prices. Where significant economies of scale exist, the most efficient (minimum cost) plants will dominate the industry and competition will tend to drive prices down to levels at which only the efficient plants can earn a profit.[1]

PURPOSE AND PROCEDURE

This study represents a first step in evaluating the economic feasibility of UHT milk in the United States and will be concerned primarily with processing costs. Cost relationships are estimated for specified new, specialized model plants of various sizes.

More specifically, the objectives are:

(I) To develop different sizes of model UHT processing plants capable of processing, packaging, and storing UHT fluid milk products.

(II) Based on these model plants and prices prevailing in 1980 and 1981, to develop representative unit costs when packaging a selected mix of container sizes for UHT fluid milk.

(III) To measure the sensitivity of unit costs to variations in efficiency of plant use as well as measure the differences in unit costs under different factor prices.

(IV) To evaluate the results generated in I through III to provide information that can be used as a guide for decisions in evaluating the feasibility of UHT processing and in planning new UHT fluid milk processing facilities.

(V) To evaluate the results as in IV to provide information on the likely structure of the UHT fluid milk processing industry.

An economic engineering approach to cost estimation will be used for this study. The primary reason for using this type of cost

[1]For a more detailed discussion, see (Wood, 1981).

estimation is that few UHT plants currently exist in the United States, therefore it is not possible actually to measure existing plant costs. Economic engineering involves planning and designing new UHT fluid milk processing plants of different sizes and collecting the costs associated with owning and operating each plant to evaluate the possible cost/size relationships that may exist.

The other major advantages of the economic engineering approach in estimating plant costs and economies of size in UHT fluid milk processing are (Fischer et al., 1979):

1. All costs are evaluated at the same point in time.

2. Rate of plant utilization can be specified and may be held constant to compare costs of different size plants.

3. Product mix may be held constant for all plant sizes to facilitate cost comparisons.

4. Technology embodied in facilities and equipment is the most modern or recent.

The principal disadvantages of the economic engineering approach are (Scherer, 1980):

1. the heavy demands it places on both the investigator's and his informant's time;

2. the tendency of some engineers to underemphasize the sensitivity of plant size decisions to changes in input prices.

3. the reliability of the estimated engineering parameters for new systems; and

4. difficulty in estimating managerial diseconomies.

The estimation procedures differ somewhat among the major types of plant costs and are discussed under two headings: capital investments and operating costs.

Capital Investments

For the purposes of this study, capital expenditures are defined as those inputs used in the production of UHT fluid milk that have a useful life of more than one year (Levy and Sarnat, 1978). These inputs include land, buildings, and equipment.

Two main types of data are needed in estimating the costs of capital inputs, architectural-engineering estimates of land and building costs, and data supplied by manufacturers of UHT fluid milk processing equipment.

Because we wish to develop processing costs on an average per-unit basis, total investment in land, buildings, and equipment must be converted to an annual cost figure. To accomplish this, we will use the following capital recovery formula (Newnan, 1980):

$$A = P \left[\frac{i(1+i)^{n}}{(1+i)^{n-1}} \right]$$

where: A = uniform annual charge for capital recovery (ACCR),

P = total investment cost,

i = interest rate,

n = economic life of the capital input.

Note that the economic life of an investment differs from physical life for two important reasons. First, economic life is influenced by the possibility of technological obsolescence of the capital asset. Second, because of the uncertainty of obtaining the estimated revenues from the project, economic life may deviate further from physical life. Note also that this formula combines an interest rate and the economic life of the capital investment into one formula to convert total investment into an annual cost figure. This annual cost figure may then be divided by the appropriate number of units produced per year to arrive at the average cost per unit processed.

Interest rate represents the cost of borrowed funds. For this analysis, all capital investment funds are assumed to be borrowed, although this need not be the situation facing actual UHT plant investors. The important point about borrowing funds is that a firm must look closely at the opportunity cost of using these funds in alternative projects. An interest rate of 15 percent was used for this study as being representative of the cost of borrowed funds for special purpose dairy processing plants as reported by Bass, Nixon, and Kennedy, Consulting Engineers, Raleigh, North Carolina. Later in the text an interest rate of 20 percent will be applied to the value of capital inputs to show the impact of increasing interest rates on per-unit processing costs.

Because land is a non-perishable asset, its economic life is assumed to be infinite. The economic life of buildings and equipment was assumed to be twenty years. Clearly, for tax purposes a firm might be required to use a different period or it might seek to depreciate its capital assets over a different period if by so doing it can enjoy the tax benefits at an earlier date. However, the economic life of the capital assets should be the paramount consideration in determining profitability. The twenty-year figure used is based on the equipment manufacturers' best estimates of the useful life of all equipment housed within each plant. The effect of depreciating buildings and equipment over a shorter time period also will be explored.

Operating Costs

Operating costs include all non-capital costs incurred from the moment raw milk enters the plant until the finished product leaves the storage area. These costs include those operating costs that vary with the level of output and certain fixed or overhead operating costs. These costs are discussed under two headings: labor and other operating costs.

Labor

Direct labor costs are estimated by first describing the plant organization, the crew setup and kinds of operations performed. For the purposes of this study, direct labor will be expressed in terms of man-hours per week. Then an hourly wage rate is applied to this number of man-hours to obtain total weekly cost of direct labor. Dividing by the number of units produced per week gives an estimate of per-unit direct labor cost in processing.

Administrative labor costs consist of salaries paid to managers, office and clerical workers, and executives. These costs are probably the most difficult to estimate of any of the various inputs, but market data are available and provide a basis for estimates of quantities of various types of administrative labor and salary scales.

Other Operating Costs

In addition to labor, other operating inputs consist of items such as electricity, fuel, water, containers, supplies, and taxes and insurance.

Electricity, water, and fuel costs may be estimated by engineering studies of chemical and mechanical processes and various machine requirements.

To estimate container costs, container sizes first must be specified for use in each model plant. The manufacturer(s) of filling equipment can then be consulted as to the per-unit cost of each container size.

Costs of office and janitorial supplies and the like, were estimated on a weekly basis.

Costs of taxes and insurance were estimated by a local tax board and an insurance agency to reflect national averages.

Aggregation and Integration

The estimation procedures outlined above, when completed, provide a set of "building blocks" for estimating individual UHT fluid milk processing plant costs. All costs are converted to a per-unit-of-output basis (gallons). After summing the individual "blocks" on a per-unit basis, the resulting costs may be used to determine the possible economies associated with plants of different sizes. The following sections first develop specifications for the UHT model plants to be analyzed, then the costs for each model plant are examined.

SPECIFYING THE MODEL PLANTS

The previous discussion of economies of size states that as plant size increases, reductions in per-unit costs may be realized. Therefore, several plant sizes must be analyzed to determine the existance and magnitude of these cost reductions. Furthermore, the plants chosen should cover the likely range of sizes that might be built in the United States if fluid UHT milk is to be generally available.

Two factors were considered in selecting the range of plant sizes, market penetration and efficient plant operation. However, before discussing efficient plant organization and likely market penetration figures for UHT fluid milk in the United States, a general description of UHT plant operation is provided.

The General Nature of UHT Processing Operations

The stages in UHT fluid milk processing are: receiving raw milk from producers, standardizing the milk, treating the milk at ultra-high temperatures, aseptically filling the container with the treated product, storing, and distributing the product to various markets.

Raw milk normally is delivered to the processing plant six days per week in transport-tanker trucks. The raw milk is pumped from the tankers through a cold milk separator that removes the butterfat. The resulting skim milk and cream (containing most of the butterfat) are stored in separate storage tanks.

As processing operations begin, skim milk and cream are pumped from their respective tanks through a ratio controller to produce milk possessing the desired fat content. Next the milk passes through a blender, where flavors and other additives such as stabilizers can be blended into the milk.

From this point the raw milk is processed differently under the UHT process and than under conventional pasteurization, starting with the heat treatment. The higher temperature used in the UHT process sterilizes the raw milk, whereas some non-pathogenic bacteria survive the lower temperatures used for conventional pasteurization. There are two basic methods used to sterilize fluid milk, usually referred to as the direct and indirect heating methods.

Direct Sterilization

In the direct system, the milk is sterilized by direct contact of the milk with steam. The milk is pumped through preheaters into a chamber where it is treated with steam under pressure.

This brings about very rapid heating of the milk. In the process, however, the milk takes on water from the steam, which must be removed to restore the milk to its original composition. The added water is removed in a vacuum chamber and the milk is then cooled before being discharged (Burton, 1979).

There are two major advantages of the direct method of milk sterilization (OMMB, 1976).

1. Such milk has an excellent flavor compared to that sterilized indirectly because it never comes in contact with a surface hotter than itself.

2. There is little tendency for the product to accumulate on equipment surfaces.

The major disadvantages of the direct method are (OMMB, 1976):

1. There is a larger initial investment compared to that for an indirect system.

2. The steam must be absolutely pure and free from odor, flavor and boiler chemicals.

3. The homogenizer must operate aseptically (in the absence of environmental contaminants).

4. The system is more complex technically.

5. More equipment maintenance is required than for a comparable indirect system.

6. The energy requirements are higher than in a comparable indirect system.

Two alternatives to the direct sterilization of fluid milk products are available (Hallstrom, 1979).

1. Injection ("steam into milk"); the product flow is the continuous phase in the mixing device and steam is injected in the product. (Manufacturers of this type of equipment include Alfa-Laval, APV, Cherry-Burrell, and Rossi-Catelli.)

2. Infusion ("milk into steam"); the steam is the continuous phase in the mixing device and the product is injected into the steam either as droplets or as a film. (Manufacturers of this type of equipment include Crepaco, Dasi, and Pasilac.)

Indirect Sterilization

In the indirect method of milk sterilization, the milk and steam are separated by a metal wall, either tubular or plate, thus eliminating any possibility of introducing water into the milk. The milk is passed through a heat exchanger and preheated to approximately 150^{0}F, then heated to 212^{0}F by a second heat exchanger. After moving through the second heat exchanger, the milk enters the sterilizer and is heated to 285^{0}F. The heated milk is partially cooled by heat exchangers before moving through coolers to reduce the temperature further, to $60\text{-}70^{0}$F (Burton, 1979). In the heat exchanger, the sterilized milk leaving the heating device flows in the opposite direction from the incoming milk and is separated by a metal wall. Heat is transferred from hot, sterilized milk to the cold, raw milk, thus reducing both the energy required to cool the sterilized milk and to heat the raw milk.

The advantages of the indirect system can be summarized as follows (OMMB, 1976):

1. It uses less energy than the direct method by using heat exchangers. It has been estimated that energy consumption can be reduced to approximately half that of the direct method.

2. It has a lower initial investment cost than the direct system.

3. It requires less equipment maintenance than a comparable direct system.

4. It does not involve the introduction of water into the product and thus is simpler from a technical standpoint than a comparable direct system.

5. It eliminates the possibility of flavors and odors being injected into the milk with steam.

6. It results in less sedimentation (presence of particulate matter) than the direct method.

7. It has a higher degree of flexibility in that it can process a wider variety of products than the direct system, e.g., fruit juices.

8. Equipment is more readily available in the United States than is equipment for direct sterilization.

The main disadvantages of the indirect sterilization method are (OMMB, 1976):

1. Milk protein is readily deposited on the heat exchange surfaces, causing loss of efficiency in the system because of shutdowns every 8 or 9 hours for cleaning.

2. The product displays a more noticeable cooked flavor than does that sterilized by the direct method.

Three equipment alternatives are available for the indirect sterilization method (Hallstrom, 1979):

1. Tubular heat exchangers. (Manufacturers include Ahrens-Bode, Cherry-Burrell, Crepaco, and Stork.)

2. Plate heat exchangers. (Manufacturers include Ahlbora, Alfa-Laval, APV, Frau, Schmidt-Bretten, and Sordi.)

3. Scraped surface heat exchangers. (Manufacturers include Cherry-Burrell and Crepaco.)

The tubular systems consist of concentric tubes that carry the steam and product separately. In the plate systems, steam and product are separated by a single plate of metal. The scraped surface systems are similar to the tubular systems except the product is mechanically agitated within the inner tube to ensure uniform heating.

After the milk has been sterilized and partially cooled, it passes through a homogenizer to break apart the fat globules present to prevent the natural separation and formation of a cream layer in the final product.

An aseptic surge tank may or may not be employed in UHT processing. However, to equate the flow rates of the sterilizer operation and filler operation, an aseptic surge tank normally is employed. As the filling operation begins, milk is moved from the surge tank(s) into the filler(s).

The Aseptic Filler

All commercial aseptic filling systems use nonreturnable containers such as cans, cartons or plastic containers of different types.

An aseptic filling system has three main requirements (Burton, 1979):

1. The container material and any closure must be adequately sterilized before filling.

2. The container must be filled with uncontaminated product in a sterile atmosphere.

3. The sealed container must have bacteriological integrity, i.e., the container and all seals must be sound so that there is no leakage of product and no contaminant can enter.

The types of commercial aseptic filling systems are summarized in Table 1. Most systems rely on combinations of hydrogen peroxide and heat for container and closure sterilization.

After filling, the containers are placed in storage to await transportation to market.

The Choice of UHT Processing Equipment

The size of each model plant to be investigated will be influenced by the capacities of the equipment housed within each plant. As was mentioned earlier, the unique aspects of UHT processing begin at the sterilization stage of plant operations.

Sterilization Equipment

Because initial investment and operating energy costs are much lower for the indirect method of UHT sterilization than for the direct and because indirect systems are more readily available in the United States, the indirect method was chosen for this study.

Table 1. Types of commercial aseptic filling systems

Container	Method of sterilization	Filling	Closure
Cans	Superheated steam	Flow, volume determined by time	Lids sterilized with superheated steam
Cartons formed from roll	Hydrogen peroxide and heat	Flow, volume determined by carton	Heat sealing of carton material
Cartons assembled from preformed blanks	Hydrogen peroxide and heat	Volumetric	Heat sealing of carton material
Plastics film form-fill-seal	Hydrogen peroxide and heat	Volumetric	Aluminum foil, sterilized with hydrogen peroxide and heat. Heat sealed
Plastics beakers	Hydrogen peroxide and heat	Volumetric	Aluminum foil, sterilized with hydrogen peroxide and heat. Heat sealed
Plastics film sachets	Hydrogen peroxide or alcohol	Volumetric	Heat sealing of sachet material
Blow-moulded thermoplastic bottles	Blow-moulding with sterile air	Volumetric	Aluminum foil or plastics seal

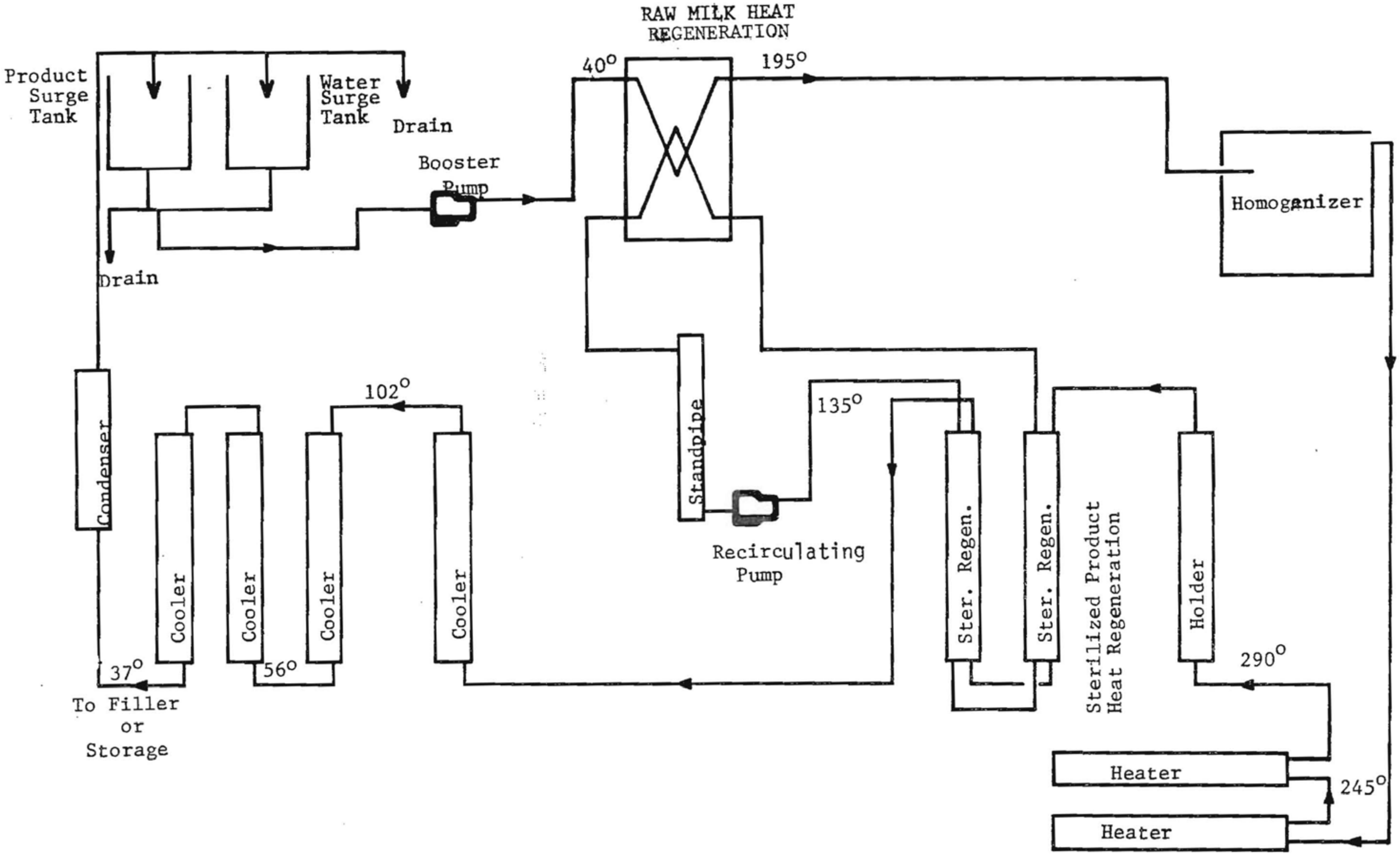
Source: Burton (1979, p. 12).

Cherry-Burrell, Inc., of Cedar Rapids, Iowa, provided the design specifications and the equipment costs for the indirect processing systems used in each model processing plant. These systems are modular, utilizing tubular heat exchangers (Figure 1). This equipment is relatively simple from a design and operation standpoint and is easily installed because of the modular nature of the components. These processing units can be arranged to feed directly into the filling and packaging equipment or to feed aseptic surge tanks for temporary storage. Also, the processing units can be linked such that two or more can be used to feed directly into a single filling and packaging machine.

In addition to the sterilizer itself, Cherry-Burrell manufacturers all of the equipment required from the raw milk receiving stage of plant operations through the temporary storage of the sterilized milk in the aseptic surge tanks, and supplied the specifications and costs used in this study.

Filling and Packaging Equipment

The aseptic filling system used in the model UHT processing plants is manufactured by Brik-Pak of Dallas, Texas, a subsidiary firm of the Tetra-Pak group in Lund, Sweden. This system was selected because it is the market leader in Europe, where UHT processing technology was largely developed and where UHT products have been commercially available for many years (Goebel, 1979). In addition, these were the only aseptic fillers commercially available in the United States when this research began. However, the Combibloc filling system was introduced at a later date.



RAW MILK HEAT REGENERATION
40°
195°
Product Surge Tank
Water Surge Tank
Drain
Booster Pump
Homoganizer
Drain
Condenser
Cooler
Cooler
Cooler
Cooler
102°
Standpipe
135°
Recirculating Pump
Ster. Regen.
Ster. Regen.
Sterilized Product Heat Regeneration
Holder
290°
37°
56°
To Filler or Storage
Heater
245°
Heater

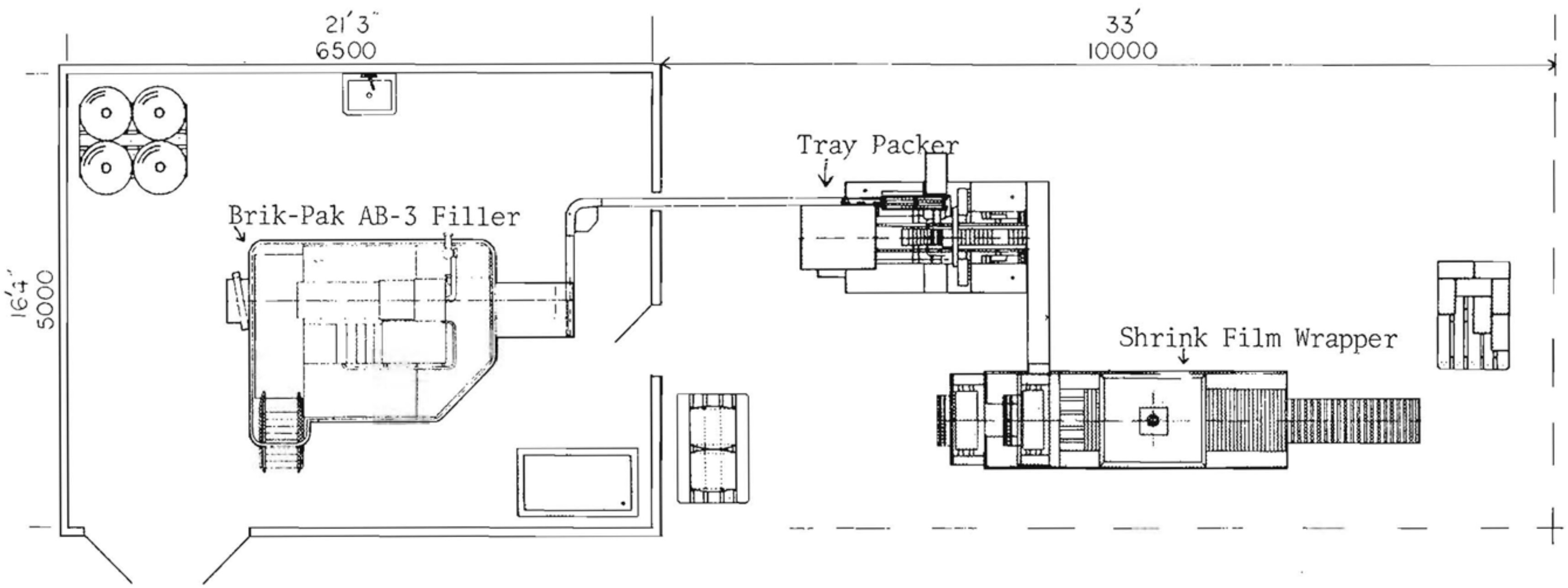
Brik-Pak aseptic filling machines operate in the following manner. The packaging material is delivered in reels containing enough material for between 2,500 to 10,000 units, depending on the volume of the finished container. The packaging material is composed of the following layers, from the outside to the inside:

1. Polyethylene plastic coating,
2. Paper,
3. Polyethylene plastic coating,
4. Aluminum foil,
5. Polyethylene plastic coating.

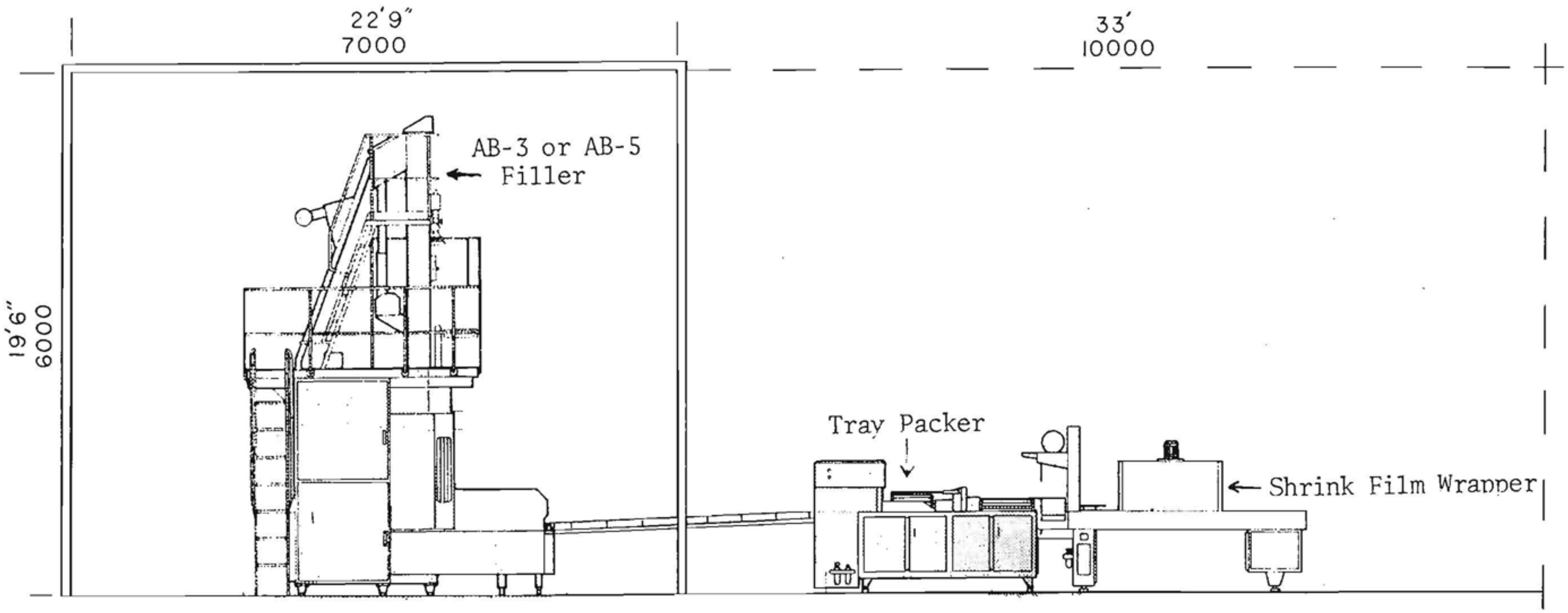
The packaging material is unwound and travels upwards in the filling machine to reach a sterilizing bath of hydrogen peroxide (H_2O_2) on top of the machine. Before the container material enters the H_2O_2 bath, a longitudinal plastic reinforcement strip is heat sealed to one edge of the material web. A film of H_2O_2 is applied to the packaging material contact surface as it passes through the sterile bath. A pair of squeeze rollers removes surplus H_2O_2, which runs back into the sterile bath. Passing a bending roller on the very top of the machine, the packaging material starts its way downward and is formed into a tube. Just prior to longitudinal sealing, the product is admitted by way of a filling pipe that extends down through the center of the packaging material tube. The tube heater - a spiral, electrically charged heating element - is placed around the filling pipe. After being sealed longitudinally, the packaging material is heated while passing the tube heater. The filling pipe extends below the level of product, the flow of which is regulated and controlled by a butterfly valve at the outlet of the filling pipe, which in turn is regulated by a float. Thus, a moderation of the flow of product can be achieved. Transverse seams are made at regular intervals below the level of the product. To seal transversely, the product has to be squeezed away from the sealing zone. This is done by closing sealing jaws, applying pressure and then heat. Individual units are cut at a rate of about one pack per second. The "pouches" thus obtained are fed into a final folder where they assume a brick-like shape by having the flaps sealed down to the sides and the bottom of the package (Bockelmann, 1979).

These fillers are available to U. S. fluid milk processing firms in half pint and quart sizes only. Brik-Pak for technical reasons has not been able to develop a package size larger than a quart. These fillers have a rated capacity of 4,500 half-pints per hour or 3,750 quarts filled per hour. No variation in the volume filled is attainable once the filling machine has been installed. Two views of the Brik-Pak filler are shown in Figures 2 and 3, along with two other pieces of equipment discussed below. The AB-3 model filler shown in Figure 2 has a single filling line. However, Brik-Pak also manufactures an AB-5 model that has two filling lines. This latter model saves 40 percent of the floor space of two AB-3 models while being able to fill the equivalent of two AB-3 models. In this study the AB-5 model will be used where justified by plant volume because of the resulting building cost advantage. There are no other cost advantages to the use of the AB-5 model as opposed to the AB-3 model, i.e., investment cost is double that of an AB-3 model.

After the packages have been filled, they proceed along a conveyor line to a tray packer that places 27 half pint packages on each cardboard tray, or 12 quarts per tray. In the case of half pint



21'3"
6500
33'
10000
16'4"
5000
Tray Packer
Brik-Pak AB-3 Filler
Shrink Film Wrapper



22'9"
7000
33'
10000
19'6"
6000
AB-3 or AB-5 Filler
Tray Packer
Shrink Film Wrapper

containers, a drinking straw applicator is employed between the filler and the tray packer. Drinking straws are not applied to quart containers.

Next, the packed tray is conveyed to a shrink film wrapper that encloses the entire tray in a plastic film.[2] One shrink film wrapper may service three tray packing lines. The wrapped tray is conveyed to the storage room, where workers manually stack them onto pallets. Ninety trays of half pint containers or 75 trays of quart containers may be placed on each pallet.

A fork lift truck is used to stack the loaded pallets two high in the storage area. For this analysis, storage time is assumed to be 10 days. This storage period has been shown to have a favorable effect on the product's flavor. Also, while in storage the product can be inspected visually for spoilage and faulty sealing of the containers and samples drawn and analyzed to determine product quality (Burton, 1979). After 10 days in product storage, the milk is shipped.

The various stages in the UHT plant operation used in this analysis are shown in Figure 4.

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[2] Information on the tray packer, straw applicator, and shrink film wrapper also was provided by Brik-Pak, Inc.

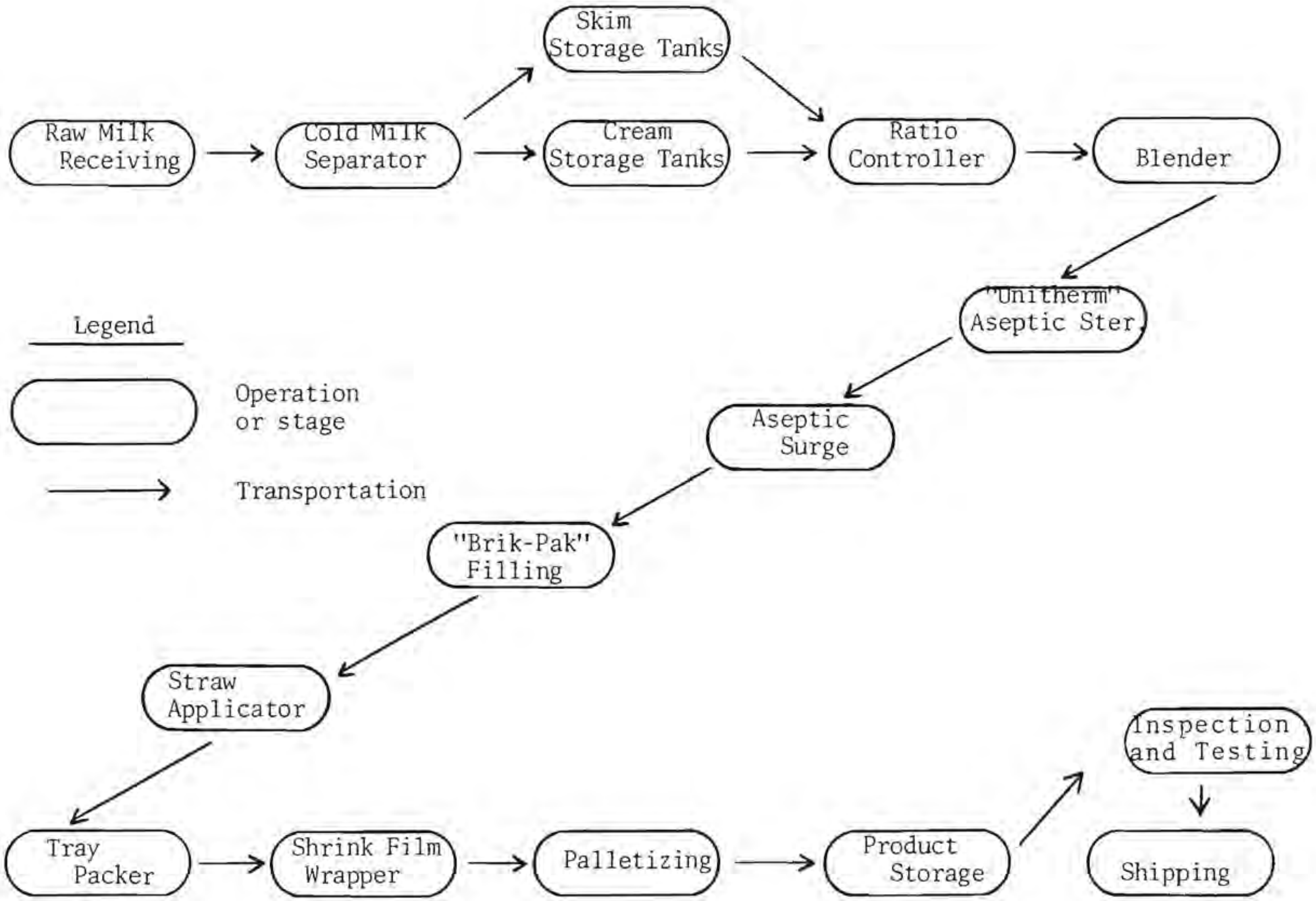

Figure 4. Process flow diagram for UHT fluid milk processing plant

The Effect of Market Penetration, Container Size and Filler Operation on Plant Size

Market Penetration

UHT-treated milk has been available in Europe for over 20 years, after its initial introduction to Switzerland in 1961. The market share for the fluid product varies from a low of 10 percent in Belgium and Holland to a high of 40-45 percent in Italy and Germany (OMMB, 1976). The reasons for the wide range of UHT market penetrations observed abroad are many and a brief discussion of some of these is necessary.

In Belgium and Holland, home refrigeration is widespread and the advantages to consumers of a product with extended storability is not great. In addition, the Belgium and Holland markets are characterized by high per capita consumption. Consumers buy quantities of milk in bulk and purchases are made frequently. On the other hand, Italy and Germany are cases at the opposite extreme, i.e., low per capita consumption, and retail milk purchases are made less frequently. In addition, there is a lack of home refrigeration and thus consumers are attracted to the storability of UHT milk (OMMB, 1976).

It is important to understand that these market situations do not apply to U. S. fluid milk markets. However, because other information is lacking, it is assumed in this study that the potential for UHT milk in the United States lies within the range observed in Europe. A second guide might be offered by the size of existing HTST plants in the various markets.

Table 2 shows data for 144 fluid milk markets in the United States. Market size varied from an average of 33,233 gallons/day in the eight smallest markets to 1,744,186 gallons/day in the 14 largest markets. If total UHT sales represented 10 percent of HTST sales, then the total volume would range from 3,322 gallons per day in the smallest market to 174,420 gallons per day in the largest market, to be shared between competing UHT plants. Average HTST plant size ranged from 3,322 gallons per day to 12,731 gallons per day. These data suggest a lower bound of only 3,322 gallons per day.

Table 2. UHT fluid milk market based on 10 percent market penetration of existing HTST markets

HTST				Total UHT market at 10% of HTST market (gallons/day)
Market size (gallons/day)	Markets (number)	Average plants (number)	Average plant size (gallons/day)	
32,223	8	10	3,322	3,322
83,056	13	16	5,191	8,306
138,427	19	22	6,292	13,843
210,410	23	29	7,256	21,041
315,615	19	47	6,715	31,562
481,728	14	58	8,306	48,173
819,491	34	100	8,195	81,949
1,744,186	14	137	12,731	174,420

Source: Cook et. al. (1978).

To formulate a likely upper bound for UHT model plant sizes using the same existing milk markets, it is assumed that sales of UHT fluid milk products would be equivalent to the average market share of the four largest pasteurized fluid milk plants (Table 3). The last column of Table 3 shows the UHT model plant sizes under these assumptions, *i.e.*, from a low of 6,636 gallons processed per day to 101,599 gallons processed per day.

Table 3. Average market share of the four largest firms, existing HTST markets

Market size (gallons/day)	Markets (number)	Average market share 4 largest firms (%)	Average plant size 4 largest firms (gal./day)
33,223	8	79.9	6,636
85,056	13	72.2	14,992
138,427	19	60.8	21,041
210,410	23	53.3	28,037
315,615	19	46.7	36,848
481,728	14	39.5	47,571
819,491	34	30.1	61,667
1,744,186	14	23.3	101,599

Source: Cook *et al.*, (1978, p. 27).

Container Size

The mix of container sizes sold to consumers affects the filler configuration in the plant. Table 4 shows the percent of HTST fluid milk sold in the United States by container size for the years 1975 through 1979. These data guided the selection of the proportion of UHT fluid milk products produced as quarts and half-pints in the model plants used in this study because no other data were available.

Table 4. Percent of HTST fluid milk sold by container sizes, federal order markets,[a] November[b] 1975-1979

Size of container	1975	1976	1977	1978	1979
			(percent)		
Gallon	43	45	49	51	53
Half-gallon	34	32	29	27	25
Quart	7	7	6	6	6
Pint	1	1	1	1	1
Half-pint	11	11	11	11	11
Other	1	1	1	1	1
Bulk[c]	3	3	3	3	3
Total	100	100	100	100	100

[a]Data are for 56 federal order markets for 1975 and 47 markets for 1976-79, for which complete data were available.

[b]November is considered representative of the annual average.

[c]Metal cans and plastic bag-in-box containers.

Source: Milk Industry Foundation (1980).

Although the maximum container size of the Brik-Pak aseptic filling machine is one quart, it is possible to market quarts in groups of two (one-half gallon) and four (one gallon) within each tray. As seen in Table 4, combined percentage totals of the three largest container sizes for HTST milk are 84 percent of the total, and 11 percent of the total is packaged in half pint containers. Sales of the remaining sizes of packages are small and these containers were disregarded. The 84 percent to 11 percent ratio is based on volume and is equivalent to a container ratio of approximately two quarts to every half pint container.

Table 5. Estimated UHT plant output for selected filler combinations

Quart fillers		Half pint fillers		
Number of fillers (AB-3 Model)	Number of shifts/day	Number of fillers (AB-3 Model)	Number of shifts/day	Total volume (gals./day)
1	1	0	0	6,563
1	2	0	0	13,126
1	2	1	1	15,095
2	2	1	2	30,188
3	2	1	2	43,313
4	2	2	2	60,375
8	2	4	2	120,750

Based on:

1 AB-3 quart filler filling 3750 qts./hour.

1 AB-3 1/2 pint filler filling 4,500 1/2 pints/hour.

Effective running time of each filler equal to seven hours per eight-hour shift.

Filler Operation

Table 5 shows estimated plant output for selected filler combinations and numbers of shifts worked per day. Based on current dairy industry practice, shifts are eight hours long and the fillers are assumed to run seven hours per shift. Note that the output rate for the quart filler differs from the half pint filler rate.

Model Plant Specifications

Four model plants were specified based on considerations of market penetration, container size, and filler operation. These were:

Plant A, with output of 13,126 gallons per day or 65,625 gallons per week, using one quart filling machine.

Plant B, 30,188 gallons per day or 150,940 gallons per week, using two quart filling line and one half pint filler.

Plant C, 60,375 gallons per day or 301,875 gallons per week, using four quart and two half pint filling lines.

Plant D, 120,750 gallons per day or 603,750 gallons per week, using eight quart and four half pint filling lines.

All plants are based on the efficient operation of the filling lines, i.e., seven hours of operation per eight-hour shift, two shifts per day, five days per week. The four plants cover the likely range in plant sizes that might be built in the United States, based on market penetration considerations. However, Plant A is considerably larger than the average HTST plant in existing markets (Table 2). On the other hand, Plant A is smaller than the average plant size of the four largest firms in all of these HTST markets except the smallest markets. These plants range in size from 6,636 to 101,599 gallons per day (Table 3).

Plants B, C and D incorporate a filling line configuration of two quart filling lines for each half pint filling line. These model plants generate 1.67 quarts for each half pint container because of the different output rates of the two types of fillers. This is the closest ratio to the observed sales of HTST containers (Table 4) that can be achieved while maintaining efficient filler operation.

The remaining pieces of plant equipment, such as the sterilizer itself, were designed to match the filler operation as efficiently as possible.

Product Mix

Table 6 shows the product mix of fluid milk items to be processed in each plant along with the amounts of each product to be processed expressed on a weekly basis. Product mix was standardized to eliminate cost differences caused by variations in proportions of products handled.

Table 6. Product mix of four model UHT fluid milk processing plants

Products	Percentage distribution[a]	Weekly production (gallons)			
		Plant A	Plant B	Plant C	Plant D
Homogenized whole milk	28	18,375	42,263	84,525	169,050
Two percent milk	42	27,563	63,395	126,788	253,575
One percent milk	8	5,250	12,075	24,150	48,300
Skim milk	13	8,531	19,622	39,244	78,488
Chocolate milk	5	3,281	7,547	15,094	30,188
Half-and-half	4	2,625	6,038	12,074	24,149
Total	100	65,625	150,940	301,875	603,750

[a]From Fischer et al. (1979).

Inventory and Processing Schedules for the Model Plants

Inventory and processing schedules for the four model UHT plants under consideration are given in Tables 7, 8, 9, and 10. These schedules were designed to minimize product change over time. Actual schedules may vary according to the product mix chosen.

The following section estimates the costs associated with the four model plants.

Table 7. Inventory and processing schedule for model UHT plant processing 65,625 gallons per week (Plant A)

Milk inventory	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			(gallons)			
Beginning raw milk inventory	10,938	8,751	6,564	4,376	2,188	0
Raw milk receipts	10,938	10,938	10,937	10,937	10,937	10,938
Total	21,876	19,689	17,501	15,313	13,125	10,938
Milk processed:						
Whole (3.5%)	13,125	5,250	0	0	0	0
2%	0	1,313	13,125	13,125	0	0
1%	0	5,250	0	0	0	0
Skim	0	0	0	0	8,531	0
Chocolate	0	0	0	0	3,281	0
Half-and-half	0	1,312	0	0	1,313	0
Total	13,125	13,125	13,125	13,125	13,125	0
Raw milk holdover	8,751	6,564	4,376	2,188	0	10,938

Table 8. Inventory and processing schedule for model UHT plant processing 150,940 gallons per week (Plant B)

Milk inventory	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			(gallons)			
Beginning raw milk inventory	25,157	20,126	15,095	10,064	5,033	0
Raw milk receipts	25,157	25,157	25,157	25,157	25,155	25,157
Total	50,314	45,283	40,252	35,221	30,188	25,157
Milk processed:						
Whole (3.5%)	30,188	12,075	0	0	0	0
2%	0	3,019	30,188	30,188	0	0
1%	0	12,075	0	0	0	0
Skim	0		0	0	19,622	0
Chocolate	0		0	0	7,547	0
Half-and-half	0	3,019	0	0	3,019	0
Total	30,188	30,188	30,188	30,188	30,188	0
Raw milk holdover	20,126	15,095	10,064	5,033	0	25,157

Table 9. Inventory and processing schedule for model UHT plant processing 301,875 gallons per week (Plant C)

Milk inventory	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			(gallons)			
Beginning raw milk inventory	50,313	40,251	30,189	20,126	10,063	0
Raw milk receipts	50,313	50,313	50,312	50,312	50,312	50,313
Total	100,626	90,564	80,501	70,438	60,375	50,313
Milk processed:						
Whole (3.5%)	60,375	24,150	0	0	0	0
2%	0	6,038	60,375	60,375	0	0
1%	0	24,150	0	0	0	0
Skim	0	0	0	0	39,244	0
Chocolate	0	0	0	0	15,094	0
Half-and-half	0	6,037	0	0	6,037	0
Total	60,375	60,375	60,375	60,375	60,375	0
Raw milk holdover	40,251	30,189	20,126	10,063	0	50,313

Table 10. Inventory and processing schedule for model UHT plant processing 603,750 gallons per week (Plant D)

Milk inventory	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			(gallons)			
Beginning raw milk inventory	100,625	80,500	60,375	40,250	20,125	0
Raw milk receipts	100,625	100,625	100,625	100,625	100,625	100,625
Total	201,250	181,125	161,000	140,875	120,750	100,625
Milk processed:						
Whole (3.5%)	120,750	48,300	0	0	0	0
2%	0	12,075	120,750	120,750	0	0
1%	0	48,300	0	0	0	0
Skim	0	0	0	0	78,488	0
Chocolate	0	0	0	0	30,188	0
Half-and-half	0	12,075	0	0	12,074	0
Total	120,750	120,750	120,750	120,750	120,750	0
Raw milk holdover	80,500	60,375	40,250	20,125	0	100,625

UHT FLUID MILK PROCESSING COSTS

UHT fluid milk processing costs for each of the four model plants are represented by the sum of capital and operating costs. The analysis presented here is termed a standard analysis, *i.e.*, the plant is assumed to operate at rated capacity each processing day.

Capital Investment

Capital investment for each model plant includes the cost of land, building, and equipment.

Land

The model UHT plants in this cost analysis require sufficient space to (1) accommodate buildings, (2) maneuver trucks into place for loading and unloading, (3) provide parking and (4) allow for future plant expansion.

The cost of land acquisition, roadway and site development, and engineering fees is estimated at $15,525 per acre. This estimate is for industrial land outside metropolitan areas; the land cost would be considerably higher within a metropolitan area. Total land investment for the four model plants is given in Table 11.

Table 11. Total land investment for four model UHT fluid milk processing plants

Plant	Acres	Cost
Plant A	3	$46,575
Plant B	4	$62,100
Plant C	5	$77,625
Plant D	6	$93,150

Source: Bass, Nixon and Kennedy, Consulting Engineers, Raleigh, North Carolina

Buildings

Buildings were designed to meet the recommendations in USDA (1963), Layouts and Operating Criteria for Automation of Dairy Plants and were modified for UHT operation as suggested by equipment manufacturers. The major building components of each plant are (1) raw milk receiving area, (2) processing area, (3) filling area, (4) laboratory, (5) cleaning-in-place (CIP) room, (6) product storage room, (7) pallet storage, (8) container storage, (9) dry warehouse, (10) refrigeration equipment room, (11) boiler room, (12) mechanical and electrical room, (13) truck maintenance garage, (14) men's locker room, (15) women's locker room, (16) corridor space, (17) offices, lunchroom, reception area.

Components were arranged to provide short and direct paths of flow of products and containers. Space requirements for various storage rooms were based on the numbers and sizes of items stored, method of stacking, and length of storage period. Table 12 shows space requirements and building investment for the model plants.

Construction costs for this type of building were estimated at $38 per square foot in late 1980. This figure includes general building costs, mechanical costs (heating ducts, plumbing, ventilation, etc.), electrical costs, and architectural and engineering fees. These costs also include the expense of constructing a pressurized filling room at each filler location. Total building investment ranges from $674,956 for Plant A to $3,778,606 for Plant D.

Equipment

A summary of equipment costs for the four model UHT plants is given in Table 13. The major cost items are the costs of sterilizing

Table 12. Space requirements and building investment for four model UHT fluid milk processing plants

Area or room	Plant A (65,625 gals./wk.)	Plant B (150,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,750 gals./wk.)
	(square feet)			
Raw milk receiving	2,352	2,940	3,528	4,163
Processing area	1,129	1,129	1,694	3,338
Filling area	918	2,010	3,339	6,678
Laboratory	95	267	267	267
CIP room	288	288	309	309
Product storage room	6,000	14,793	29,586	59,172
Pallet storage	250	616	1,233	2,466
Container storage	1,000	2,000	2,800	3,344
Dry warehouse	1,020	2,040	3,082	4,000
Refrigeration equipment room	396	723	1,446	2,892
Boiler room	605	907	1,000	1,111
Mechanical and electrical	622	756	807	845
Truck maintenance garage	1,400	1,400	2,700	2,700
Men's locker room	204	204	255	297
Women's locker room	95	204	255	297
Corridor	160	237	320	358
Offices, lunchroom, reception area	1,228	4,300	6,000	7,200
Total	17,762	34,814	58,621	99,437
Total building cost:	$674,956	$1,322,932	$2,227,598	$3,778,606

Source: Bass, Nixon and Kennedy, Consulting Engineers, Raleigh, North Carolina

Table 13. Summary of equipment costs for four model UHT processing plants

Operation or function	Equipment cost			
	Plant A (65,625 gals./wk.)	Plant B (150,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,750 gals./wk.)
Receiving	$ 31,625	$ 31,625	$ 31,625	$ 37,318
Cold milk separator	39,500	80,000	118,500	147,000
Raw milk and cream storage	46,000	68,000	108,000	197,000
Ratio controller	27,000	27,000	50,000	72,000
Blender system	15,000	15,000	15,000	15,000
UHT sterilization	224,000	290,000	394,000	766,000
Aseptic surge tanks	45,000	76,000	125,000	184,000
Filling operation[a]	305,000	1,000,000	2,000,000	4,000,000
Milk testing, COP	6,000	6,000	8,000	8,000
Pallet handling	7,000	14,000	28,000	56,000
Refrigeration	48,475	65,293	80,594	120,365
Boilers	81,075	256,680	363,400	474,000
Installation[b]	121,365	211,092	283,698	469,060
Total investment	$997,040	$2,140,690	$3,605,817	$6,545,743

[a]Includes Brik-Pak filling machines, straw applicators for 1/2 pt. fillers, tray packers, and shrink film wrappers. This equipment cost is based on a base rental fee plus installation.

[b]Calculated at 25% of raw milk and cream storage, 25% of processing, and 30% of cost of refrigeration and boilers. Also includes cost of sanitary lines and valves.

equipment and fillers. Itemized equipment needs and costs for each model UHT plant as recommended by the equipment manufacturers are given in Appendix Tables 1, 2, 3, and 4.

Total investment in land, buildings, and equipment is $1,718,571 in Plant A, $3,525,722 in Plant B, $5,911,040 in Plant C, and $10,417,499 in Plant D (Table 14).

Table 14. Investment in land, buildings, and equipment for four model UHT fluid milk processing plants

	Cost			
Item	Plant A (65,625 gals./wk.)	Plant B (150,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,750 gals./wk.)
Land[a]	$ 46,575	$ 62,100	$ 77,625	$ 93,150
Building[b]	674,956	1,322,932	2,227,598	3,778,606
Equipment[c]	997,040	2,140,690	3,605,816	6,545,743
Total	$1,718,571	$3,525,722	$5,911,040	$10,417,499

[a]From Table 11.

[b]From Table 12.

[c]From Table 13.

These investment costs must be converted into annual costs to compute total costs per unit processed.

Annualized Capital Cost

To arrive at an annual cost of owning land, buildings, and equipment, the capital recovery formula presented on page 15 was used.

Useful economic life of buildings and equipment was assumed to be 20 years. This figure represents the equipment manufacturer's best estimate of the useful life of the machinery and storage tanks. All capital funds were assumed to be borrowed, although this need not be the situation for actual plants. An interest rate of 15 percent was used for the special purpose plant and equipment, as quoted by Bass, Nixon, and Kennedy. For ease in calculation, it was assumed that there would be no salvage value associated with the capital inputs at the end of the twenty year period. The investment in land was subject to an interest charge only and the salvage value is assumed to be equal to the acquisition cost.

Table 15 shows the annual charge for capital recovery (ACCR) for owning land, buildings, and equipment for each of the four model plants.

Table 15. Annual Charge for Capital Recovery (ACCR) of land, buildings, and equipment for four model UHT fluid milk processing plants[a]

	ACCR			
Item	Plant A (65,625 gals./wk.)	Plant B (150,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,750 gals./wk.)
Land	$ 6,986	$ 9,315	$ 11,644	$ 13,973
Buildings and equipment	267,135	553,383	932,005	1,649,831
Total annual cost	$274,171	$562,802	$943,824	$1,663,804
Total weekly cost	$ 5,273	$ 10,823	$ 18,150	$ 31,996

[a]Based on a 20-year expected useful life of equipment and building, 15 percent interest rate, and 52-week processing year.

Table 16. Estimated weekly labor requirements for four model UHT fluid milk processing plants

Operation	Plant A (65,625 gals./wk.)	Plant B (150,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,750 gals./wk.)
		(man-hours)		
Receiving and cleaning tankers[a]	35	45	60	80
Separate, sterilize milk[a]	80	80	160	320
Filling[b]	80	160	240	400
Pallet handling[b]	80	160	240	480
Product storage[b]	80	80	160	160
Warehouse and supply handling[b]	80	80	160	160
Cleanup and janitorial[b]	20	40	80	160
Maintenance	120	120	240	360
Relief	—	—	40	80
Total regular hours	575	765	1380	2200
Overtime hours 5%	29	38	69	110
Total hours	604	803	1449	2310

[a]Based on eight working hours per day, five days per week.

[b]Based on sixteen working hours per day, five days per week.

Operating Costs

Labor

Direct labor requirements were estimated for each plant activity from information supplied by equipment manufacturers (Table 16). On a per-shift basis, seven employees are needed in Plant A, ten employees in Plant B, seventeen employees in Plant C, and twenty-eight employees in Plant D. A base wage of $8.60 per hour was used for hourly employees. Employee benefits, including payroll taxes, workman's compensation, unemployment insurance, pensions, and uniforms were assumed to add 25 percent to the base wage (U. S. Department of Labor, 1978). Table 17 shows the computation of weekly direct labor costs for each of the four model plants.

Table 17. Total weekly direct labor cost for four model UHT fluid milk processing plants

Item	Plant A (65,625 gals./wk.)	Plant B (510,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,705 gals./wk.)
Weekly base wage (8.60/hr.)[a]	$4,945	$6,579	$11,868	$18,920
Weekly overtime wage (12.90/hr.)[a]	374	490	890	1,419
Cost of benefits at 25% base wage	1,236	1,645	2,967	4,730
Total weekly direct labor costs	$6,555	$8,714	$15,725	$25,069

Source: United States Department of Labor, 1978.

Administrative and clerical personnel include office workers, managers, and clerical workers associated primarily with in-plant activities. Weekly payroll expense for administrative and clerical labor amounted to $2,400 in Plant A, $3,800 in Plant B, $5,300 in Plant C and $7,200 in Plant D.[3]

Containers

Volume discounts are not available on container material. There is, however, a labor cost savings at plant size D because of the use of 10,000-unit container rolls instead of the customary 2,500-unit rolls used in Plants A, B and C. Table 18 shows container cost by size of container as well as the costs associated with trays and shrink film.

Table 18. Weekly container cost for four model UHT fluid milk processing plants

Container size	Plant A (65,625 gals./wk.)	Plant B (150,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,750 gals./wk.)
Quart	$17,588	$35,176	$ 70,352	$140,704
1/2 pint[a]	0	9,450	18,900	37,800
Total container	$17,588	$44,626	$ 89,252	$178,504
Trays: Qt.	$ 3,281	$ 6,562	$ 12,124	$ 26,248
1/2 pt.	0	1,750	3,500	7,000
Shrink film	219	555	1,110	2,220
Total container plus accessories	$21,088	$53,493	$106,986	$213,972
Cost per quart	$ .0803	$ .0803	$ .0803	$ .0803
Cost per 1/2 pt.	0	.0360	.0360	.0360
Cost per gallon equiv.	.3213	.3544	.3544	.3544

[a]Includes cost of straws.

[3]Estimates provided by Bass, Nixon and Kennedy, Consulting Engineers, Raleigh, North Carolina.

Supplies

The four model plants can be expected to use a wide assortment of cleaning, laboratory, janitorial, and office supplies. The costs of these items on a per-gallon basis are assumed to be constant for all plant sizes. Cost estimates for supplies were obtained from equipment manufacturers (Cherry-Burrell, Brik-Pak). Weekly cost for supplies amounted to $385 in Plant A, $891 in Plant B, $1,781 in Plant C, and $3,562 in Plant D.

Brik-Pak Maintenance

In addition to the customer's own maintenance costs already included in Tables 16 and 17, the filler manufacturer provides maintenance service for the fillers at a cost of $.0113 per gallon of fluid milk filled. Total weekly Brik-Pak maintenance charges amount to $742 in Plant A, $1,706 in Plant B, $3,411 in Plant C, and $6,822 in Plant D.

Pallet Expense

For every pallet of milk loaded daily, there are estimated to be five empty pallets awaiting pickup at various points along distribution routes and in the pallet storage room, and the product remains on the pallet for ten days in storage. Each pallet is assumed to hold 152 gallons of product in half-pint containers or 225 gallons of product in quart containers. For Plant A an inventory of 0.067 pallet per gallon of daily output is required. The average pallet load for Plants B, C and D is assumed to be 198 gallons, and the pallet inventory is 0.76 pallets per gallon of daily output. At a cost of $8 per pallet and a 50 percent annual replacement rate, the weekly pallet expense is $67 in Plant A, $176 in Plant B, $353 in Plant C, and $706 in Plant D.

Electricity

Electricity rates used in this analysis were those quoted by Carolina Power and Light Company as being representative of national averages. These rates include a "demand charge" and "energy charge." The demand charge is based on peak average kilowatt load during any 20-minute interval. The energy charge is based on the total number of kilowatt hours (KWH) used. Both demand and energy charges are priced on a decreasing block rate basis, leading to lower electricity cost per KWH as quantity of energy used increases.

Electricity used in UHT milk sterilization, aseptic packaging, pallet handling, and refrigeration was calculated by (a) multiplying motor horsepower by weekly operating hours for each motor, (b) adding to get total weekly horsepower hours (Hp.-Hrs.), (c) converting to kilowatt hours with the factor 1 Hp-Hr. = 1 KWH.[4] Electrical energy use for lighting was specified at 3 watts per square foot of building space and applied to the total number of hours per week the plant operates. Energy use and weekly cost are summarized for the four model UHT plants in Table 19.

Fuel

Natural gas was specified for sealing containers and for water, product, and plant heating. Gas consumption estimates were calculated for 35 hours of operation in Plant A, 41 hours in Plant B, 44 hours in Plant C, and 50 hours in Plant D, plus the actual operating times and gas requirements for filling equipment. Estimated weekly gas consumption is 161 million cubic feet (MCF) in Plant A, 336 MCF in Plant B, 406 MCF

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[4]The theoretical conversion factor is 1 Hp-Hr = 0.7456 KWH, but the actual energy use is greater because motors operate at less than 100 percent efficiency and the load characteristics may differ from rated horsepower of the motor.

in Plant C, and 812 MCF in Plant D. Total gas costs were calculated with the 1980 national average gas price of $2.2563 per MCF.[5]

Weekly natural gas cost amounted to $363 in Plant A, $758 in Plant B, $916 in Plant C, and $1,832 in Plant D.

Table 19. Electrical energy use in four model UHT fluid milk processing plants

Operation	Plant A (65,625 gals./wk.)	Plant B (150,940 gals./wk.)	Plant C (301,875 gals./wk.)	Plant D (603,750 gals./wk.)
	(kilowatt hours per week)			
UHT processing	1,475	5,365	10,059	18,777
Filling, tray packing, shrink film wrapping, straw applicator	963	2,951	5,633	9,388
Pallet handling	1,341	4,024	5,365	8,906
Refrigeration	2,414	2,682	4,694	9,388
Lighting	674	1,200	1,800	2,600
Total	6,867	16,222	27,551	49,059
Weekly cost	$ 323	$ 649	$ 1,047	$ 1,864
Cost per gallon	$0.0049	$0.0043	$0.0035	$ .0031

Water and Sewage

The weekly cost for water and sewage disposal amounted to $151 in Plant A, $340 in Plant B, $694 in Plant C, and $1,389 in Plant D. These costs were estimated by equipment manufacturers and by Bass, Nixon and Kennedy, the consulting firm questioned in this analysis.

[5]Estimated by equipment manufacturers and by Bass, Nixon and Kennedy, Consulting Engineers, Raleigh, North Carolina.

Taxes and Insurance

Property taxes were applied to 100 percent of the average value of land and buildings over the expected life of the buildings. The tax rate used was 83 cents for every $100 of land and building value. This rate is representative of the national average in 1980 as reported by Bass, Nixon and Kennedy. Weekly property taxes amount to $160 for Plant A, $334 for Plant B, $531 for Plant C, and $893 for Plant D.

Boiler, fire and refrigeration system insurance, based on premiums suggested by State Farm insurance, is $161 per week in Plant A, $187 in Plant B, $193 in Plant C, and $216 in Plant D. These insurance rates are national averages as calculated by the insurance agency.

UHT Fluid Milk Processing Costs

Table 20 summarizes total UHT fluid milk processing costs for the four model plants. Estimated cost per gallon declines from $.5740 in Plant A to $.5424 in Plant B, $.5137 in Plant C and $.4895 in Plant D.

Because the UHT fluid milk is packaged in quarts and half pints, it is also useful to express total per-unit cost of processing on the basis of these container sizes.

To generate these costs, each model plant's total cost is broken down into container cost and non-container cost. As an example, plant size B has total weekly cost of $81,871. Of this total, $53,493 is attributable to the cost of containers including trays, straws and shrink film, leaving $28,378 for non-container cost. Non-container cost per gallon processed in Plant B is $.1880. Expressed in terms of quarts and half pints, these costs are $.0470 and $.0118, respectively. Container cost may now be added to non-container cost. Container costs, Table 18, were $.0803 per quart filled and $.0360 per half pint filled for each plant size. The

Table 20. Investment and operating costs for four model UHT fluid milk processing plants, per week and per gallon

Item	Plant A (65,625 gal./wk.)		Plant B (150,940 gal./wk.)		Plant C (301,875 gal./wk.)		Plant D (603,750 gal./wk.)	
	Weekly cost	Cost/ gal.	Weekly cost	Cost/ gal.	Weekly cost	Cost/ gal.	Weekly cost	Cost/ gal.
Capital investments								
Land[a]	$ 134	$.0020	$ 179	$.0012	$ 224	$ .0007	$ 269	$.0004
Buildings and equipment[a]	5,138	.0783	10,644	.0705	17,927	.0594	31,727	.0525
Operating costs								
Direct labor	6,555	.0999	8,714	.0577	15,725	.0521	25,069	.0415
Administrative and clerical labor	2,400	.0366	3,800	.0252	5,300	.0176	7,200	.0119
Containers, trays, and shrink film	21,088	.3213	53,493	.3544	106,986	.3544	213,972	.3544
Supplies	385	.0059	891	.0059	1,781	.0059	3,562	.0059
Brik-Pak filler maintenance	742	.0113	1,706	.0113	3,411	.0113	6,822	.0113
Pallet expense	67	.0010	176	.0012	353	.0012	706	.0012
Electricity	323	.0049	649	.0043	1,047	.0035	1,864	.0031
Fuel	363	.0055	758	.0050	916	.0030	1,832	.0030
Water and sewage	151	.0023	340	.0023	694	.0023	1,389	.0023
Taxes and insurance	321	.0049	521	.0035	724	.0024	1,109	.0018
Total	$37,667	$.5740	$81,871	$.5424	$155,088	$.5137	$295,521	$.4895

[a]Based on ACCR and upon a 52-week processing year.

total of the container and non-container cost per quart processed in Plant B is $.1273 and total processing cost per half pint is $.0478.

The same procedure was used to generate costs per quart and half pint for the remaining plant sizes, resulting in the following:

Total cost per quart processed in Plant A is $.1435, Plant B, $.1273, Plant C, $.1201, and Plant D, $.1141.

When expressing the cost of half pints for each plant size, total costs decrease from $.0478 in Plant B to $.0460 in Plant C and $.0444 in Plant D.

Interest on Inventory

Because UHT products have an extended shelf life, there are likely to be higher inventory costs than for similar HTST products. At this stage, it is not clear who will bear these costs, the processor, the wholesaler or the retailer. However, this analysis assumes that the packaged product would be stored in an unrefrigerated warehouse for a minimum of ten days to permit the flavor to improve and for quality control purposes. This represents an added expense to the UHT processor in the form of interest charges on the cost of the product in inventory, including the raw product cost. The 1980 average Class I minimum price in federal order markets was $13.77 per hundred pounds. Using a conversion factor of 11.6 gallons per hundred pounds and assuming 2.0 percent loss yields a raw product cost of $1.2113 per gallon to be added to the processing costs calculated above. Using an annual interest rate of 15 percent yields interest on inventory costs of $.0022 for the quart packages for Plant A, $.0019 per quart for Plants B and C, and $.0018 for Plant D. The interest cost is $.0005 for the half pint container for Plants B, C and D.

The final cost of the quarts and half pints for each plant size is summarized in Table 21.

Table 21. Total processing, packaging and inventory costs for four model UHT fluid milk processing plants, by container size

Item	Total cost per unit			
	Plant A (65,625 gal./wk.)	Plant B (150,940 gal./wk.)	Plant C (301,875 gal./wk.)	Plant D (603,750 gal./wk.)
Quart	$.1455	$.1292	$.1220	$.1159
1/2-pint	-	.0483	.0465	.0449
Gallon	.5818	.5501	.5213	.4970

RESULTS

Model UHT fluid milk processing plants were developed to process, package, and store 65,625 gallons of milk per week (Plant A), 150,940 gallons per week (Plant B), 301,875 gallons per week (Plant C), and 603,750 gallons per week (Plant D).

Standard Analysis

When model plants are operated at their rated capacity, unit costs decrease as plant size increases from 65,625 to 603,750 gallons processed per week. This indicates that UHT fluid milk processing operations exhibit economies of scale. These economies are illustrated in Figure 5 and are based on the data in Table 20.

By calculating the percentage change in unit costs as plant size increases, it can be seen that these economies are not uniform but tend to diminish as plant size increases. Between Plants A and B, there is a 5.50 percent decrease in the cost per gallon of fluid milk processed. Between Plants B and C there is a 5.29 percent decrease, and between Plants C and D, a 4.71 percent decrease. Cost per gallon decreased by 14.72 percent across the entire range of plant sizes. This figure compares to a 9.14 percent decrease in the cost per liter processed

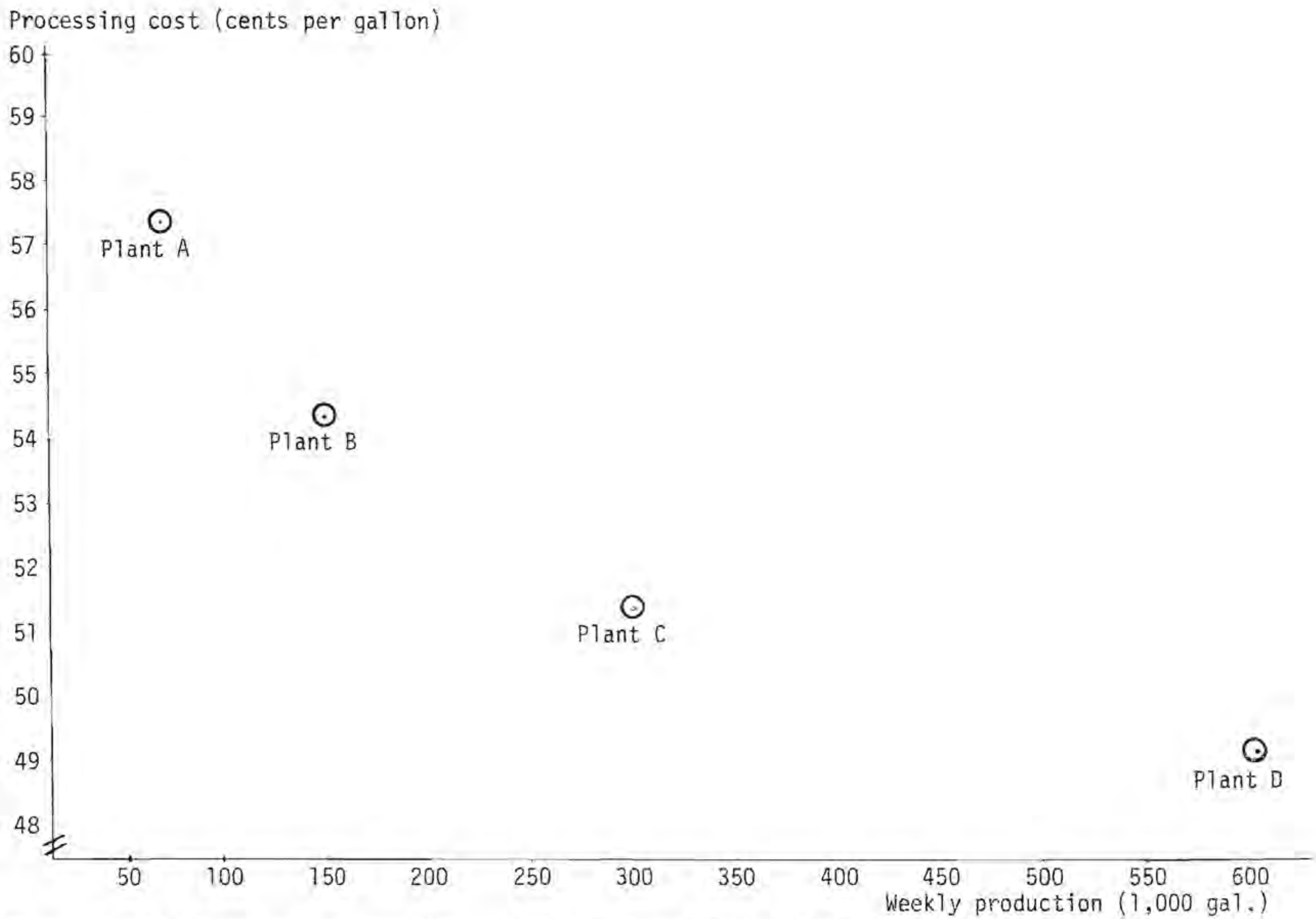

Figure 5. Total per unit processing cost for four model UHT fluid milk processing plants.

estimated by a study conducted by the Manitoba Dairy Board (Weijs, et. al., 1977). The main reason for the difference in the extent of observed economies of scale between the two studies is that the Manitoba study dealt with much smaller plants than those studied here and so did not capture the cost savings associated with larger capacity UHT fluid milk processing plants.

In general discussions of the feasibility of UHT products in the United States, the costs of UHT processing invariably will be compared to those of conventional pasteurization. This is because UHT milk products probably will be sold in competition with HTST products. Therefore, it is useful to compare the estimated costs of UHT fluid milk processing found in this study with Fischer's (Fischer et al., 1979) study, which estimated processing costs for HTST fluid milk. By comparing the two studies, feasibility of UHT fluid milk processing may be better understood from the individual firm's perspective.

The estimated cost of UHT fluid milk processing, Table 20, varies from a high of $.5740 per gallon for plant size A (65,625 gallons per week) to $.4895 per gallon for plant size D (603,750 gallons per week). These costs are approximately double those estimated by Fischer et al. (1979) for new HTST processing operations. Fischer estimated fluid milk processing costs from $.2614 per gallon for a plant processing 50,000 gallons per week to $.1970 per gallon for a plant processing 400,000 gallons per week after adjusting for differences in cost catagories included in his estimates and the UHT estimates presented here. Because Fischer's work was done almost two years before this UHT study, it is necessary to adjust his cost estimates for inflation. The adjusted estimates are a $.3302 cost per gallon for a 50,000-gallon per week plant, $.2610 for a

200,000-gallon per week plant and $.2451 for a 400,000-gallon plant. By interpolation, these estimates suggest that UHT processing costs are 80 to 100 percent higher than HTST processing costs for similarly sized plants, and that small HTST plants have lower costs than large UHT plants. Furthermore, Fischer also found that HTST processing costs decreased by 24.1 percent as plant production increased from 50,000 to 400,000 gallons per week, whereas UHT processing costs decrease by only 14.7 percent as plant increases from 65,625 to 603,750 gallons per week. Therefore, the economies to be gained in UHT processing are less pronounced.

It is beyond the scope of this study to evaluate the likely market share of UHT fluid milk products, but it must be noted that a small market share relative to HTST products implies smaller, higher cost UHT plants competing with larger HTST plants enjoying the substantial cost advantages of economies of scale. Furthermore, existing HTST plants already have made their capital investments and can, if necessary, operate under price and volume conditions that permit them to cover their operating expenses only. However, a new UHT plant is a financially attractive venture only if the expected returns exceed both the investment and operating costs.

These results imply that for UHT fluid milk to compete successfully with HTST fluid milk in the United States, substantial cost savings must lie in other areas of UHT milk marketing relative to HTST milk marketing, e.g., in the distribution and retailing aspects of UHT fluid milk. UHT fluid milk requires no refrigeration and thus, cost savings may arise in the distribution and retailing of UHT fluid milk products in comparison to HTST products. If not, feasibility will depend on consumers being willing to pay a price premium for UHT fluid milk products to offset the additional processing costs.

To clarify the differences in estimated per-unit processing costs between UHT and HTST fluid milk products, a breakdown of the various cost items in both studies is presented.

Capital costs for the UHT processing building, land, and equipment constitute 14.0 percent of total cost for Plant A, 13.2 percent for Plant B, 11.7 percent for Plant C, and 10.8 percent for Plant D, Table 20. Capital investment cost declined by $.0274 per gallon across all plant sizes. This figure translates into a 34.1 percent decrease in capital cost per gallon across all plant sizes. This savings results from substantially lower investment requirements per gallon of weekly output for large plants, even though there are no cost savings attributed to numbers of fillers in operation. These cost reductions stem from lower per gallon investment costs for sterilization equipment and buildings as plant size increases.

In contrast, HTST capital investment costs per gallon decreased by 58.5 percent across all plant sizes, suggesting that UHT operations exhibit less of a reduction in capital costs relative to HTST operations as plant size increases (Fischer et al., 1979).

Operating costs constitute 86.0 percent of total cost in Plant A, 86.8 percent in Plant B, 88.3 percent in Plant C, and 89.2 percent in Plant D, Table 20.

Among operating inputs, containers are the most costly item, accounting for 56.0 percent of total cost in Plant A, 65.3 percent in Plant B, 69.0 percent in Plant C, and 72.4 percent in Plant D. The reason container costs account for a higher percentage of total costs as plant size increases is that total per-unit cost decreases, but the container cost per unit is constant at $.3544 per gallon processed for Plants B, C and D.

Comparable container costs for HTST processed products are approximately $.122 per gallon, based on Fischer's study and adjusted for inflation. Thus, container costs in UHT processing operations are approximately $.23 more per gallon than in HTST operations, and they contribute to a greater percentage of total per-unit costs than do HTST containers.

Non-container costs constitute the remainder of operating costs. Labor cost (including administrative and clerical labor) accounts for 23.8 percent of total cost in Plant A, 15.3 percent in Plant B, 13.6 percent in Plant C, and 10.9 percent in Plant D. These figures suggest that higher labor productivity is achieved as plant size increases and is most pronounced between Plants A and B (see Table 20). Labor cost savings are the major contributing factor to economies of size as plant size increases. These savings resulted mainly from the use of less labor in the filling and product storage stages of plant operations as plant size increased (see Table 16). Fischer *et al*. (1979) found that labor costs contributed roughly 20 percent to total cost across all plant sizes. This suggests that UHT processing operations are less labor intensive than comparable HTST plant operations.

Effect of a Change in Plant Utilization Level

Because of seasonal variations in fluid milk sales, all fluid milk processing firms experience variation in plant utilization levels. Generally, peak daily sales occur in October or November, and sales "bottom out" in June. Daily fluid milk sales in June average 80 to 83 percent of daily sales during October and November (Fischer *et al*., 1979).

In addition to seasonal variations in fluid milk sales, there also exist daily fluctuations in the demand for fluid milk within any one plant in the United States. Because of the increased storability of UHT fluid milk products in contrast to HTST ones, we would expect to see a higher level of efficiency in UHT plants as processors or retailers would be able to meet daily fluctuations out of stored inventory. It is interesting to note that also because of the extended storability of UHT fluid milk compared to HTST fluid milk, some of the seasonal fluctuations may be reduced.

To illustrate the economic effect of plant utilization level on total cost, the four model plants were assumed to operate at 80 percent of their rated output. Capital, taxes, insurance, administrative, and general maintenance costs were held constant because these costs are fully incurred regardless of output rate. Costs for hourly labor, containers, filler maintenance, supplies, and other variable items were reduced in proportion to output, and the effects of plant utilization at an 80 percent level were compared to the standard analysis.

It was found that per-unit costs increased by \$.0333 (5.8 percent) for Plant A, \$.0278 (5.1 percent) for Plant B, \$.0228 (4.4 percent) for Plant C, and \$.0196 (4.0 percent) for Plant D. This result shows that unit costs are proportionately less affected by variations in plant utilization at the larger plant sizes than at the smaller ones. Effects on unit costs of operating the plants at the 80 percent and the 100 percent utilization levels are illustrated in Figure 6.

Effect of Change in Wage Rate

It was previously noted that labor costs were the major factor contributing to realized economies of size in UHT fluid milk processing. The wages used, while representative of wages throughout the industry,

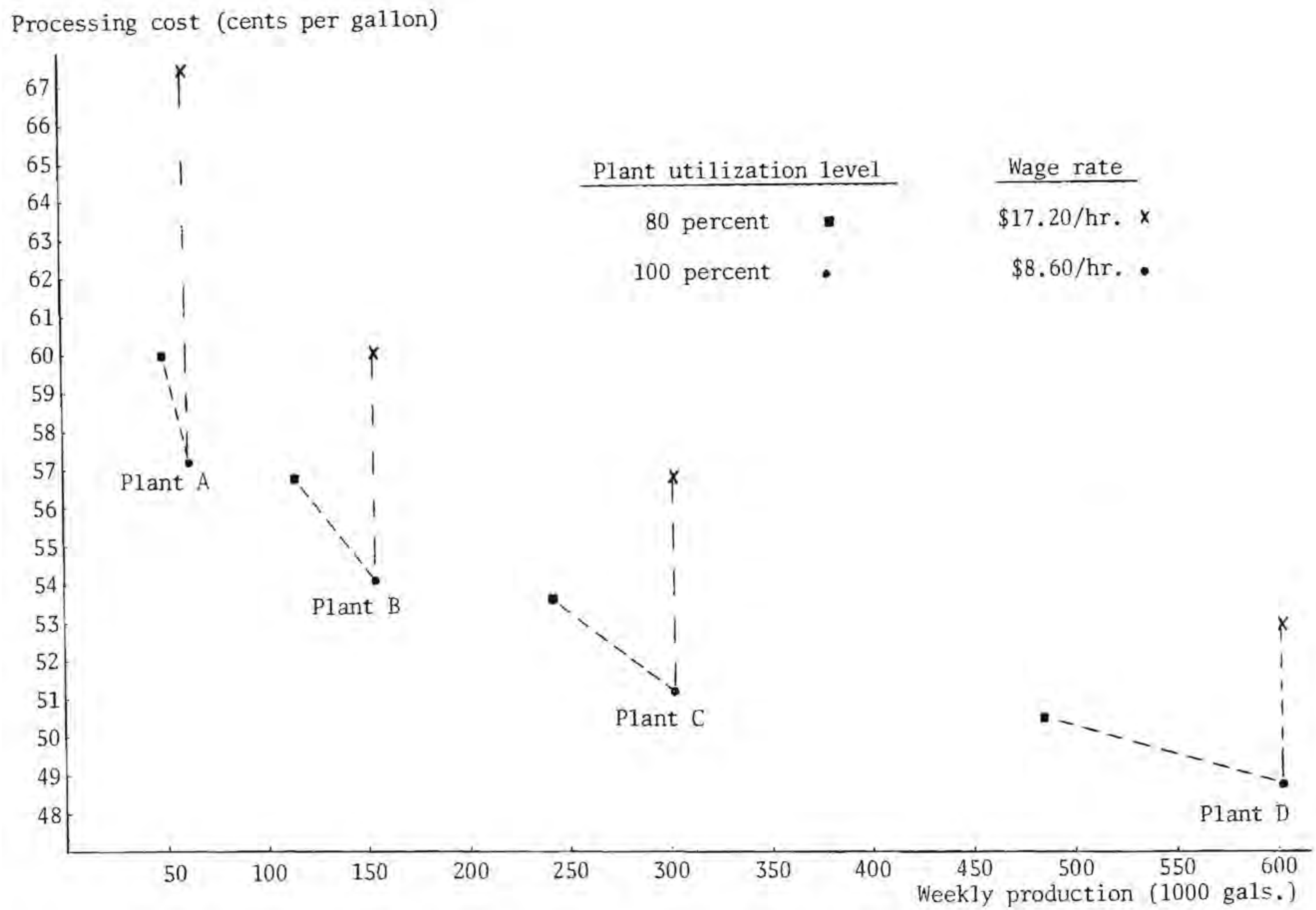

Figure 6. Effects of plant utilization level and wage rate on UHT fluid milk processing costs for four model UHT fluid milk processing plants.

will not apply to all individual plants or in all seasons. Local labor conditions and customs may lead to costs that differ significantly from the least cost figures for each model plant in this study.

To estimate the effect on total plant cost of variable direct labor wage rates, an hourly wage of $17.20 was compared with the standard $8.60 per hour rate. Unit cost increased by $.0999 (17.4 percent) in Plant A, $.0577 (10.6 percent) in Plant B, $.0521 (10.1 percent) in Plant C, and $.0415 (8.5 percent) in Plant D. These results suggest that unit costs are much more affected by wage rate increases in Plant A than in the three larger plants. This is because labor costs contribute more to total cost on a per-unit basis in Plant A than in any other plant. Graphically, these results are shown in Figure 6.

Effect of Change in Interest Rate

Interest rates have varied considerably during the past few years. For this reason, an interest rate of 20 percent was compared to the standard 15 percent interest rate used.

An interest rate of 20 percent for capital investments increased per-unit costs by $.0230 (4.0 percent) in Plant A, $.0205 (3.8 percent) in Plant B, $.0172 (3.3 percent) in Plant C, and $.0152 (3.1 percent) in Plant D. Again, it can be seen that per-unit costs in the smaller plants are more affected by interest rate increases than they are in larger plant sizes because capital investment contributes to a larger percentage of total per-unit cost in the smaller plant sizes. Graphically, these results are seen in Figure 7.

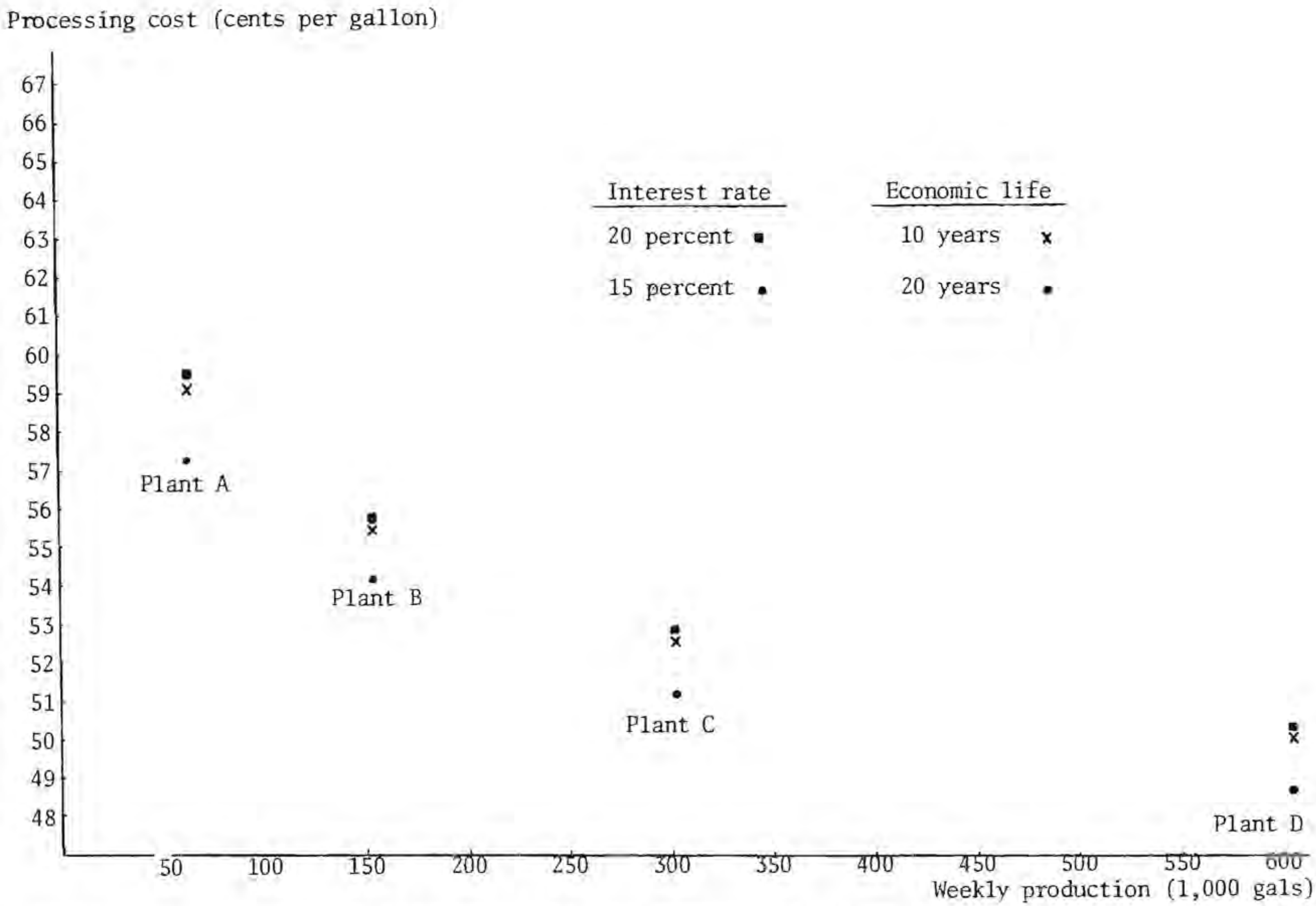

Figure 7. Effects of interest rate and economic life on UHT fluid milk processing costs for four model UHT fluid milk processing plants.

Effect of Change in Economic Life

A firm wishing to invest in UHT fluid milk processing is also confronted with a decision as to the time horizon over which to depreciate its capital investments. To illustrate the effect of different perceived economic lives of buildings and equipment on total per-unit costs, an economic life of 10 years on buildings and equipment was compared to the standard 20-year analysis.

It was found that total per-unit cost increased by $.0193 (3.4 percent) in Plant A, $.0174 (3.2 percent) in Plant B, $.0147 (2.9 percent) in Plant C, and $.0130 (2.7 percent) in Plant D. Note that the increases are small and there is very little difference in the increases in total per-unit cost between plant sizes, suggesting that a change in the expected economic life of buildings and equipment will have little effect on the feasibility of UHT investments or in the choice of plant sizes to be built. The effect on total per-unit cost of a 10-year economic life on buildings and equipment in contrast to the standard 20-year analysis is illustrated in Figure 7.

OTHER FACTORS

Assembly, Distribution and Retailing Costs

The size UHT milk processing plant a firm might wish to build will depend on raw milk assembly costs and wholesale distribution costs in addition to the processing costs evaluated in this study.

UHT milk is processed from Grade A raw milk and there are no unique differences between the assembly of raw milk for UHT or HTST processing.

Therefore, assembly costs will be equivalent to those experienced by similar HTST plants. Wholesale delivery methods and costs will differ from HTST delivery because refrigeration is not required. This allows UHT milk to be handled as a dry grocery item and distributed through grocery warehouse channels. Retail store costs will differ for the same reason. Estimating these costs is beyond the scope of this study; however these costs are likely to be lower for UHT than for HTST milk for comparable deliveries (Benson, 1979).

The optimum size of plant and its location, will be the one having the lowest combination of assembly, processing and wholesale distribution costs.

Investment Analysis

Before deciding to invest in UHT milk processing, a firm should evaluate the expected profits from the investment. The procedures used in this study are not appropriate for investment analysis and, therefore, a review of the alternative methods for evaluating investment opportunities is appropriate.

Traditionally, many firms have used the payback formula as a rough approximation of the desirability of alternative investment projects. If we assume that a project has equal annual net revenues, the payback can be calculated from the following formulas (Levy and Sarnat, 1978):

$$\text{Payback period} = \frac{\text{Initial Investment}}{\text{Annual Net Revenue}}$$

Even if net revenue is expected to fluctuate over time, the payback period is still easily calculated by summing the annual net income until the initial investment outlay is recovered.

The payback formula has some rather obvious defects. The formula does not discount for the future returns, thus $1 of future income receives the same weight as current income. Perhaps even more important, it concentrates attention solely on net income within the payback period, ignoring income in later years.

Two methods of investment appraisal are available that incorporate the concept of discounting expected future income and expenses and include the stream of earnings and expenses over the entire economic life of the investment. These two methods are: Net Present Value (NPV), derived by discounting a project's net income using the minimum required rate of return on new investment or the cost of capital, summing them over the lifetime of the proposal and deducting the initial investment outlay; and the Internal Rate of Return (IRR), which expresses the stream of net income as a rate of return on the initial investments (Levy and Sarnat, 1978).

Assuming that the firm wishes to maximize profits and therefore the wealth of its shareholders, the following decision rules can be derived for the NPV method:

When NPV is positive, accept the project.

When NPV is negative, reject the project.

The following decision rules are associated with the IRR method:

If IRR exceeds the required rate of return, accept the project.

If IRR is less than the required rate of return, reject the project.

Net Present Value and the Internal Rate of Return both give equivalent results with regard to independent conventional projects; they do not, however, rank projects the same. This difference in ranking becomes crucial when projects are mutually exclusive, that is when the firm must choose the best (highest ranking) proposal out of two or more alternatives. NPV provides the more appropriate criterion because it reflects the absolute magnitude of the project's returns, whereas the IRR does not. This is a point in the NPV's favor because the firm is concerned with absolute profits and not merely with the rate of profit. Also, in some cases it is not possible to compute an IRR for a project (Levy and Sarnat, 1978).

NPV provides an optimal solution to a firm's investment and capital budgeting decisions based on projected cash flows and the appropriate cost of capital (discount rate).

Industry Structure

As discussed in the introduction, economies of scale are a major factor determining industry structure and prices. The cost estimates generated in this study and depicted in Figure 5 show substantial economies of scale in UHT milk processing. This suggests that, if the initial experience with UHT milk is successful, new and relatively large plants can be expected to enter the market. In the long run, the larger plants will dominate the industry and prices will be determined, in part, by the costs of these more efficient plants. Survival of a particular firm will depend on its processing and distribution costs relative to those of its competitors in a given market, including both HTST and other UHT processors.

Size of capital investment can be viewed as a barrier to the entry of firms into UHT milk processing. The high cost of promotion and the financial risk associated with a new product are additional barriers to entry. Therefore, the large regional and national multi-plant dairy organizations seem more likely to enter this market than the smaller, single plant firms.

SUMMARY AND CONCLUSIONS

The objectives of this study were:

(I) To develop different sized models of UHT plants capable of processing, packaging, and storing UHT fluid milk products.

(II) Based on these model plants and 1980 and 1981 prices, to develop representative unit costs of packaging a selected mix of container sizes for UHT fluid milk.

(III) To measure the sensitivity of unit costs to variations in efficiency of plant use, as well as to measure the differences in unit costs under different factor prices.

(IV) To evaluate the results generated in I through III to provide information that can be used to guide decisions in evaluating the feasibility of UHT processing and in planning new UHT fluid milk processing facilities.

(V) To evaluate the results as in IV to provide information on the likely structure of the UHT fluid milk processing industry.

Model plants were developed that were capable of processing, packaging, and storing 65,625 gallons of fluid UHT milk per week (Plant A), 150,940 gallons per week (Plant B), 301,875 gallons per week (Plant C), and 603,750 gallons per week (Plant D). These model plants were designed to cover the expected range in plant sizes if UHT fluid milk products were to become commercially successful in the United States. Furthermore, these models were designed to maximize the operating efficiency of each plant relative to rated filler capacity.

Based on the technology of the filler and recent U. S. market data, each plant was assumed to employ a constant filler mix of two quart fillers for each half pint filler in operation, except for Plant size A, which utilizes one quart filler only.

This study estimated the per-unit processing and packaging costs to be $.5740 per gallon for plant size A, $.5424 per gallon for plant size B, $.5137 per gallon for plant size C, and $.4895 per gallon for plant size D. When interest on the value of inventory of processed UHT milk, including raw product cost, was included these costs increased by $.0078 to $.0075 per gallon. These results suggest that UHT processing operations are characterized by economies of scale. These economies are most pronounced in labor cost savings as plant size increases. However, a comparison of these cost estimates with a previous study of HTST processing costs shows that UHT processing costs are 80 to 100 percent greater than equivalent costs for new HTST plants of similar size. Furthermore, the HTST plants exhibited greater economies of scale than did UHT plants.

Container costs represent the greatest percentage of total costs in UHT processing and packaging. Volume discounts are not available on UHT containers and they were found to contribute $.3544 to the average cost of every gallon of fluid milk processed compared to $.122 per gallon for HTST processed, conventionally packaged products.

Compared to new HTST processing plants, UHT processing plants are more capital intensive and less labor intensive. A sensitivity analysis revealed that when utilization of each plant was reduced, unit costs were found to be less affected at the larger plant sizes.

These findings suggest that the feasibility of producing UHT processed fluid milk products will depend in large measure on the availability of offsetting cost savings in distribution or the willingness of consumers to pay a price premium for UHT products. The structure of the UHT processing industry will depend on consumer acceptance of the product at a price that covers production and distribution costs. Large consumer demand within a small geographic area is necessary both to obtain the processing cost reductions through economies of scale and to minimize distribution costs. Thus, economies of scale in processing are only one factor to consider. A firm interested in UHT fluid milk processing would be well advised to consider the total anticipated demand for UHT products, competition from other UHT processors and competition from HTST and non-milk products, raw product supplies, and distribution costs when deciding the optimum size and location of a UHT plant.

Further study needs to be undertaken both to establish consumer acceptance and public demand for UHT fluid milk products and to determine the costs of distribution and retailing of UHT fluid milk products before the overall feasibility of UHT processing in the United States can be determined.

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APPENDIX

ITEMIZED EQUIPMENT REQUIREMENTS AND COSTS FOR THE FOUR-MODEL UHT FLUID MILK PROCESSING PLANTS

Appendix Table 1. Itemized equipment requirements for plant A

Item	Cost[a]
100 GPM receiving pump	$ 1,650
2 tank CIP unit[b]	27,000
CIP transport tank washer	1,100
COP portable tank	1,875
25,000 lbs./hr. cold milk separator	39,500
7,000 gallon raw storage tank[c] (2)	34,000
500 gallon cream storage tank[c] (2)	12,000
Ratio controller	27,000
Blender system	15,000
"Unitherm" sterilizing system	224,000
1,000 gallon aseptic surge tank (2)	45,000
3750 quart per hour Brik-Pak aseptic filler	225,000
Tray packer	58,000
Shrink film wrapper	22,000
Milk testing, COP	6,000
Pallet handling (1 fork lift truck)	7,000
Refrigeration equipment (ammonia receiver, compressor, condensor, glycol pumps)	48,475
Boilers - 75 bhp (2)	81,075
Installation[d]	121,365
Total equipment cost	$997,040

[a]1980-1 prices.

[b]Includes pumps, valves, and control panels.

[c]Includes level indication and accessories.

[d]Calculated by equipment manufacturing personnel at 25% of raw milk and cream storage cost, 25% of processing cost, and 30% of cost of refrigeration and boilers. Filling equipment prices include installation fees.

Appendix Table 2. Itemized equipment requirements for plant B

Item	Cost[a]
100 GPM receiving pump	$ 1,650
2 tank CIP unit[b]	27,000
CIP transport tank washer	1,100
COP portable tank	1,875
50,000 pounds/hour cold milk separator	80,000
15,000 gallons raw storage tank[c] (2)	50,000
1000 gallon cream storage tank[c] (2)	18,000
Ratio controller	27,000
Blender system	15,000
"Unitherm" sterilizing system	290,000
2,500 gallon aseptic surge tank (2)	76,000
3750 quarts/hour Brik-Pak aseptic filler	510,000
4500 one-half pints/hour Brik-Pak aseptic filler	255,000
Straw applicator	39,000
Tray packer (3)	174,000
Shrink film wrapper (1)	22,000
Milk testing, COP	6,000
Pallet handling (2 fork lift trucks)	14,000
Refrigeration equipment (ammonia receiver, compressor, condensor, glycol pumps)	65,293
Boilers - 200 bhp (2)	256,680
Installation[d]	211,092
Total equipment cost	$2,140,690

[a]1980-1 prices.

[b]Includes pumps, valves, and control panels.

[c]Includes level indication and accessories.

[d]Calculated by equipment manufacturing personnel at 25% of raw milk and cream storage cost, 25% of processing cost, and 30% of cost of refrigeration and boilers. Filling equipment prices include installation fees.

Appendix Table 3. Itemized equipment requirements for plant C

Item	Cost[a]
100 GPM receiving pump	$ 1,650
2 tank CIP unit[b]	27,000
CIP transport tank washer	1,100
COP portable tank	1,875
55,000 lbs./hr. cold milk separator	118,500
30,000 gallon raw storage tank[c] (2)	86,000
2000 gallon cream storage tank[c] (2)	22,000
Ratio controller	50,000
Blender system	15,000
"Unitherm" sterilization system	394,000
5,000 gallon aseptic surge tank (2)	125,000
3750 quarts per hour Brik-Pak aseptic filler (4)	1,020,000
4500 one-half pints per hour Brik-Pak aseptic filler (2)	510,000
Straw applicator (2)	78,000
Tray packer (6)	348,000
Shrink film wrapper (2)	44,000
Milk testing, COP	8,000
Pallet handling (4 fork lift trucks)	28,000
Refrigeration equipment (ammonia receiver, compressor, condensor, glycol pumps)	80,594
Boilers - 300 bhp (2)	363,400
Installation[d]	283,698
Total equipment cost	$3,605,817

[a]1980-1 prices.

[b]Includes pumps, valves, and control panels.

[c]Includes level indication and accessories.

[d]Calculated by equipment manufacturing personnel at 25% of raw milk and cream storage cost, 25% of processing cost, and 30% of cost of refrigeration and boilers. Filling equipment prices include installation fees.

Appendix Table 4. Itemized equipment requirements for plant D

Item	Cost[a]
200 GPM receiving pump	$ 3,650
2 tank CIP unit[b]	30,693
CIP transport tank washer	1,100
COP portable tank	1,875
60,000 lbs./hr. cold milk separator	147,000
30,000 gallon raw storage tank[c] (4)	172,000
4,000 gallon cream storage tank[c]	25,000
Ratio controller	72,000
Blender system	15,000
"Unitherm" sterilizing system (2)	766,000
7,500 gallon aseptic surge tank (2)	184,000
3750 quarts per hour Brik-Pak aseptic filler (8)	2,040,000
4500 one-half pints per hour Brik-Pak aseptic filler (4)	1,020,000
Straw applicator (4)	156,000
Tray packer (12)	696,000
Shrink film wrapper (4)	88,000
Milk testing, COP	8,000
Pallet handling (8 fork lift trucks)	56,000
Refrigeration equipment (ammonia receiver, compressor, condensor, glycol pumps)	120,365
Boilers - 500 bhp (2)	474,000
Installation[d]	469,060
Total equipment cost	$6,545,743

[a] 1980-1 prices.

[b] Includes pumps, valves, and control panels.

[c] Includes level indication and accessories.

[d] Calculated by equipment manufacturing personnel at 25% of raw milk and cream storage cost, 25% of processing cost, and 30% of cost of refrigeration and boilers. Filling equipment prices include installation fees.