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ABSTRACT

A Case Study Analysis of Energy Utilization and Conservation Potential in the MSU Dairy Plant

By

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This study deals with an investigation of processing operations at the Michigan State University Dairy Plant to determine total energy utilization and to explore potential energy conservation opportunities. The purpose is to identify conservation opportunities that presently exist during the manufacture of cheese, yogurt and ice cream and to evaluate the economic feasibility of all applicable conservation techniques.

Energy conservation opportunities were found to exist in three areas: (1) electrical requirements, through a comprehensive lighting management program; (2) thermal energy requirements for processing through insulation of all uninsulated steam lines; (3) thermal energy inputs for cleaning operations through a system of recovering heat from discarded condensate, hot cleaning solutions and hot processing fluids.

Economic incentives to conserve were found in both the lighting management program and the insulation of uninsulated steam lines. Considered in this economic

analysis was annual price increases for fossil fuels of 5, 10 and 15 percent. Although a waste heat recovery system could significantly reduce total energy consumption levels, the capital expenditure necessary for the installation of the system is not justified economically.

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INTRODUCTION

The oil embargo of 1973 was the stimulus which prompted the American public to realize the magnitude of the energy crisis. Since then it is generally agreed that the era of cheap fossil energy sources is over and a new era of energy awareness and conservation had begun. Legislators at all levels of the government, businessmen and consumers have realized the need for energy conservation in all facets of life.

Even though energy utilization is gaining high priority in many commercial and industrial plants as well as in the home, the world energy demand by the year 2020 is expected to be between three to four times present consumption levels if average economic growth is similar to that achieved in the past forty to fifty years (Bloodworth, 1977). This illustrates the urgent need for everyone to tighten their belts a little more as well as warranting research in all areas of energy utilization.

It has been estimated that the food system utilizes almost 17 percent of the total energy used in the United States (Slater, 1976). Due to the complexity of the industry there are many areas where research in energy consumption could prove favorable for reducing total energy usage.

Presently, researchers are looking into the use of alternate energy sources, such as solar energy, as well as applicable energy conservation techniques.

This study deals with energy conservation potential in food processing plants. Specifically, it investigates the energy conservation potential in the Michigan State University (MSU) Dairy Plant which manufactures cheese, yogurt and ice cream. Because of the similarity of many thermal operations and energy management practices in food processing plants, several of the energy conservation techniques discussed could be utilized in various areas of the food processing industry.

In the study, the MSU Dairy Plant was surveyed for total energy consumption involved in the processing of cheese, yogurt and ice cream as well as overhead considerations such as lighting. Conservation opportunities are available mostly when energy management and waste heat recovery are considered.

Economic evaluations were calculated for all suggested energy conservation techniques. This indicates the feasibility of these techniques based on current and expected price increases in fossil fuels.

Review of Literature

I. THE TOTAL RESOURCE OUTLOOK

Two key terms used in defining a total resource outlook are reserves and resources. Generally reserves define those quantities of an energy resource which have been discovered and to some extent explored, and which are considered to be producible under current economic conditions with existing technology. The term resources includes reserves but also includes deposits already identified but not presently considered to be economically recoverable, as well as undiscovered deposits that may or may not be economically producible when found.

Estimates of the major energy resources should, therefore, not be considered exact but only as guides to the relative abundance of the worlds energy resources. A discussion of some of the more recent estimates will follow beginning with oil.

OIL

Often these estimates lump reserves, undiscovered resources, and past production together to obtain a total figure for ultimately recoverable crude oil. McKelvey (1977) reports a surprising convergence of recent oil estimates around the figure of two trillion barrels (275 billion tons) as shown in Table 1.

If these estimates prove to be as compatible with reality as they are with each other, it means that at this point about half the worlds recoverable crude oil has been discovered; about one sixth of it has been used up, and the total available for future supply is about 1700 billion barrels.

World production of oil in 1976 was 21 billion barrels (McKelvey, 1977). When this is compared to the 1,700 billion barrel total no basis for immediate concern about future supply appears. However, when cumulative demand between now and the end of the 20th century is projected at a 3 percent annual rate of increase, which is considerably less than half the 6.5 percent annual growth rate since 1940, a different picture appears. At this rate of increase, by the end of the century much of the oil production will have to come from new discoveries and by the end of 2024 all of the oil would have to come from sources which are not discovered today. Under a zero-growth assumption, that is if the demand was held constant at the 1976 level, the projected requirements for the year 2024 would be one trillion barrels. Although this lower production rate would give us more time for shifting to other sources, the end of oil production for its current largest uses would come eventually, and within the lifetime of millions of people now living.

Table 1. Estimates of Ultimately Recoverable Crude Oil Worldwide (BBL)

Researcher	Past Production	Reserves	Undiscovered Recoverable Resources	Total
Weeks (1971	240	520	1490	2250
Jodry (1972)	260	540	1180	2980
Warman (BP) (1972)	260	540	1100	1900
Moody (1974)	400	450	1170	2020
Hubbert (1974)	400	450	1150	1200
Exxon (1975)	450	450	1000	1900
Comrate (1975)	450	450	1115	2015

Source: McKelvey (1977)

Natural Gas

The situation for natural gas is very similar to that of oil. Ultimately recoverable gas resources have recently been estimated to range between 6,000 and 12,000 trillion cubic feet as shown on Table 2. Of the total recoverable resources, 2,300 trillion cubic feet were reported as proved reserves and nearly 1,000 trillion cubic feet have been produced at the end of 1976 (McKelvey, 1977).

The relationship between production and remaining recoverable resources is somewhat more comfortable for gas than for oil, but not much. Marketed production in 1976 was approximately 50 trillion cubic feet which was about two percent of proved reserves. Using the same three percent annual growth projection as for oil, about 5,310 trillion cubic feet would be required for consumption between now and 2024, most of which would have to be discovered from new sources. As in oil when the relationship between production and remaining recoverable resources is also evaluated (assuming a zero percent growth rate in production) the problem could be ameliorated somewhat, however, by the 21st century just about all of our natural gas production will be coming from resources which are not discovered at this time.

Unconventional Hydrocarbons

Much interest has developed in recent years with respect to certain unconventional sources of oil and gas that have been ignored in the past because of the great

Table 2. Estimates of Ultimately Recoverable Natural Gas Worldwide (trillion cubic feet)

Researcher	Past Production	Reserves	Undiscovered Recoverable Resources	Total
Weeks (1971)	650	1650	3950	6250
Koppack (Shell) (1973)	750	1750	6550	7050
Hubbert (1973)	750	1750	9550	12050
Linden (1973)	750	1650	8000	10500
Adams-Kirkby (1974)	800	1700	3500	6000
Comrate (1975)	900	1600	5250	7750

Source: McKelvey (1977)

difficulty and cost in producing them. Some examples of these unconventional sources are: (1) the tar sands of Northern Alberta and the Orinoco Basin in Venezuela; (2) the oil shales of the Western United States; (3) the vast quantities of gas believed to be contained in coal beds, the marine block shales of Eastern United States, the sandstones of the Rocky Mountain Region, and the geopressured zones underlying the Gulf of Mexico and adjacent costal Plains (McKelvey, 1977).

These sources all have two things in common: all are very large in extent, and all, with very few exceptions, can not presently be produced commercially. Culbertson (1977) states that the world price of oil would have to rise about \$20 per barrel in order to make the production of oil from shale and tar sand economical.

Although present technology does not enable us to commercially produce significant volumes of these energy sources, it is probable that some of these sources will be utilized in years to come. The immediate requirement, however, is for much more knowledge about these resources than we presently have.

Coal

Coal, the most abundant of our fossil fuels, had 669 billion tons of identified reserves as of 1974. This figure is almost 200 times greater than the 3.5 billion tons consumed by the world in that year. Identified coal resources including reserves are thought to be nearly 6,400 billion tons and an additional 10,000 billion tons of undiscovered coal resources are also estimated to exist (McKelvey, 1977).

Auer, Manne, and Yu (1976) state that the United States will have a heavy reliance on coal for the production of both electricity and synthetic fuels in future years especially if a nuclear moratorium existed. Exactly how much will depend on the price of energy in the future and what options the United States takes in moving away from their heavy dependence on oil and gas to a more diversified energy economy.

Hydroelectric

As of January 1, 1976 the Federal Power Commission reports that the total potential conventional hydroelectric power capacity developed and estimated to be available for development, amounted to some 170.7 million kilowatts capable of generating an average of about 675 billion kilowatt-hours annually. Approximately 57.0 million kilowatts or 33.4 percent of the total potential had been developed, with the capability of an average annual generation of about 271 billion kilowatt-hours. Of the undeveloped potential of 113.7 million kilowatts with a corresponding average annual energy production of about 404 billion kilowatt-hours, about 8.2 million kilowatts were in the construction stage. The amount of the remaining undeveloped potential is subject to revision as additional information is obtained. Development of some of this potential may be precluded by economic, environmental and other factors such as the Wild

& Scenic Rivers Act. Nevertheless, these estimates currently indicate the long range overall conventional hydroelectric power potential of the United States.

Geothermal

Geothermal energy is still another potential source. Geothermal "hot spots" throughout the world have been tapped for local heat and generation of electricity by several countries, including ours, although the total capacity to date is less than 2,000 megawatts (McKelvey, 1977). In immediate areas where they exist, geothermal resources can be an important supplement to other forms of energy, but on the world scale they are only marginal contributors.

Nuclear Fuels

Presently the role to be played by nuclear fission and fusion is unsettled and unknown because of both, wide differences in estimates of uranium and thorium resources and the deep-seated controversy over the use of nuclear power (McKelvey, 1977). The two main problems to date include disposing of dangerous radioactive waste materials and the use of the nuclear reactors that could release radioactivity if they became damaged such as by a melt down (Teller, 1976). At any rate, nuclear fuels are an important potential source of energy which is being researched in several countries.

Solar Energy

The problem realized with solar energy is that of recovery, how to extract useful quantities of the resource from the limitless supply that exists. Several approaches

have been tried, with encouraging progress in such areas as space and water heating (McKelvey, 1975). In a survey conducted by the Federal Energy Administration (F.E.A.) in 1977 it is shown that the production of various types of collectors is expanding continuously. Medium temperature collector production, which are used for space and water heating in houses and offices, for the second half of 1976 totaled about 1,000,000 square feet, which is 65 percent more than the 65,000 square feet produced in the first six months. Special collector production in that same period jumped 178 percent from about 50,000 square feet to about 150,000 square feet. Special collectors are units that have mirrors or lenses to concentrate sunlight on collector panels. Production of low-temperature collectors used to heat swimming pools was about 2,000,000 square feet for July through December of 1976 which shows a 47 percent increase in this area.

The FEA (1977) reports an average of 35 companies entering the solar collector business every six months. The total number of firms producing medium-temperature collectors from July through December equaled 177, up from 142 firms for the first half of 1976 and 39 companies in 1974.

Alich (1975) states that the economics of terrestrial growth of vegetation for its energy content is far more favorable than more technically sophisticated methods of large scale solar conversion. This method involves the growing of vegetation specifically for energy uses. The vegetation can supply energy via direct combustion or when treated with a chemical method for the production of substitute natural gas (SNG). The conversion efficiency of this SNG is estimated at about 60 percent.

Vindum, Bentz (1977) through the Energy Research and Development Administration (ERDA), estimates that 10 percent of the energy used by industry and 50 percent of the energy used by agriculture will be supplied by solar energy by the year 2000.

II. ENERGY CONSUMPTION

It is estimated that the industrial sector of the economy utilized 29 to 30 percent of the total energy consumed in the United States in 1976 (Gelb, 1977; Limaye, Sharo, Kayser, 1976). The food system, which is part of the industrial sector, is defined as the entire sequence of events from planting to harvesting, to preparation for consumption and to disposal of the waste (Cambel, 1976).

Food production in Western societies is typically more energy intensive than in Eastern societies primarily because in Western societies food goes from the farm to the processing plant where it is cleaned, frozen, packed and eventually sold where as in Eastern societies food substantially goes from the farm to the consumer and is generally fresh. Booz, Allen & Hamilton (1976) report that in 1971, 17 percent of all the U.S. energy requirements are related to the food system and Slater (1976) reports 1976 levels as being over

16 percent. These estimates were made by separating the food system into the categories noted on Table 3.

Table 3. Breakdown of Energy Use in the Entire Food System

Categories	% of Total US Energy Consumption
production	2.9
manufacture	4.8
distribution & wholesale	0.5
retail trade	0.8
out of home preparation	2.8
in home preparation	4.3
manufacture of trucks	0.4
Total	16.5

Source: Slater, 1976.

The largest area in the food system regarding energy use is manufacturing. The latest figures by Slater show that the manufacturing of food represents 29 percent of the food-related energy use and Heldman (1975) reports as high as 33 percent of food-related energy is accounted for in food processing. As with many industries the energy use involved in food processing has more than doubled since 1940 (Steinhart & Steinhart, 1974). This is easily understood when one understands the need for processed foods. As of 1974, 38 percent of the U.S. labor force was composed of females (U.S. Bureau of Census, 1975). Thus the female in

this industrialized life style can not spend a majority of her time shopping for fresh foods in markets and preparing it for one time consumption.

At any rate the food processing and related industries are collectively a major industrial energy user in the United States. According to the U.S. Bureau of Census (1972) the food system is ranked sixth in the U.S. regarding energy consumption. Because of this high ranking the Food and Kindred Products industry was one of eleven industrial energy studies commissioned by the Federal Energy Administration and the U.S. Department of Commerce in early 1974. Unger (1975) reports the findings of this study as follows. The food and kindered products group comprises 44 industries. Among these 44 industries 14 accounted for approximately two-thirds of the total energy used. Of the top 14 industries the Meat Packing Industry used the most energy accounting for an annual use of 99.3 trillion BTU or 11.9 percent of the total. The Fluid Milk Industry is the fourth leading energy consumer utilizing 78.5 trillion BTU's or 9.4 percent of the total. Frozen Fruits and Vegetables ranked eighth in energy consumption using 62.2 trillion BTU's or 7.4 percent of the total while the canned Fruit and Vegetable industry ranked tenth using 52.5 trillion BTU's or 6.2 percent of the total. Table 4 shows the relative types of fuels these four industries utilize.

The 14 industries as a whole are primarily dependent on natural gas for their energy utilizing natural gas for 48

Table 4. Energy Use and Rank of Four Leading Energy-using Food and Kindred Product Industries for 1973.

Industry	Natural gas (%)	Purchased Electricity (%)	Petroleum Products (%)	Coal (%)	Other (%)	Total (%)
Meat Packing	46	31	14	9	0	100
Fluid Milk	33	47	17	3	0	100
Frozen Fruit & Vegetables	41	50	5	4	0	100
Canned Fruit & Vegetables	66	16	15	3	0	100

Source: Unger, 1975

percent of their energy needs. Purchased electricity was second in importance with about 28 percent of the total gross energy coming from this source. The third most important energy source was coal followed by petroleum-based products with about 9 percent and 15 percent respectively of the gross energy coming from these sources.

III. ENERGY CONSERVATION AND TECHNIQUES

Noland (1976) discussed two main incentives for industry to develop energy management policies. First, direct reduction in costs based on savings realized by reducing energy use and second, by facilitating energy security which will prevent economic losses by avoiding loss of production when fuel supply is curtailed.

If energy conservation goals are to be met, top management is going to have to reorient the management job to energy conservation. Cook (1976) suggested three general categories for energy conservation opportunities which include:

1. Improved utilization through engineering improvements of existing processes and equipment.

2. Process changes to utilize potential fuel sources that are currently being discarded, or used for other purposes of higher added value, such as solid wastes. These opportunities tend to be a function of cost or value per BTU related to the new investment required to change one's process.

3. Discovery of new technology reducing the energy requirement per unit output.

Snyder (1977) also identified a general format for classifying energy conservation opportunities (ECO'S) into three categories, which may be more convenient from the management standpoint. These are as follows:

1. Procedural ECO'S which involve housekeeping and maintenance type actions with little or no cost involved.

2. Equipment modification, addition or replacement ECO's which can be implemented using available "off the shelf" hardware and technology with a capital expenditure involved.

3. Research and development ECO'S which not only involve capital expenditure but also involve research and development activities such as re-design of a production process.

Many suggestions have been made relative to the conservation of energy. A list that seems appropriate for the food industry is presented below under six general headings. These suggestions were combined from a variety of sources listed. FEA (1974), Rippen (1975), Rippen (1976), Quality Chek'd Dairy Products Association (1971), Fanaritis and Streich (1973), U.S. Department of Commerce/NBS (1974), FEA (1976a) FEA (1976b).

<u>The Steam System</u>

1. Check the boiler to be sure it is operating efficiently. Adjust the burner for maximum combustion efficiency

for the fuel being burned. Chart boiler efficiency daily. Fuel to steam conversion efficiency should not drop below 80 percent.

2. In purchasing new boilers make sure they have an economizer or stack heat recovery blowdown heat exchanger, air-fuel ratio control, and an automatic flue gas analyzer. Take observations periodically to confirm proper control operation. Flue gas should contain approximately 10-14 percent CO_2 level depending on the type of fuel used, 0.0 percent CO, and 1-2 percent O_2 level when complete combustion is obtained. The exhaust gas temperature should not exceed the saturated steam temperature by more than 150°F for most food plants.

3. Descaling and tube cleaning to facilitate heat transfer should be done on a regular basis. Use of a water softener to pretreat feed water helps in controlling scale build-up.

4. Keep steam pressures as low as possible, to improve heat transfer efficiency in the boiler and to reduce heat losses in the steam lines.

5. Consider the use of waste and by-products as additional fuels.

6. Insulate all steam lines. Uninsulated steam lines will accomplish some space heating, however this is hard to control and usually wasteful.

7. Investigate the use of discarded hot flue gases to preheat boiler feedwater, combustion or for such applications

such as direct-contact dryers.

8. Return condensate to the boiler wherever feasible. Heat water near use point with direct fired heat or steam coils, so that treated condensate can be returned to the boiler. Direct live steam injectors waste heat.

Space Heating

1. Examine each window of the plant and office, and install permanent or temporary storm windows wherever it is practical to do so. A storm window cuts heat losses through glass in half.

2. Eliminate unused roof openings or abandoned stacks. Keep fresh air intake and exhaust from the building to a minimum but sufficient to provide humidity control. Installation of adjustable orifices or dampers in ducts helps to regulate air flow.

3. Install airlocks from warm spaces to cooled areas and use well insulated, lighter doors with electric door closers for coolers and freezers.

4. Use central heat, air conditioning and refrigeration units where possible rather than a multitude of small, less efficient package units.

5. Utility and storage rooms may be warmed or ventilated in some instances with exhaust air from areas requiring a higher rate of air changes, such as the processing room. It is important, however, to determine whether or not condensation problems can occur due to the warmer air.

6. Heat rooms to a temperature no higher than necessary by "dialing down" the thermostat whenever possible. For each degree the temperature is lowered approximately 3 percent fuel saving occurs. The converse is also true when cooling is considered (FEA 1974). Investigate the use of infra-red heating units rather than space heaters for poorly insulated areas in the plant.

7. Evaluate building insulation. Proper ceiling and wall insulation is essential to prevent condensation on these surfaces.

Lighting

Total energy consumption for direct lighting in the United States in 1972 was slightly over 20 percent of the total electricity generated for all purposes. This percentage represents about 5 percent of the total national energy consumed. Estimated possible energy savings in lighting are as high as 43 percent (FEA, 1974). Some of the recommended conservation measures are as follows:

1. Survey present lighting levels by area or operation and establish minimum requirements consistent with good lighting practices. The survey should also note location and type of light source including switches and other controls.

2. Use photoelectric cells and timer switches to control outside lights based on need for security and intermittent use.

3. Splitting lighting circuits so that more flexibility is provided for lighting only those areas in the plant where activities require it. Use separate switches on perimeter lighting which may be turned off when natural light is available.

4. Increase light reflectance of walls and ceilings, and follow a maintenance program for regular luminaire cleaning, lamp replacement, and fixture ventilation.

5. Lower light fixtures in high ceiling areas when possible.

6. Install pilot lights outside of all storage areas or utilities which indicate that lights are on inside. This permits monitoring of these lights.

7. Install efficient light sources such as fluorescent or metal halide. Consider mercury vapor or high-pressure sodium in high bays or outside areas where color is not important. Table 5 shows the relative efficiency of some of the more common lighting systems.

Table 5. Efficiency of Common Light Sources

Type.	Lumens/watt
incandescent	10-20
mercury	40-60
fluorescent	50-70
metal halide	70-90
high-pressure sodium	90-120

Source: Rippen, 1975

Power

1. Use reflective coating on the roof directly over freezer areas or other cooled areas in the plant.

2. Design coolers with unimpeded air flow of sufficient quantity to control condensation. Also apply more insulation in cooler freezer walls, ceilings and floors.

3. Purchase water cooled refrigeration units rather than air cooled type. Water cooled units require up to 10 to 15 percent less energy than air cooled units for the same output. If air cooled refrigeration units must be employed, choose units which are designed to duct heated air to building space during the winter time or to atmosphere during hot weather.

4. Excessive head pressures in refrigeration systems significantly increase power consumption while the desired refrigerating effect is substantially reduced. This condition suggests a need to purge air from the system and clean the condensers.

5. Use two stage compression on low temperature loads such as ice cream freezers or hardening rooms.

6. Install compressor air intakes in the coolest location.

Processing & Clean-up Methods

1. Re-evaluate all processing temperatures. Perhaps the temperature can be reduced on some products without adversely affecting the safety or shelf life. For example, the steam requirement can be reduced 8 percent if the

temperature of milk pasteurization is lowered from $177^{o}F$ to $165^{o}F$. This would also reduce the refrigeration load significantly.

2. The principle of regenerative heating and cooling should be used whenever practicable for recovering heat or utilizing a cooling effect either to the product directly or through a transfer medium such as water.

3. Keep clean-in-place systems well maintained so they function according to design in time, temperature and pressure relationships.

4. Where feasible retrieve heat from spent cleaning solutions and rinse waters using a heat exchanger.

5. Control the solution circulation times when cleaning equipment or processing parts both in C.I.P. (clean-in-place) units and parts washers.

Other Methods

Gill (1976) stated that the potential benefits of energy conservation practices are not fully realized and never will be unless certain perverse economic and institutional incentives are expeditiously removed. Some of these incentives he mentions are: Waste inducing rate policies for truck, automobile and airplane travel by regulatory bodies such as the Interstate Commerce Commission (ICC) and the Civil Aeronautics Board (CAB); Governmental intervention via controlled oil and gas price policies maintaining low energy prices; declining block rate structures of electric and natural gas utilities versus marginal cost pricing.

Cavagnaro (1977) also stated that the rate structure prescribed by a regulatory commission can be used as an effective method to conserve energy and that public utilities commissions and the legislature have given the rate structure high priority in this regard.

Eckert (1976) mentioned that the ground surrounding a heated or cooled structure as a source of sink or as an energy storage should be considered. The energy required to maintain a structure (building cavity) at a constant temperature can be reduced drastically by burying it in the ground or locating it under the ground surface.

IV. THE ENERGY AUDIT

The basic concept of an energy audit is quite simple. It involves an analysis of a facility to determine the forms of energy used, the quantities of various forms of energy, the purposes for which energy is used and the identification of energy conservation opportunities. Limaye, Sharko, and Kayser (1976) described two principal methods for conducting an energy audit. The first approach, noted as the survey approach, involved the use of questionnaires or personal communication with authorities regarding factors affecting fuel use, use patterns, anticipated technological changes and future requirements. The second method involves a detailed engineering process analysis involving an indepth look at energy data for each product.

Snyder (1977) stated that there are two principal phases of an energy audit, the first being the billing audit and the second being the field audit. In the first phase, data is collected and analysed based on available energy consumption and cost records as well as production records in facilities where production is a function of the facility. It is noted that the principal source of information concerning historical energy consumption and cost is from utility bills. The purposes of this phase of the process is as follows:

1. To examine historical energy consumption, energy cost, and production levels for trends or abnormalities.

2. To allocate (at least approximately) energy use for space conditioning and for production processes.

3. To determine energy consumption per unit of production where appropriate.

The second phase of this process (field audit) involves gathering information about every energy consuming device in the facility. The purposes of this phase are:

1. To allocate energy use by function, physical location, department or any other appropriate division.

2. To observe the operation of processes and facilities from an energy use perspective.

3. To identify potential energy conservation opportunities.

Snyder (1977) stated that the importance of the energy audit can not be overstressed. In making correct energy management decisions the availability of reliable energy use information as a data base is of primary importance.

V. CASE STUDIES

Due to the increased interest and opportunities in energy conservation in recent years there has been many published case studies where conservation programs have been successfully implemented. Because of the general concepts of energy conservation many times certain principles can be applied to a wide variety of industries. For example, the Federal Energy Administration (1974) reported on nineteen cases where via energy conservation measures in lighting systems and thermal operations such as cooling and heating office rooms, significant reductions in energy consumption resulted in electrical use. In this study the average savings in these nineteen cases was 27 percent. The highest reported savings was 42 percent, with the low being 15 percent. Although this study involved commercial office buildings rather than industrial facilities, a potential in energy conservation in heating and cooling office areas can be realized and probably applied to a variety of industries.

In another study Ziemba (1974) reported that a small low-energy equipment installation on a potato chip processors effluent has reduced sewage and water use costs while producing a highly saleable waste byproduct. In this process the waste starch slurries coming from slicing machines are collected and concentrated while water is recycled back to the slicing machines. Since reported the company reports a 30 percent cut in its $5,000 monthly municipal sewage bill and a 50 percent reduction in a $2,500 monthly water bill.

As an added advantage 20,000 pounds of starch slurry is sold to A.E. Staley Co. each year. Although direct energy savings are hard to calculate in this case, indirect savings are realized by using wastes rather than treating them or paying for them to be neutralized.

In a 1974 study, Fleming, Lambrix and Smith reported on nine industrial processes in which energy conservation could be achieved. One of these areas involved furnace efficiency. The study involved a comparison of energy costs for the year 1960 to the 1975-80 period. In 1970 the net savings for installing an air preheater on a 400 million BTU/hour steam boiler would be $16,000/year. The savings which result for the 1975-80 period were estimated at $126,000. Actual fuel prices or method of economic analysis was not reported in this case.

The energy crisis in the winter of 1973-74 prompted immediate attention and the need for conservation measures in the canning industry. This resulted in the organization of an Ad Hoc committee of canning engineers by the National Canners Association (NCA) research personnel in an effort to pool energy conservation ideas and promote voluntary energy conservation efforts in the industry (Farrow, 1977). The Ad Hoc committee worked with the Department of Commerce in January of this year to organize procedures for surveying the canning industry to monitor results of their efforts using 1972 as the base year for comparison purposes. In all, data was obtained from companies responsible for an estimated 64 percent of the total annual production of canned foods in 1973. The results of this survey indicated a two percent reduction in energy input on a unit production basis in 1973 and a six percent reduction in 1974. Farrow also mentioned several factors complicating conservation efforts specific for the canning industry. Most of these factors involve the seasonal nature involved in most canning operations, compliance with OSHA, EPA, FDA, USDA and state and local regulatory requirements. Product mix can also hinder conservative efforts in the canning industry. For example, conductive packed products require substantially longer heat process to achieve commercial sterilization in comparison with convective type packs.

Thermal energy derived from natural gas and coal constitutes about 69 percent of the energy consumed in the fruit and vegetable canning industry (Unger, 1975). For this reason thermal energy losses and conservation were the targets of a study by Rao, Katz, Kenny and Downing in 1976. Four vegetable canneries located in western New York were analyzed. A summary of thermal energy losses in these plants is represented in Table 6.

By utilizing conservation measures the researchers found that 95 percent of the equipment and steam pipe losses could be eliminated by insulation, between 28 to 42 percent of the building losses could be recovered, and as high as 50 percent of the losses resulting from discarded hot water could be recovered.

Table 6. Thermal Energy Losses in Four Vegetable Canning Plants

Source of Loss	Heat loss (BTU)			
	Plant A	Plant B	Plant C	Plant D
Building[b] ($t=70^{o}F$)	1.32×10^{10} (12.3%)	8.77×10^{9} (15.6%)	1.13×10^{10} (16.5%)	5.91×10^{9} (16.4%)
Equipment	2.33×10^{9} (2.2%)	1.31×10^{9} (2.3%)	1.25×10^{9} (2.0%)	1.01×10^{9} (2.8%)
Steam Pipes	7.83×10^{9} (7.4%)	5.62×10^{8} (1.0%)	2.60×10^{9} (4.1%)	2.27×10^{9} (6.3%)
Discarded Hot Water	1.6×10^{10} (14.7%)	1.22×10^{10} (21.6%)	9.34×10^{9} (13.6%)	6.96×10^{9} (19.3%)

a. Numbers in parentheses are losses expressed as percentages of the net heat input into the plants.

b. Building heat loss area equal 2.11×10^{5} sq. ft., 1.49×10^{5} sq. ft., 2.17×10^{5} sq. ft., and 1.23×10^{5} sq. ft. for plants A,B,C,D, respectfully.

Source: Rao et al. (1976).

In a follow up study an economic analysis of these conservation measures was performed by Rao et al (1977). Life cycle analysis was used considering taxes, depreciation and rising fuel prices. In this study all conservation measures mentioned above were found to be economically lucrative.

Anheuser-Busch Brewery, Williamsburg, VA. (Annon., 1973) reported economic advantages as well as improvements in product quality through the use of plastic foam (styrofoam) insulation throughout the plant. They found that the best way to keep the temperature of the product within predetermined limits is by insulating all equipment thoroughly. This includes nine miles of low temperature pipes, cooler towers, liquid CO_2 storage tanks, as well as fermentation and lager rooms. The lower the desired temperature limit the more insulation is required. The thickness of the insulation ranges from one, 1 inch layer for cooling towers to two, 3 inch layers for storage tanks.

In analysis of the Baking Industry the FEA (1976) picked five representative plants varying in size, location, and energy requirements through the United States. After the energy audit was performed for each plant a conservation program was established. The program was divided into four categories:

1. Short term actions which can be accomplished within six months with little or no expenditures required.

2. Intermediate term actions that can be accomplished in six to eighteen months which require some study and some

expenditures.

3. Long term actions which would require more than eighteen months to accomplish, and would require relatively large expenditures.

4. In conducting the audit, notes were made on the process as there may be method improvements which will not only save energy but also result in cost reduction.

In summary the average BTU savings for the five plants was 20.6 percent with a range between 27 and 12 percent. Estimated savings on annual energy cost exceeded 12 percent with a range between 17.8 and 9.4 percent.

A dairy in the process of expanding its production and warehouse facilities was faced with the problem of maintaining a minimum temperature of approximately 65^{o}F in the planned 13,000 square foot warehouse (Rudoy, 1976). Gas had been the energy source of the plant and additional gas was unavailable. The management of the plant in conjunction with the gas company looked at the possibility of using waste heat from the process steam boiler. The idea proved feasible so a system utilizing waste heat was engineered. Standard hot water forced-convection heaters were used for the warehouse space heating. The hot water was supplied by a standard finned tube coil placed in the boiler stack. The make-up water for the boiler ranged in temperature from 40-60^{o}F. An additional advantage was realized in this system with a parallel heat exchanger was added to preheat the makeup feedwater when space heating was not required. This now meant that the dairy could heat the new warehouse and do it using less gas. Rudoy also mentions a case study where a plant saves 20 to 25 percent in fuel consumption by using a similar system to preheat combustion air through heat exchangers called recuperators.

Thompson (1977) reported on a complete system involving the use of energy conservation and solar energy which has been installed at the milking parlor of the Agricultural Research Center in Beltsville, Md. This system is operating economically and now provides about 75 percent of the total daily requirements of heat and hot water. The conservation measures in the milking parlor now employed included:

1. Precooling milk via a heat exchanger which accounts for a 30 to 40 percent reduction in energy consumed in this area.

2. Insulation, which allows savings of 50 percent in building heating and saves about 25 percent of the energy that was lost through equipment and pipes found in the parlor. He notes that stationary collectors are placed on southfacing walls and/or roof above the horizon at an angle equal to the local latitude plus 10 degrees for optimum collection. The solar energy collected in this system is capable of providing most of the hot water needed in the parlor. It supplies all of the hot water for preparing the cows and about half the energy needed to heat clean-up water. It also provides most of the heat required to warm the working area during cold months. Thompson briefly described the differences in

collectors used in colder climates and mentions parameters such as the hot water needs, the temperature the water is to be raised, and the geographic location, which are involved in determination of collector size. To maximize financial savings a comprehensive energy conservation program is recommended in conjuction with a solar heating system.

Slater (1977) described two energy conservation measures in use today which entail equipment modification or new equipment installation. The first case deals with a company which added a fourth effect to a three effect evaporator which increases the product solids content prior to drying from 45 to 52 percent. The addition of this fourth effect amounted to a savings of $220 each day. The total investment amounted to $75,000 and was paid off in less than one year.

In the second case Slater described a hyperfiltration process which is used in place of a vacuum evaporator to concentrate whey at a dairy plant in France. The system concentrates 60 tons of whey to 20 tons of whey concentrate each day prior to its shipment to a regional drying plant. In general membrane separation energy requirements are in the range of 50-200 BTU's per gallon of water permeated as compared to 2000 BTU's per gallon, or more, for a conventional evaporator system utilizing a multistage evaporator. Slater also mentions ancillary benefits that result in product quality because the process is inherently nondestructive and very gentle on the product. The process is

described as simple, easy to operate and offers investment economy for small production rates.

Anon (1968, Aseptic Production Throughout The World) discussed aseptic production and packaging present in Italy, Switzerland, France, Austria, Germany, Holland, Belgium and Spain. The concept of aseptic packaging, which has not been used extensively by American food processors, offers possibilities throughout the entire food processing distribution system. Although the integrated package forming, filling and sealing system is a big energy saver it is the product itself which offers many cost benefits to both, the consumer and to industry. Aseptic packaged foods compete in nutritional and organoleptic quality with pasteurized and frozen products which require refrigeration in processing, distribution and in the home. The over-all energy savings of aseptically packaged foods as compared to refrigerated have been estimated as high as 90 percent.

Rippen and Mintzias (1977) suggested a method of utilizing steam condensate for a Michigan Dairy Plant. The system includes the collection of the condensate in an insulated 3,000 gallon tank formerly used for milk products. This condensate will then serve as the primary source of heat for a 130°F water supply system for hose outlets for cleaning certain areas of the plant. The control system will adjust the temperature using cold water or steam to maintain 130°F or another selected temperature. Although this system is not presently in use preliminary economic indications seem favorable.

EXPERIMENTAL METHODS

Audit of Energy Consumption

To evaluate the energy conservation potential in the MSU dairy plant an energy audit was conducted to obtain a reliable data base on present energy consumption levels in the processing operations. Not considered in this audit were energy inputs for the following: space heating for the plant, transportation involved in providing the dairy with milk, refrigeration involved in the cheese aging or storage operations, and overhead inputs involved with the sale of the products at the M.S.U. dairy store. The audit did consider all electrical and heat inputs necessary for the manufacturing of yogurt, cheese and ice cream illustrated in the flow charts below.

FLOW CHART FOR YOGURT MANUFACTURE

Combining of ingredients

Sterilization
(40-185^{o}F)

Homogenization
(5000 psig)

Inoculation

Homogenization
(0 psig)

Filling (packaging)

Equipment cleaning

FLOW CHART FOR ICE CREAM MANUFACTURE

Combining of ingredients

Pasteurization
(40-145^{o}F)

Homogenization
(2500 psig)

Cooling and holding

Packaging

Equipment Cleaning

FLOW CHART FOR CHEESE MANUFACTURE

Milk receiving

Pasteurization (145^{o}F)

Cool & hold

Heating (88^{o}F)

Curd cooking (102^{o}F)

Cheddaring milling

Hooping

Dipping

Equipment cleaning

Note: This process varies according to the variety of cheese processed.

The electrical power required to run motors and pumps associated with the physical handling of the product in the plant was determined in two steps. First, all processing operations were observed over a period of six weeks to determine average run times of electrical equipment on a

daily and weekly basis. Secondly the actual power drawn by each piece of equipment (watts) was assessed by the use of a Weston Industrial Analyzer (Model 639, Type 2, No. 4161) which was inserted into the respective electrical circuits at the magnetic starter of each motor. Thus an average power versus time relationship was established (WATT-HOUR) for each piece of electrical equipment.

A similar approach was used in the determination of energy consumption by the various lighting systems. First a survey of the plant provided information regarding average daily and weekly hours lights were in operation throughout the plant. The plant consists of both fluorescent and incandescent lighting systems. The power consumption levels for all incandescent bulbs is considered to be the wattage taken directly from the bulb. The power consumption levels for all incandescent bulbs is considered to be the wattage taken directly from the bulb. The power consumption levels for the fluorescent lights was determined by multiplying the wattage rating of the bulb by a factor of 1.2 to compensate for any heat losses in the fixture (Surbrook, 1978). There are two sizes of fluorescent bulbs used in the plant; four feet and eight feet. The wattage ratings of these fixtures is 45 watts and 75 watts, respectively (Surbrook, 1978).

Live steam generated by the M.S.U. Power Plant is used as a heat source for all clean-up operations and for processing the milk during the manufacture of cheese, ice cream and yogurt. The steam generated leaves the power plant at approximately 90 psig and arrives at the dairy plant at about 85 psig assuming a 5 psig pressure drop during transport (Rippen, 1978). Thermal energy inputs for these operations were calculated using formula 1. These calculations include all heat lost through uninsulated steam lines during processing hours. Formula 2 was used for this calculation.

(1) Heat input requirements for liquid products (Farrall, 1973)

$$BTU = \frac{(W)\ (CP)\ (\Delta T)}{\%\ Efficiency}$$

Where: W equals the weight of the liquid in pounds

% Efficiency equals the heating efficiency of the heat exchanger expressed as a decimal (85%)

ΔT equals the difference in product temperature in ^{o}F before and after heating

CP equals the specific heat of the product being heated (BTU/lb/^{o}F)

The specific heat used for milk, ice cream mix and yogurt was 0.93, 0.80 and 0.80 respectively. The weight per gallon of milk, ice cream mix and yogurt was taken as 8.6 lbs, 9.14 lbs, and 9.0 lbs respectively.

(2) Heat loss through bare steam pipes (Farrall, 1973).

$$BTU = (U)\ (A)\ (T_2 - T_1)$$

Where: A equals the area of uninsulated pipe (ft^2)

U equals the overall coefficient of heat transfer (BTU/hr-^oF-ft^2)

T_2-T_1 equals the temperature difference between the outside surface of the pipe and ambient air (^oF)

U in the equation above represents heat lost from the surface of bare pipe via convection and radiation. Values used for U in this study were taken from experimental work of Heilman (1929). Some of these values for steam under 85 psig are given in Table 7.

Table 7. U values for bare pipes under 85 psig

Nominal Pipe Size	U Value
3/4"	2.5
1.0"	2.4
1.5"	2.2
2.0"	2.1

Source: Heilman (1929)

In gathering the data during the audit the information was allocated according to energy use by function for lighting, cleaning or processing operations. For simplicity all energy calculations are converted to BTU's. All necessary conversion factors were obtained from Farrall (1973).

Energy Conservation Opportunities Considered

During the energy audit the operations of the plant were observed so that potential energy conservation opportunities (ECO's) could be identified. Although it was beyond the scope of this paper to examine all ECO's because of the diversity of the building in which the plant is located, there are six areas where potential energy savings were explored. These six areas are:

(1) Heat recovery from spent washing solutions and hot rinsing waters.

(2) Load shedding in lighting systems throughout the plant.

(3) A comprehensive lighting management policy of turning off lights when not in use.

(4) Heat recovery from discarded condensate from all processing equipment.

(5) Heat recovery from discarded whey and water used for starter manufacture during the cheese manufacturing process.

(6) Insulation of all uninsulated steam lines.

Heat Recovery Evaluation

When conservation of thermal energy through heat recovery was considered, it was necessary to collect data on all hot solutions being discarded. Next, a calculated estimate of the amount of city water that could be preheated with these discarded solutions was determined.

Average daily volumes of discarded hot cleaning-rinsing solutions, discarded whey, and discarded hot water used for starter manufacture were measured directly for this analysis.

Average volumes and temperatures of discarded condensate from processing equipment were used. These values were obtained by measuring average flowrates of condensate from each piece of equipment. Since all condensate flowrates are held constant over a given process it was possible to construct temperature versus time graphs to establish the average temperature and volume of condensate that was discarded for each process. To check this method all the condensate from a selected piece of equipment was collected in a ten gallon container and the temperature was determined with a standardized thermometer. These two values were compared for accuracy. Graphs for the various pieces of equipment can be found in appendicies A through A_9.

Two systems were used for making a calculated estimate of the amount of heat which could be recovered. For condensate a 10 percent loss through condensate lines was assumed. Condensate was considered to be a potable water supply and could bypass the heat exchanger during passage directly to the storage tank. Hot solutions such as discarded whey, cleaning solutions and hot water used for starter manufacture would have to go through a heat exchanger. For this a 75 percent efficient heat exchanger system was assumed (Bakker, 1978).

Almost all discarded warm solutions exceeded 125^{o}F. Only cheese whey from the manufacture of cheddar and related fermented cheese was lower than 125^{o}F. This is discarded at 100^{o}F. Since there is significant volumes of other warm discarded solutions and because of inherent losses that would occur minimizing the amount of heat that could be recovered from 100^{o}F cheese whey, only those discarded solutions exceeding 125^{o}F were considered in this analysis. Formula 3 was used to estimate the amount of 125^{o}F water that could be supplied by the heat recovery system.

(3) $Q = (M)\ (CP)\ (\Delta T)$

Where: Q equals the amount of heat available from discarded solutions (BTU/hr)

M equals flow rate of recovered water (lbs/hr)

CP equals the specific heat of the hot solution

ΔT equals the temperature difference

Figure 1 shows a schematic diagram of the heat exchanger system considered. The insulated storage tank shown has a capacity of 2,500 gallons and would contain an electrical resistance type coiled water heater. The tank would be located on a lower floor to minimize the use of pumps. The heat exchanger shown is of the counter flow type with a capacity of 7 gallons per minute. All condensate and hot solution return lines would be fully insulated with one inch of fiberglass insulation with a multipurpose sanitary jacket.

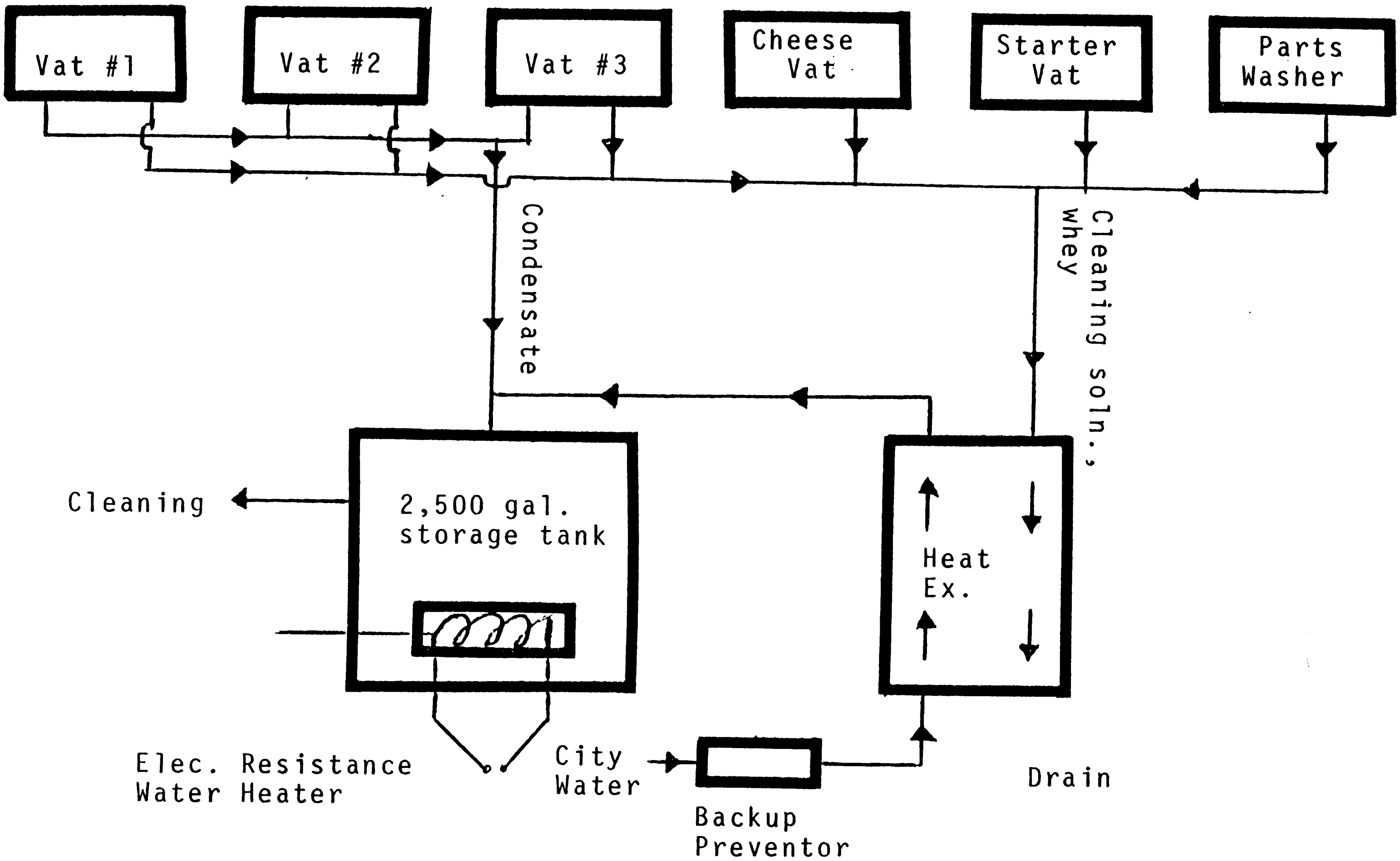


Figure 1. Schematic diagram of the heat recovery system considered.

Evaluation of Lighting Systems

When exploring ECO's in lighting systems the plant was divided into seven areas. Namely, these areas are:

1. Hallway
2. Receiving room
3. Storage room
4. Cheese processing room
5. Main processing room
6. Starter manufacture room
7. Office

Energy conservation opportunities existed in the plant lighting in two areas of energy management. First load shedding, or reducing actual lighting levels and secondly by following a regular program of turning off lights in the plant when they are not needed or when that particular area of the plant is not in use. Two steps were involved when load shedding ECO's were explored. First by use of a General Electric light meter, (Type 214, No. 195) actual lighting levels in foot candles were measured throughout the plant. These measured values were recorded in the early morning so sunlight entering through plant windows was not a factor.

Secondly, the actual lighting levels were compared to the recommended minimum standards of illumination for milk plants taken from the Manual for Milk Plant Operators (1967). The difference in thest two values were then calculated as a percent possible savings. A 5.0 percent margin of safety and worker comfort in all of these calculations was considered. It should be noted that although the plant areas were not named as such in this source, by use of a description they were matched to the various plant areas at the M.S.U. plant. The recommended standards used for the various areas in the plant were as follows:

Area	Lighting Level Foot Candles
Hallway	30
Receiving room	50
Storage room	30
Cheese processing room	40
Main processing room	40
Starter manufacture room	30
Office	150

Two steps were involved when considering ECO's in regard to the implementation of a program for turning out lights when not needed. First, during the audit, the operations in the plant were observed to determine the amount of time lights were in use and the amount of time lights were actually needed. This difference was calculated as a percent savings in lighting requirements. For example, the lights in a storage area need not be on all day but only when plant workers are actually in the storage area. Next it was calculated how many kilowatt-hrs. could actually be saved after considering the corrected lighting levels calculated in the load shedding step. In other words, these

ECO's can be expressed as an additional energy savings in the lighting systems after actual lighting levels have been reduced. A nine hour working day is assumed.

Uninsulated Steam Line Evaluation

Heat radiated through uninsulated steam lines at the dairy plant is not always lost since it does accomplish space heating during most of the year. In evaluating energy savings through insulation a sixteen week period during summer months when space heating is not needed is assumed.

The steam pressure in the lines is approximately 85 psig and 316^{o}F. The ambient air temperature of the plant is assumed to be 70^{o}F. Ninety five percent of the heat lost from uninsulated lines can be recovered through insulation (Rao, Katz, 1976). All data were collected on a weekly basis, by noting the number of hours per week the uninsulated steam lines were hot. The energy lost was assessed as an increased energy demand during processing operations. Formula 2 was used to determine the amount of energy lost.

Economic Evaluation

In computing the economic feasibility of these energy conservation techniques "Life-Cycle Costing" is used. As described by Kreider and Kreith (1975) the added cost of the energy saving system each year is compared to the cost of fuel saved each year. Thus one can determine whether or not a given system is economically viable for a given operation in a given location throughout the predicted life of the system. This method is described below.

First, additional capital costs are converted to an annual basis by the use of equation 4.

(4) $C_h = (C_{h,\ tot})\ (C.R.F.)$

Where: C_h equals the annual additional cost of the system (\$/year)

$C_{h,\ tot}$ equals total additional investment in energy savings hardware (\$)

C.R.F. equals the capital recovery factor (\$/\$/year)

The capital recovery factor is described by equation 5.

(5)
$$C.R.F. = \frac{i_d\ (1 + i_d)^t}{(1 + i_d)\ t-1}$$

Where: i_d equals the annual discount (or interest) rate (\$/\$/year)

t equals the expected lifetime of the system (years)

The cost of energy saved with a conservation system is defined by equation 6.

(6)
$$C = \frac{\text{Additional annual cost of hardware}}{\text{Total annual energy saved by the system}}$$

When justifying the system based on savings in reduced energy requirements over the life of the system, conventional compound-interest calculations are used. The future

value (x) of a sum of money whose present worth is P invested at an annual interest rate (i_{ann}) over a period of t years is:

(7) $X = P(1 + i_{ann})^t$

Consequently, the present worth of a sum X payable t years from now is:

(8)
$$P = \frac{X}{(1 + i_{ann})^t}$$

The compound interest value of a mortgage with constant annual payments of P_{ann} is:

(9)
$$X = \frac{P_{ann}\ (1 + i_{ann})^{t-1}}{i_{ann}}$$

The present worth P is then defined as:

(10)
$$P = P_{ann}\ \frac{(1 + i_{ann})^{t-1}}{i_{ann}\ (1 + i_{ann})^t}$$

If the annual payment P_{ann} is not constant but increases at an annual rate j, in \$/\$/year due to price escalation then P can be calculated as:

(11)
$$P = \frac{P_o\ (1 + i_{eff})^{t-1}}{i_{eff}\ (1 + i_{eff})^t}$$

Where P_o is the initial annual payment, and the effective interest rate i_{eff} is:

(12)
$$i_{eff} = \frac{1 + i_{ann}}{1 + j} - 1 = i_{ann} - j$$

Thus equation 11 is used to answer the question, "what is the economically justifiable principal, $C_{h,tot}$ a processor can invest in an energy conservation system if the present annual savings in heating costs is P_o, a cost that is increasing at an annual rate of j and for which the interest rate for borrowing is i_{ann}?" An example of this calculation is shown in Appendix M.

For this part of the analysis a life expectancy of 20 years was assumed for insulation and for the heat recovery system. All material and labor estimates were based on published construction cost data by Mean's 1977. The system was evaluated using a 10, 12 and 15 percent interest rate after taxes for borrowing money and considered 5, 10 and 15 percent annual increases in fuel prices.

Energy saved through conservation measures was compared to possible savings of conventional fossil fuels. The prices of these fuels were obtained per million BTU for the first quarter of 1978 from Consumers Power Company of Michigan. They represent State averages and are as follows: (1) $10.83 for electricity; (2) $2.38 for natural gas; (3) $2.16 for industrial grade coal; (4) $2.20 for fuel oil #6.

RESULTS AND DISCUSSION

Audit of Energy Consumption

In conducting an energy audit of the M.S.U. dairy plant data were collected according to energy use by function for the various energy consuming systems necessary in the manufacture of cheese, yogurt and ice cream. Specific areas of energy consumption which are considered are as follows:

1. Electrical - This represents the electrical energy necessary for the operation of 23 motors and pumps used for the physical movement of the product. The various motors and pumps are described by function in Appendix D_4. Also included in electrical demand are the lighting requirements in the plant.

2. Processing - This includes all thermal energy inputs required for the processing of the products.

3. Cleaning - This represents the total thermal energy input necessary in the sanitation of all processing equipment and for general plant cleaning. A description of all processing equipment is found in Appendix G_3.

The operating areas of the plant are in use five days per week, fifty weeks per year between the hours of 7:00 am and 4:00 pm.

The major product manufactured in the dairy plant is a variety of cheeses. Cheddar and other similar varieties of fermented cheeses are made four days per week. Casa Blanca or a similar variety of acid set cheese is made one day per week. Approximately 6,000 pounds of milk per day is processed in the manufacture of about 2,850 pounds of finished cheese per week.

Table 8 summarizes the present energy demand in the manufacture of cheese on a weekly basis. Appendices B, C, D, E, and F provide a breakdown of the various energy inputs according to how the energy was used during the manufacture of cheese.

Table 8. Weekly energy consumption for cheese manufacture

Energy Input	BTU/week	BTU/lb Finished Product
Electrical	2,382,000	836
Processing	2,520,000	884
Cleaning	3,908,000	1,371
Total	8,810,000	3,091

Ice cream and yogurt are manufactured one day per week on alternating weeks. When yogurt is manufactured during one week, ice cream is made the following week. Approximately 100 gallons of ice cream mix and 100 gallons of yogurt are made every other week. These are relatively small amounts of each product so their energy demand is minimal in comparison to the energy required for cheese manufacture. Tables 9 and 10 summarize the total energy demand on a weekly basis for the manufacture of these two products. Appendices D_1, D_2 and G describe the breakdown of the various energy inputs in accordance with function for yogurt and ice cream manufacture.

It was possible to estimate average yearly energy demands for the manufacture of cheese, yogurt, and ice cream because of relatively consistent product mix schedules throughout the year. The energy intensity of a given manufacturing process can be measured in BTU per pound of finished product. As seen in Tables 8, 9 and 10 cheese processing is the most energy intensive process of the three. This factor could indicate that substantial gains in energy conservation are more likely to exist during the manufacture of cheese than in the manufacture of ice cream and yogurt.

Evaluation of Energy Conservation Opportunities

There are various opportunities for reducing total energy requirements at the dairy plant. Table 11 summarizes the energy usage estimates on an annual basis and compares this value with the existing potential for energy conservation. Appendix K provides a breakdown of Table 11 showing where specific reductions in energy conservation can be accomplished.

Table 9. Weekly energy consumption for ice cream manufacture

Energy Input	BTU/week	BTU/lb Finished product
Electrical	193,000	211
Processing	88,000	96
Cleaning	376,600	412
Total	657,600	719

Table 10. Weekly energy consumption for yogurt manufacture

Energy Input	BTU/week	BTU/lb Finished product
Electrical	84,000	94
Processing	112,000	124
Cleaning	306,600	341
Total	502,600	559

Table 11. Total annual energy consumption and the potential for energy conservation

Energy Input	Present Usage (BTU)	Possible Requirement (BTU)	Conservation Potential (%)
Electrical[1]	1.2865×10^8	9.2650×10^7	28.0
Process Heat[2]	1.3600×10^8	9.6384×10^7	29.1
Cleaning[3]	2.0875×10^8	7.2650×10^7	65.2
Total	4.7340×10^8	2.6168×10^8	44.7

1. Potential savings resulting from the ECO's in reducing electrical demand.

2. Potential savings resulting from the ECO's in insulating steam lines.

3. Potential savings resulting from the ECO's in waste heat recovery.

Appendices C_1, C_2, E_1, F_1, G_1, H, I, and J provide the data showing how these estimates were derived.

In evaluating energy conservation opportunities (ECO's) in electrical usage it was found that lighting systems throughout the plant accounted for approximately 63 percent of the total electrical usage. Of the energy needed for lighting 44 percent can be conserved through load shedding and improved lighting management practices. This will result in a 28 percent reduction in the amount of electrical energy used.

Motors and pumps accounted for the additional 37 percent of the total electrical energy consumed. Since all motors and pumps are used only when they are needed, ECO's did not exist in this area. Electrical requirements presently account for 27.2 percent of the total BUT's of energy used in the plant. With the potential for conservation in this area it is possible to reduce this figure to 19.6 percent of the total energy consumption level.

As seen in appendices D_1 and D_2 motor number 17 (the filler) requires more electrical power during ice cream manufacture than it does during yogurt manufacture. This is because the ice cream mix is partially frozen during the filling operation whereas yogurt is not. Since the filler is running closer to a maximum load during ice cream packaging, it probably has a higher power factor when filling ice cream than when yogurt is filled.

Various areas were considered when exploring the possibility of reducing the energy used for actual processing operations. Energy conservation through insulation of presently uninsulated steam lines proved to be substantial in reducing thermal energy required during processing. Although heat given off from steam lines is not always lost when space heating is considered, it is wasted during non heating months of the year. A 29.1 percent savings could be realized through insulation when only 16 weeks of the year are considered. Presently thermal energy inputs for processing account for about 29 percent of the total energy requirement. By eliminating losses through uninsulated lines this figure could be reduced to about 20.4 percent.

Another area considered for ECO's is that of reducing certain process temperatures or times to conserve thermal energy inputs. Becuase of the specific nature of process time and temperature relationships in processing yogurt, ice cream and cheese, ECO's would be negligible if present levels of overall product quality were to be maintained.

As seen in appendices A through A_8 the condensate flow rates and the time it takes to heat milk varies in the three vats. A possible reason for this would be that the efficiency of the pasteurization vats differ. Since they are relatively old pasteurization vats there could be more scale build up on the heat exchange surface on one vat than another. If the heat exchange surfaces of the three vats were cleaned the efficiency of the vats would probably be improved and more uniform heating could be obtained.

Wasteful practices of discarding hot solutions and processing water are presently being used. It is possible through heat recovery methods to recover most of this heat. Even though this would not reduce the thermal energy required for processing, it can substantially reduce the energy demand for equipment and plant cleaning operations. Recovering heat from discarded condensate, cheese whey and hot cleaning solutions by use of the systems described on pages 41 through 44 it is possible to reduce the energy demand for cleaning by approximately 65 percent. Since cleaning operations presently require the largest energy input of all energy consuming processes in the plant this figure is especially significant. The energy requirements can be reduced approximately 11.4 percent by recovering condensate, 39.8 percent by recovering discarded cleaning solutions and 14.0 percent by recovering discarded whey and hot water used in starter manufacture.

Presently, the energy input for cleaning represents 44.1 percent of the total energy requirements. Through the various heat recovery systems this could be reduced to about 15 percent. These figures assume a 90 percent efficient recovery system for condensate and a 75 percent efficient heat recovery system for discarded processing solutions.

In terms of actual water supplied to a hot water storage tank these systems would supply about 665 gallons of 125°F water to the tank four days per week and 2,000 gallons of 127^{o}F water one day per week. This assumes that all operations done only once per week such as starter manufacture, ice cream or yogurt manufacture and Casa Blanca cheese manufacture would all be done on the same day of the week. Appendix L shows the specific solutions considered for heat recovery.

Economic Evaluations

Various parameters such as discount rates (interest rates) and future increases in fossil fuel prices are important when evaluating the economics of any conservation system requiring a capital investment. By altering these two parameters the economic feasibility of a conservation system can become more or less justifiable.

In evaluating the feasibility of the described heat recovery system and the insulation of steam pipes three different discount rates were assumed. A 10 percent discount rate was used to represent what a public institution such as Michigan State University would have to pay; 12 and 15 percent discount rates were used to represent the range a private company would have to pay. Presently an actual discount rate might fall anywhere between 12 and 15 percent depending on the size of the particular company.

The systems were also analyzed assuming a 5, 10 and 15 percent annual increase in fossil fuel prices. Fuel price increases would probably not occur in such a consistent manner in reality but would probably fluctuate somewhat, however, these percentages can be used to illustrate how the economic feasibility of the various conservation systems are effected by fuel prices.

Tables 12 through 17 show the economics of the two systems being discussed. The net present value (N.P.V.) shows how much money would actually be saved over the 20 year life expectancy of the system. The maximum allowable investment figure represents the maximum dollar amount that could be invested in a system to break even over the life expectancy of the system. All calculations shown were determined on a present dollar basis.

As shown in the tables the heat recovery system is only justified economically, with the exception of when electricity is used as a primary source of heat generation, when considering 10 and 12 percent discount rates, and if the price of fossil fuels increases by 15 percent annually. Unlike coal, fuel oil and natural gas, there are very few food processors who use electricity as their primary source of heat generation. This figure, then, can not be considered as significant as the figures for the fossil fuels.

Although the heat recovery system does not seem to be economically justifiable for the M.S.U. Dairy Plant it should be noted that the dairy uses very little energy in comparison to other industrial dairy operations. The economics of a heat recovery system may be improved considerably for a plant which uses considerably more energy.

The cost of insulating steam pipes is justified by the savings in the cost of energy that would occur. This is especially significant because many of the steam pipes are already insulated in the plant. Since the insulation is justified considering a 5 percent increase in fuel prices and a 15 percent discount rate it would be safe to assume that insulation of any uninsulated steam line in any processing plant can save the plant energy and money.

Although energy should be conserved whenever possible the results of the economic evaluation indicate that insulation of steam pipes would presently be a better investment for the M.S.U. Dairy than a heat recovery system. This could change, however, as the cost of energy as well as its availability would dictate.

Electricity can be conserved by improving the management of lighting systems. By following the described methods of reducing the electrical demand for lighting a sum of $390.000 per year could be saved with a corresponding present value of about $3,300.00 over a period of 20 years. This figure is significant because it does not consider future price increases for electricity and offers greater economic rewards than any of the other energy conservation methods discussed even though it would require no capital investment on the part of the dairy.

Since lighting circuits are split in the dairy plant an effort should be made to use only as much light as needed to maintain safety and worker comfort.

Table 12. Economic analysis of heat recovery system (10% discount rate)

Fossil Fuel	Cost/MBTU ($)	Annual Savings ($)	Estimated System Cost ($)	Maximum[1] Allowable Investment ($)	Maximum[2] Allowable Investment ($)	Maximum[3] Allowable Investment ($)	N.P.V.[1]	N.P.V.[2]	N.P.V.[3]
Fuel oil #6	2.20	300	7,600	3,800	6,190	9,870	-3,800	-1,410	2,270
Coal	2.16	295	7,600	3,740	6,090	9,710	-3,860	-3,740	2,100
Nat. gas	2.38	325	7,600	4,120	6,710	10,690	-3,480	-890	3,090
Electricity	10.83	1,475	7,600	18,700	30,530	48,530	11,100	22,930	40,930

1. Assuming a 5% annual increase in fossil fuel prices

2. Assuming a 10% annual increase in fossil fuel prices

3. Assuming a 15% annual increase in fossil fuel prices

Table 13. Economic analysis of insulating bare steam pipes (10% discount rate)

Fossil Fuel	Cost/MBTU ($)	Annual Savings ($)	Estimated System Cost ($)	Maximum[1] Allowable Investment ($)	Maximum[2] Allowable Investment ($)	Maximum[3] Allowable Investment ($)	N.P.V.[1]	N.P.V.[2]	N.P.V.[3]
Fuel oil #6	2.20	90	180	1,140	1,860	2,960	960	1,680	2,780
Coal	2.16	85	180	1.080	1,750	2,800	900	1,570	2,620
Nat. gas	2.38	95	180	1,200	1,960	3,130	1,020	1,780	2,950
Electricity	10.83	430	180	5,450	8,870	14,150	5,270	8,690	13,970

1. Assuming a 5% annual increase in fossil fuel prices

2. Assuming a 10% annual increase in fossil fuel prices

3. Assuming a 15% annual increase in fossil fuel prices

Table 14. Economic analysis of heat recovery system (12% discount rate)

Fossil Fuel	Cost/MBTU ($)	Annual Savings ($)	Estimated System Cost ($)	Maximum[1] Allowable Investment ($)	Maximum[2] Allowable Investment ($)	Maximum[3] Allowable Investment ($)	N.P.V.[1]	N.P.V.[2]	N.P.V.[3]
Fuel oil #6	2.20	300	7,600	3,260	4,990	8,005	-4,340	-2,610	405
Coal	2.16	295	7,600	2,310	4,910	7,870	-5,290	-2,690	270
Nat. gas	2.38	325	7,600	3,535	5,410	8,670	-4,065	-2,190	170
Electricity	10,83	1,475	7,600	16,040	24,550	39,350	8,440	16,950	31,750

1. Assuming a 5% annual increase in fossil fuel prices
2. Assuming a 10% annual increase in fossil fuel prices
3. Assuming a 15% annual increase in fossil fuel prices

Table 15. Economic analysis of insulating bare steam pipes (12% discount rate)

Fossil Fuel	Cost/MBTU ($)	Annual Savings ($)	Estimated System Cost ($)	Maximum[1] Allowable Investment ($)	Maximum[2] Allowable Investment ($)	Maximum[3] Allowable Investment ($)	N.P.V.[1]	N.P.V.[2]	N.P.V.[3]
Fuel oil #6	2.20	90	182	980	1,500	2,400	798	1,318	2,218
Coal	2.16	85	182	925	1,410	2,270	743	2,088	2,088
Nat. gas	2.38	95	182	1,035	1,580	2,530	853	2,348	2,348
Electricity	10.83	430	182	4,680	7,160	11,470	4,498	6,978	11,288

1. Assuming a 5% annual increase in fossil fuel prices

2. Assuming a 10% annual increase in fossil fuel prices

3. Assuming a 15% annual increase in fossil fuel prices

Table 16. Economic analysis of heat recovery system (15% discount rate)

Fossil Fuel	Cost/MBTU ($)	Annual Savings ($)	Estimated System Cost ($)	Maximum[1] Allowable Investment ($)	Maximum[2] Allowable Investment ($)	Maximum[3] Allowable Investment ($)	N.P.V.[1]	N.P.V.[2]	N.P.V.[3]
Fuel oil #6	2.20	300	7,600	2,640	4,990	6,070	-4,960	-2,610	-1,530
Coal	2.16	295	7,600	2,600	4,910	5,970	-5,000	-2,690	-1,630
Nat. gas	2.38	325	7,600	2,860	5,410	5,470	-4,740	-2,290	-2,130
Electricity	10.83	1,475	7,600	12,980	24,540	29,820	5,380	16,940	22,220

1. Assuming a 5% annual increase in fossil fuel prices

2. Assuming a 10% annual increase in fossil fuel prices

3. Assuming a 15% annual increase in fossil fuel prices

Table 17. Economic analysis of insulating bare steam pipes (15% discount rate)

Fossil Fuel	Cost/MBTU ($)	Annual Savings ($)	Estimated System Cost ($)	Maximum Allowable Investment[1] ($)	Maximum Allowable Investment[2] ($)	Maximum Allowable Investment[3] ($)	N.P.V.[1]	N.P.V.[2]	N.P.V.[3]
Fuel oil #6	2.20	90	180	790	1,500	1,820	610	1,320	1,640
Coal	2.16	85	180	750	1,410	1,720	570	1,230	1,540
Nat. gas	2.38	95	180	840	1,580	1,920	660	1,400	1,740
Electricity	10.83	430	180	3,780	7,150	8,700	3,600	6,970	8,520

1. Assuming a 5% annual increase in fossil fuel prices
2. Assuming a 10% annual increase in fossil fuel prices
3. Assuming a 15% annual increase in fossil fuel prices

CONCLUSIONS

Present levels of energy consumption and the existing potential for energy conservation at the Michigan State University Dairy Plant were studied. The thermal and electrical energy required to manufacture cheese, ice cream and yogurt were determined.

The results of this study support the following conclusions.

1. Electrical requirements for the operation of motors and lighting systems is presently approximately 129 million BTU annually which represents 27.2 percent of the total energy consumed by the dairy plant.

2. The incorporation of a comprehensive lighting management program including load shedding and turning out lights when not in use can reduce total electrical energy consumption by approximately 28 percent.

3. At present costs for electricity savings of $390.00 annually are possible with a comprehensive lighting management program.

4. Thermal energy requirements for actual processing operations presently consumes approximately 136 million BTU annually which represents 28.7 percent of the total energy consumed at the dairy plant.

5. By insulating all uninsulated steam lines in the plant a reduction of approximately 29 percent in thermal energy requirements for processing could be realized.

6. The cost of insulation is justified economically considering present and expected fossil fuel prices over the life expectancy of the insulation.

7. Thermal energy requirements for equipment and general plant cleaning operations presently consumes approximately 200 million BTU annually which represents 4.0 percent of the total energy consumed by the dairy plant.

8. The installation of a waste heat recovery system for discarded condensate, cleaning solutions and hot processing fluids could reduce the energy requirements for cleaning operations by approximately 65 percent.

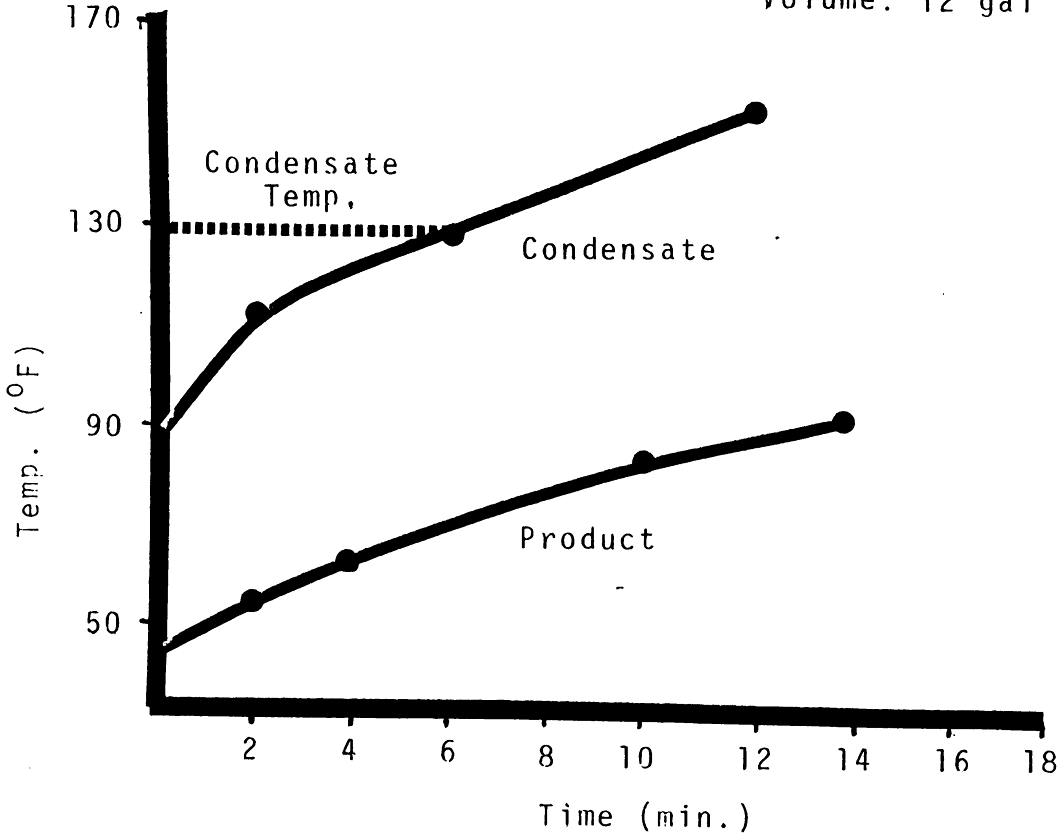
9. The cost of installing a waste heat recovery system is not presently justified economically considering present and expected fossil fuel prices over the life expectancy of the system.

APPENDIX

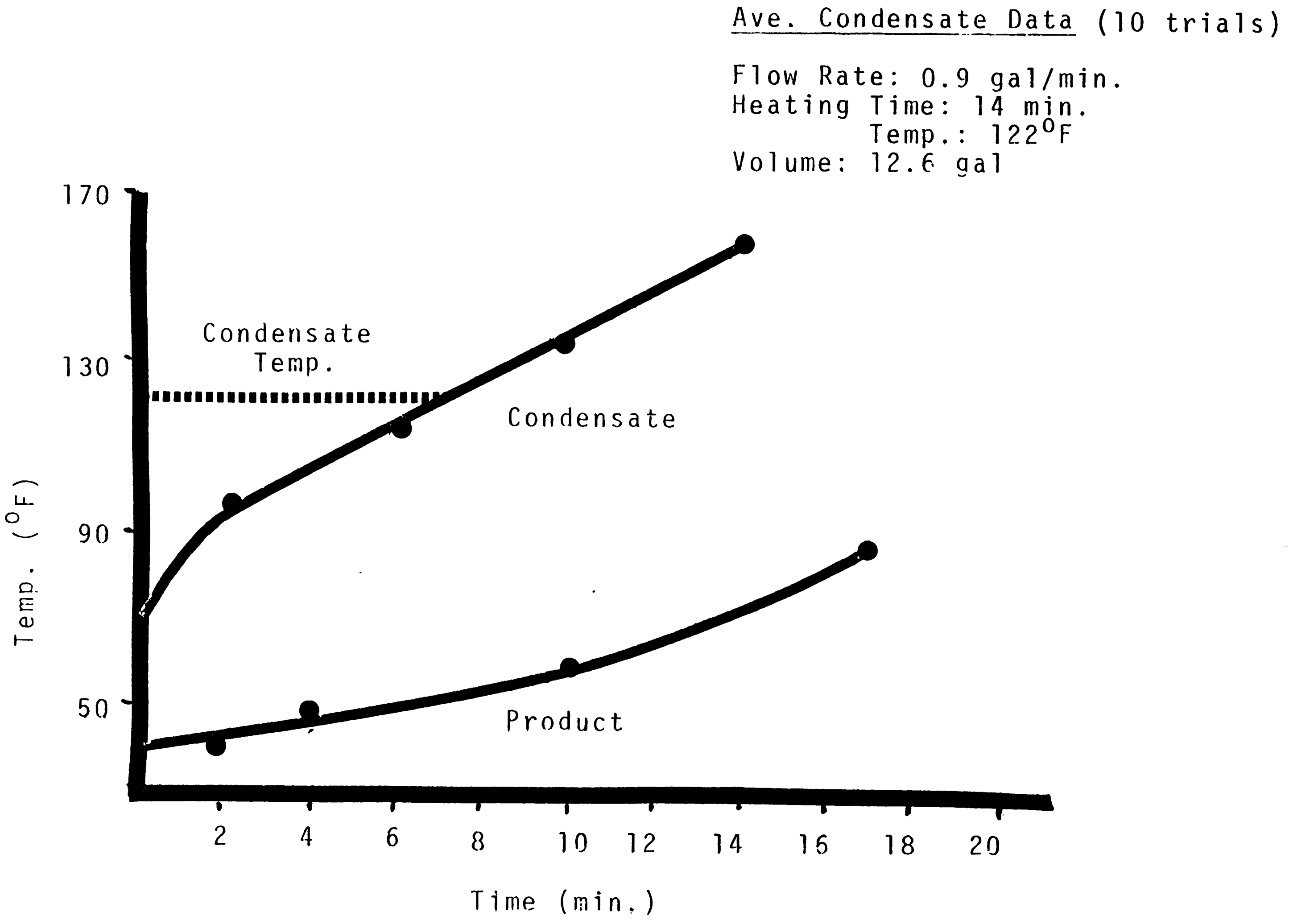
Appendix A. Heating milk from 40 to 88^{0}F (VAT #1)

<u>Ave. Condensate Data</u> (10 trials)

Flow Rate: 1.0 gal/min.
Heating Time: 12 min.
Temp.: 130^{0}F
Volume: 12 gal



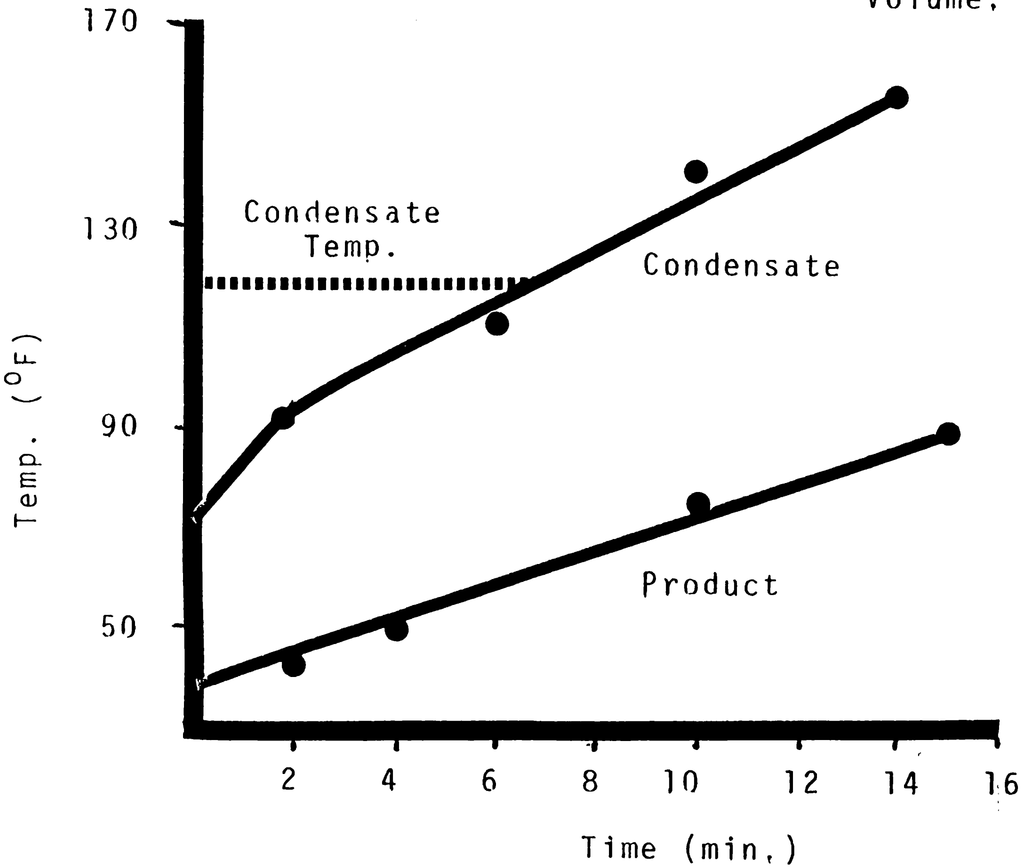
Appendix A_1. Heating milk from 40 to 88^{0}F (VAT #2)



Appendix A_2. Heating milk from 40 to 88^{o}F (VAT #3)

<u>Ave. Condensate Data</u> (10 trials)

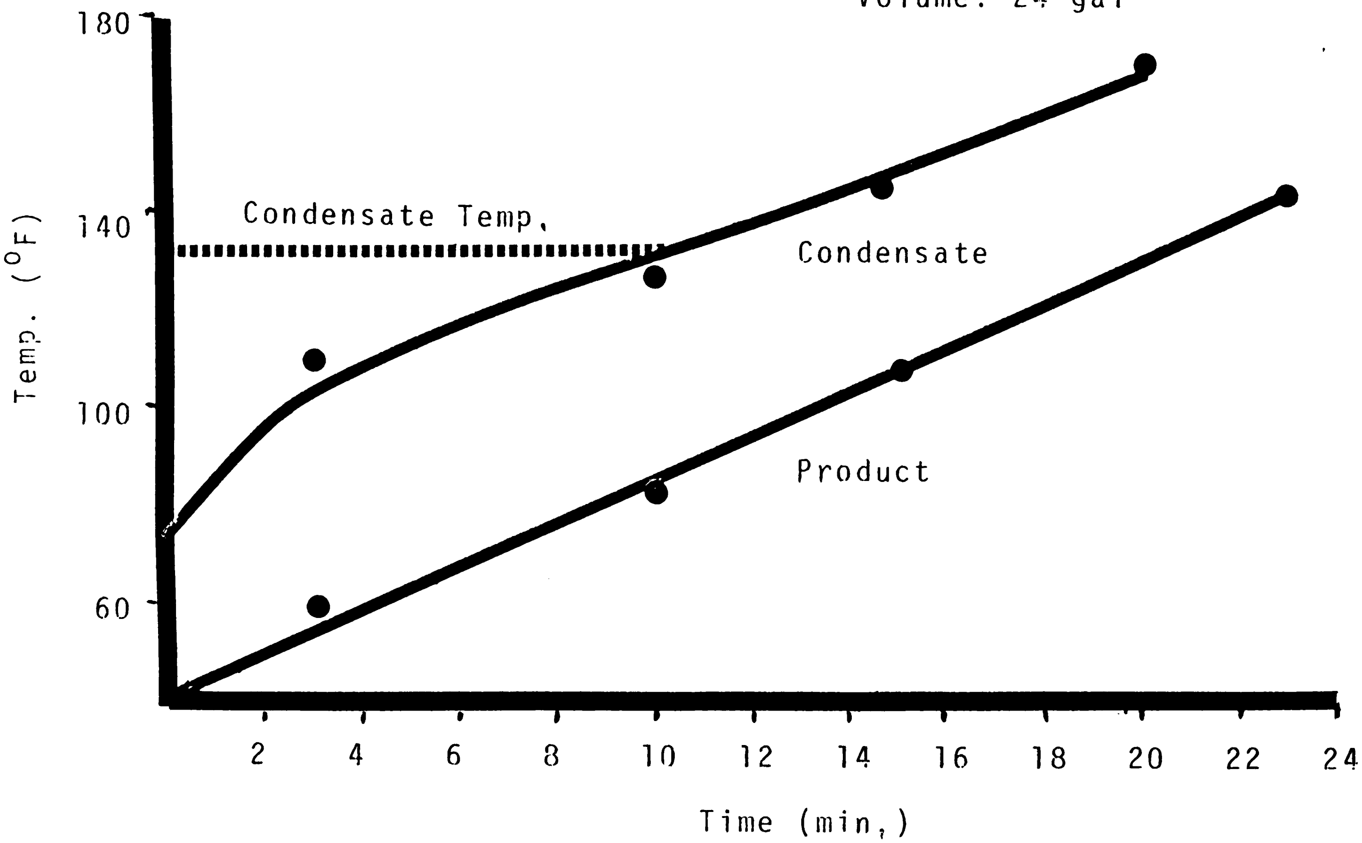
Flow Rate: 1.2 gal/min.
Heating Time: 14 min.
Temp: 119^{o}F
Volume: 16.8 gal



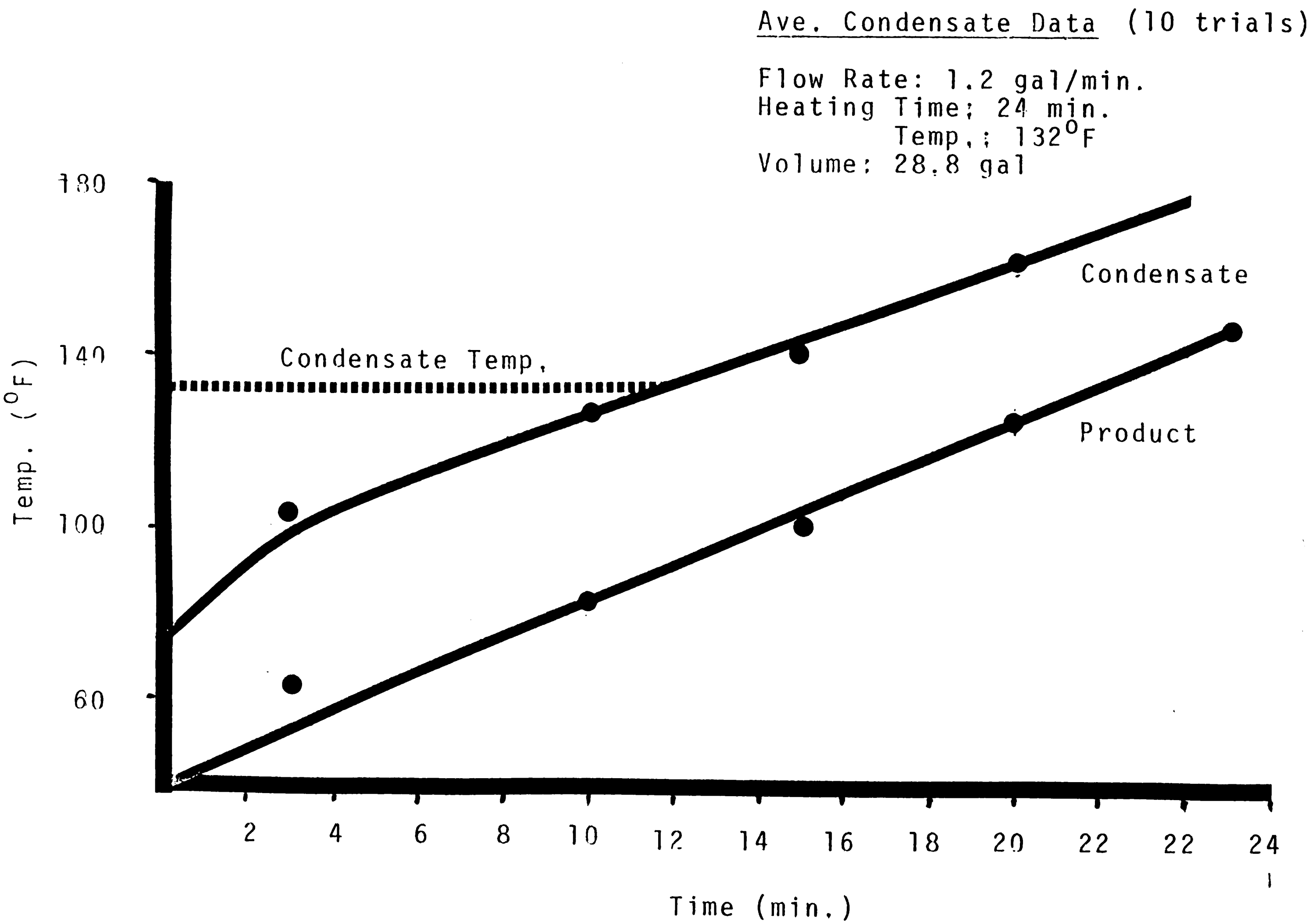
Appendix A_3. Heating milk from 40 to 145^oF (VAT #1)

<u>Ave. Condensate Data</u> (10 trials)

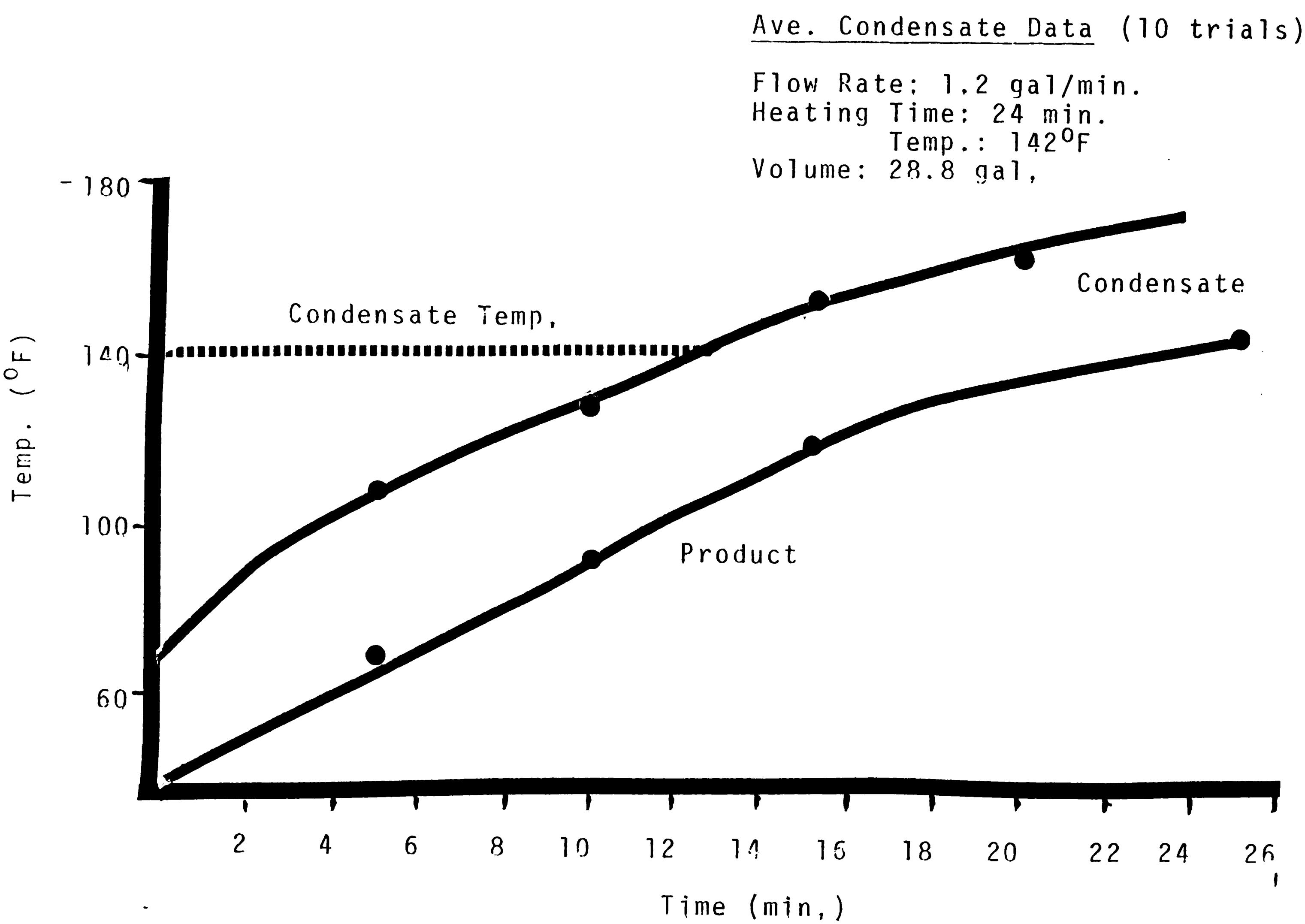
Flow Rate: 1.2 gal/min.
Heating Time: 20 min.
Temp.: 134^oF
Volume: 24 gal



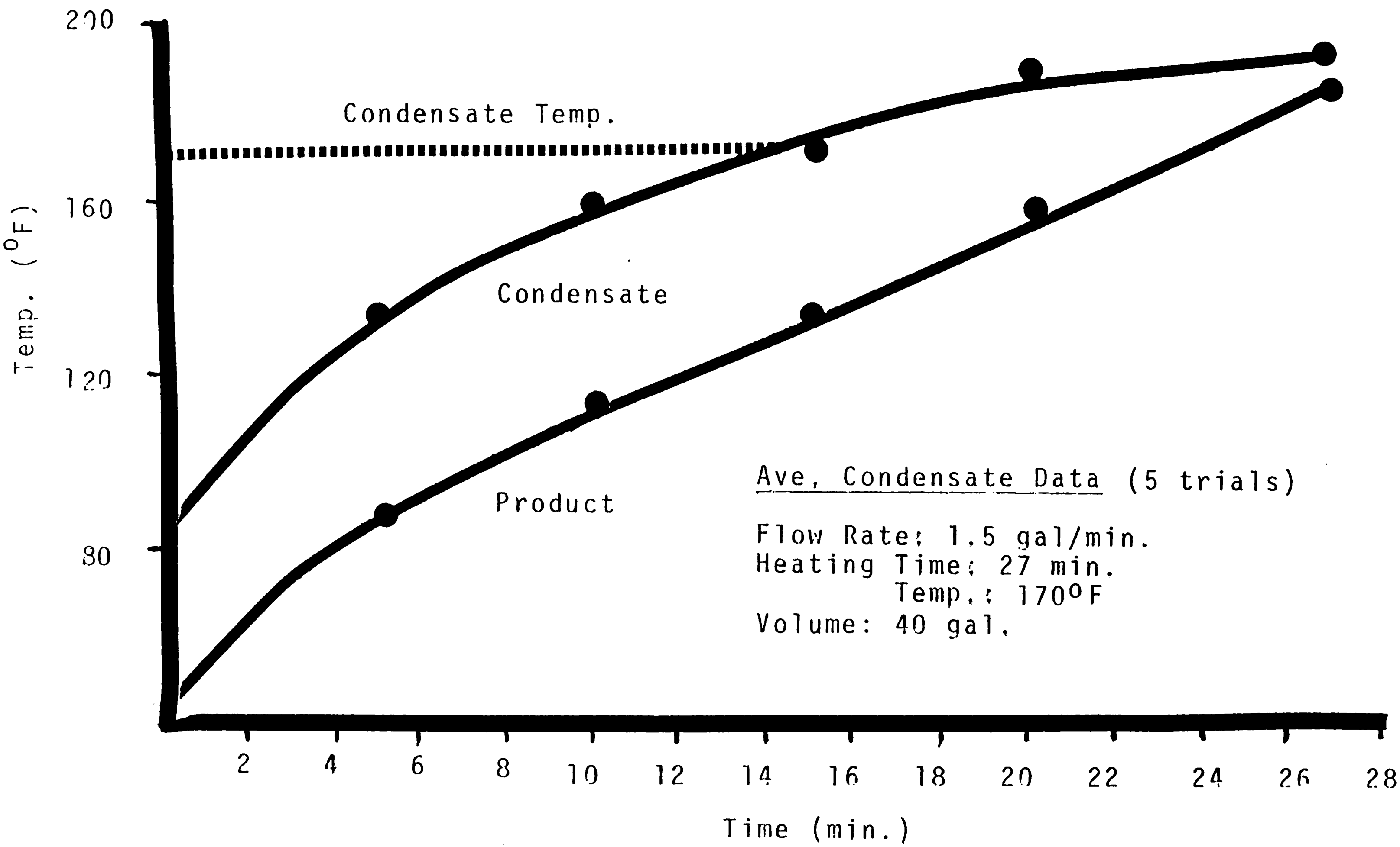
Appendix A_4. Heating milk from 40 to 145^{o}F (VAT #2)



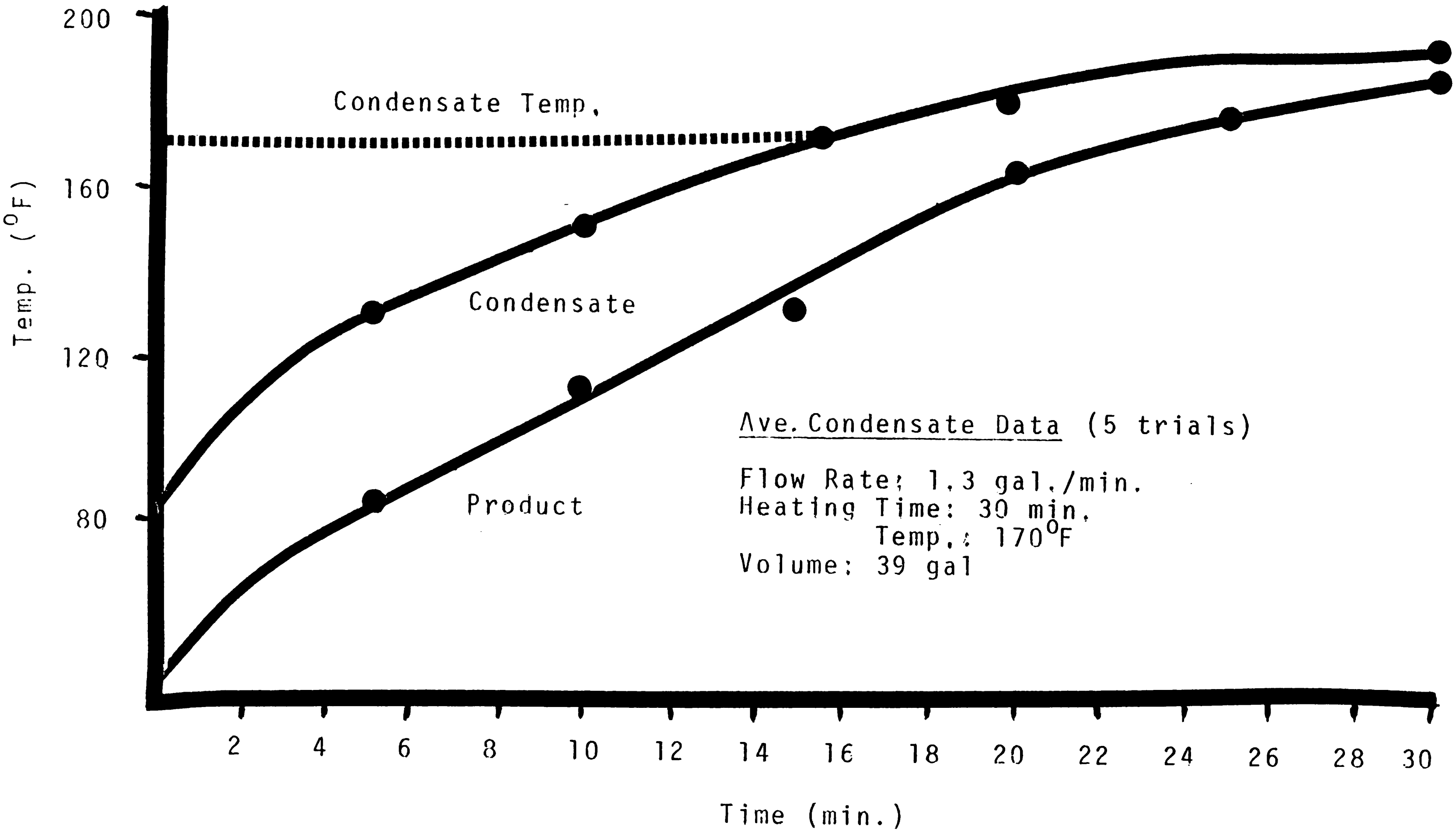
Appendix A_5. Heating milk from 40 to 145°F (VAT #3)



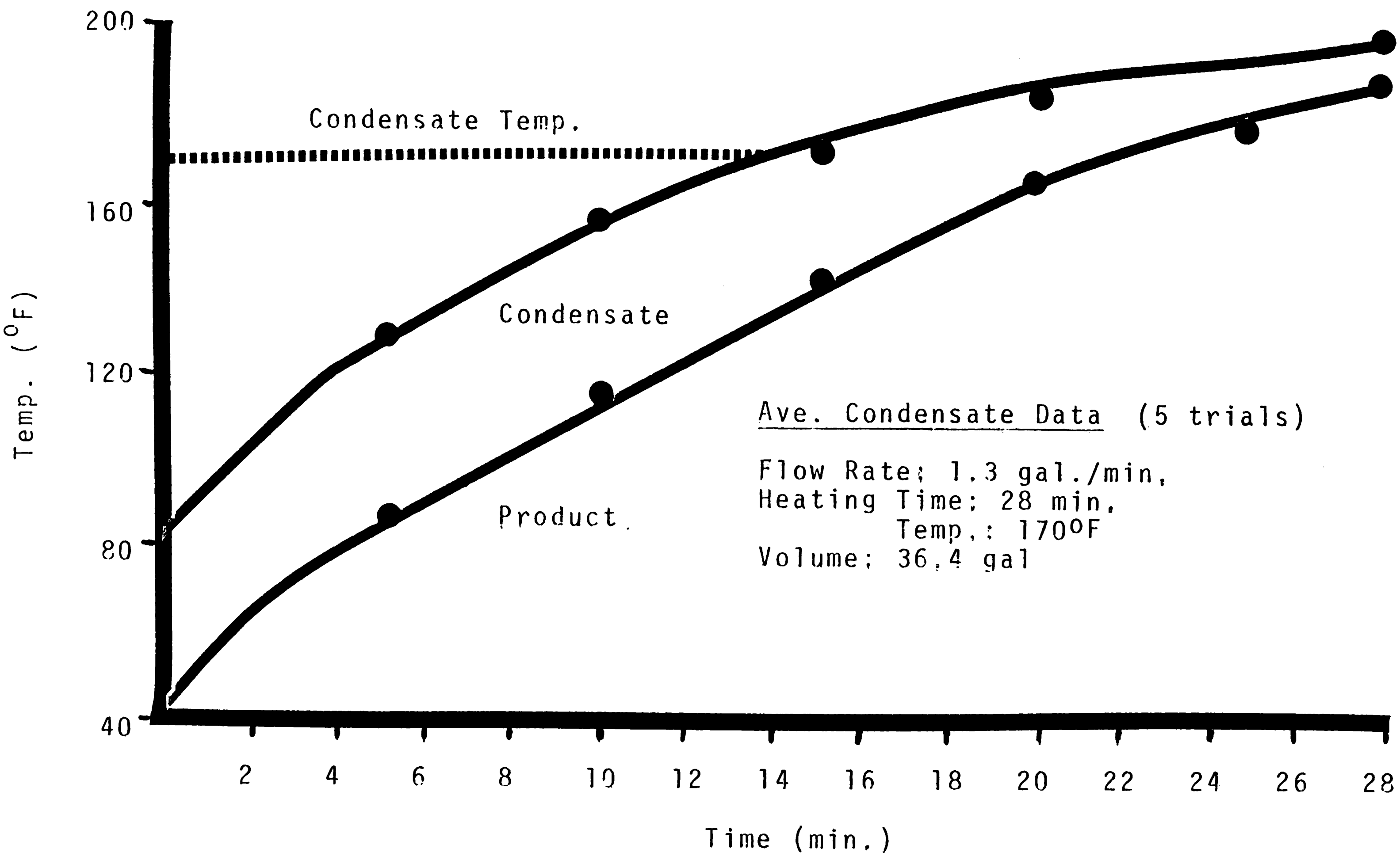
Appendix A_6. Heating milk from 40 to 185°F (VAT #1)



Appendix A_7. Heating milk from 40 to 185^{o}F (VAT #2)



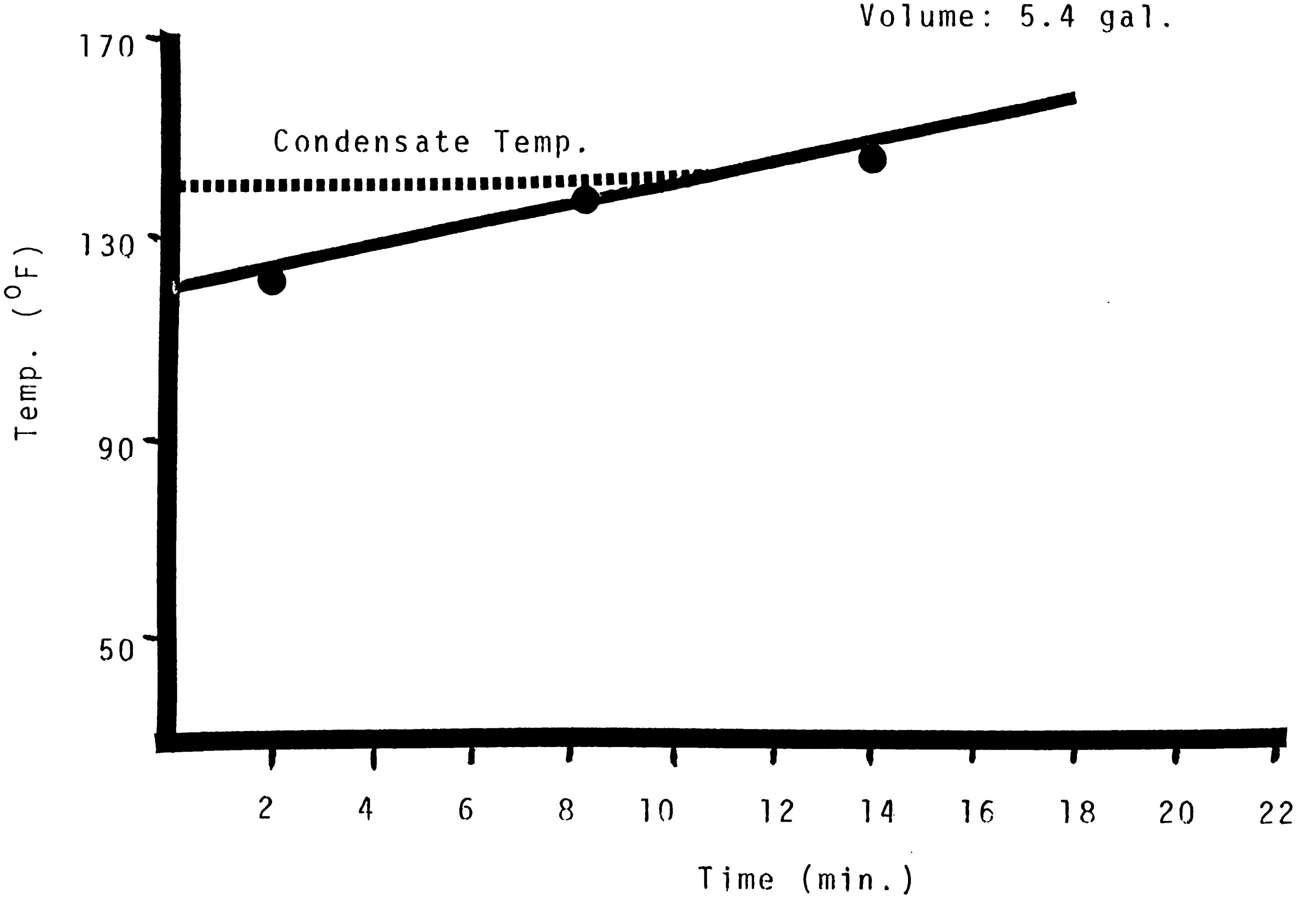
Appendix A_8. Heating milk from 40 to 185^{o}F (VAT #3)



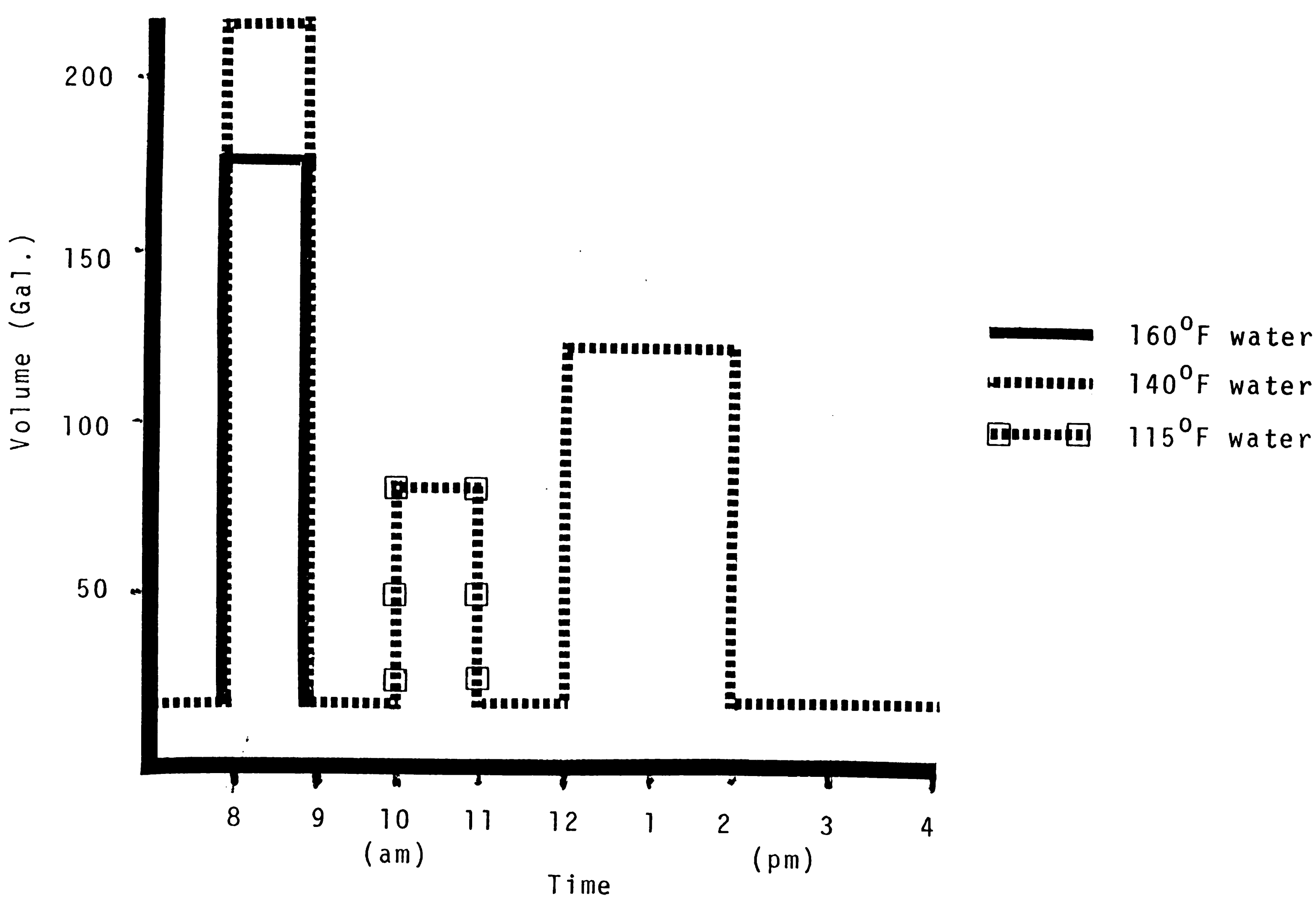
Appendix A_9. Cheese vat condensate

Ave. Condensate Data (10 trials0

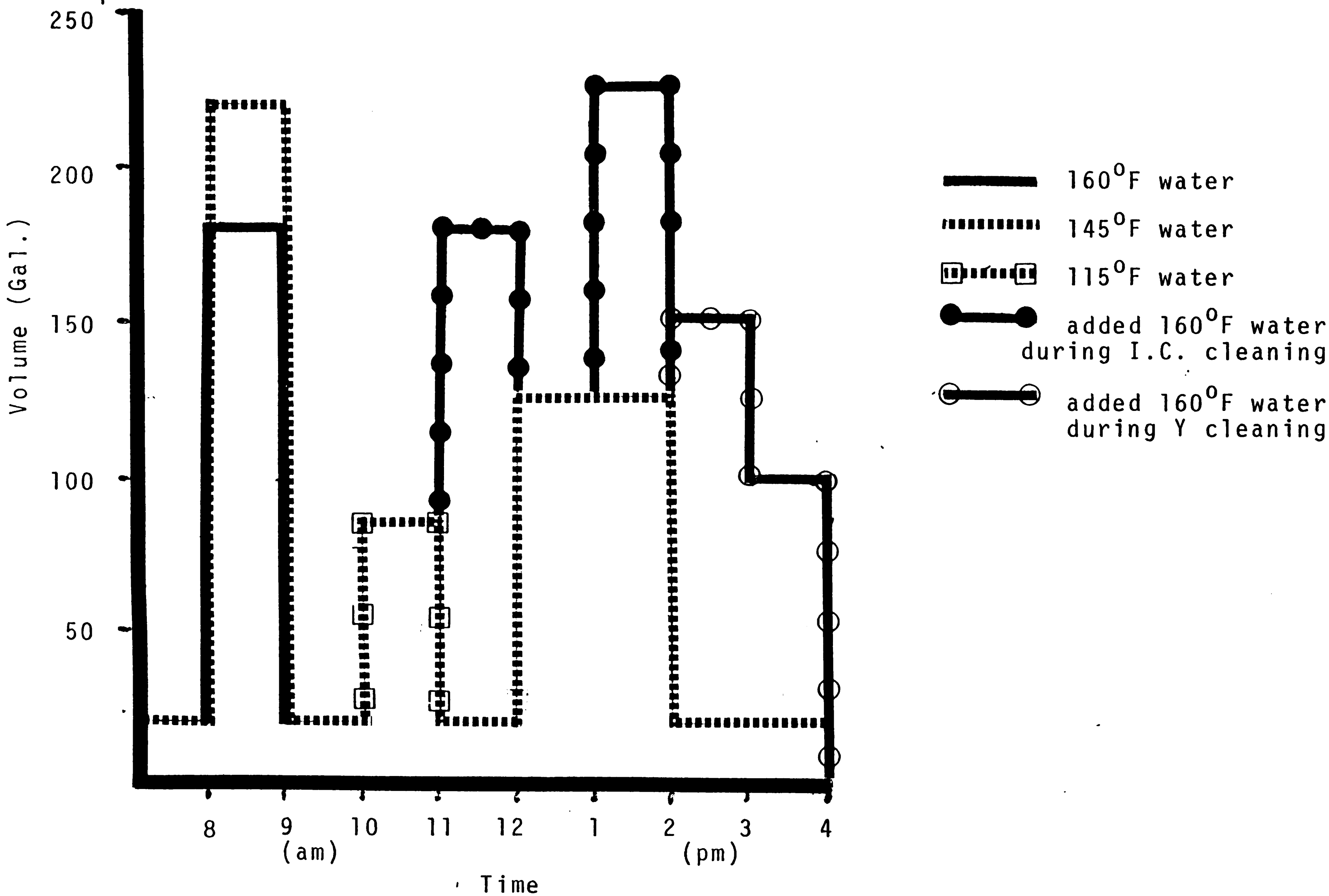
Flow Rate: 0.3 gal./min.
Heating Time: 18 min.
Temp.: 142°F
Volume: 5.4 gal.



Appendix B. Average hourly warm water use pattern (4 days/week)



Appendix B_1. Average hourly warm water use pattern (1 day/week)



Appendix C. Total lighting requirements for the M.S.U. dairy plant

Area	Hrs./Day	Number of Bulbs	Power (KW)	KWH (Day)	BTU/Day[4]
Storage Rm.	9	15[3]	4.5	40.5	138,000
Receiving Rm.	5	4[3]	1.2	6.0	20,000
Proc. Rm.	9	18[1] + 18[2]	2.5	22.5	77,000
Hoop Rm.	5.5	3[3]	0.9	5.0	17,000
Cheese Rm.	7.0	22[1] + 4[2]	2.2	15.4	53,000
Hallway	9.0	6[1]	0.5	4.5	15,000
Office	9.0	2[2]	0.2	2.0	7,000
Total					328,000

1. 8' fluorescent bulbs 90 watts each
2. 4' fluorescent bulbs 48 watts each
3. Incandescent bulbs pulling 300 watts each.
4. Conversion of 3,413 BTU's/KWH was used

Appendix C_1: ECO's in lighting requirements

Area	Recommended Lighting[1] Levels (Foot Candles)	Actual Lighting Levels (Foot Candles)	Possible Savings[2] (%)
Storage Rm.	30	37	6.8
Receiving Rm.	50	90	36.0
Proc. Rm.	40	75	39.0
Hoop Rm.	30	40	14.0
Cheese Rm.	40	70	34.0
Hallway	30	32	0.0
Office	150	170	0.0
Total			21.3

1. Taken from the Manual for Milk Plant Operators (1967)

2. Savings include a 5% margin for safety and worker comfort

Appendix C_2: ECO's in lighting management

Area	Present[2] Hrs./Day	Suggested Hrs./Day	Possible[1] Savings (%)
Storage Rm.	9.0	4.5	50
Receiving Rm.	5.0	3.0	40
Proc. Rm.	9.0	9.0	0
Hoop Rm.	5.5	5.5	0
Cheese Rm.	7.0	7.0	0
Hallway	9.0	6.0	33.3
Office	9.0	9.0	0
Total			22.7

1. Savings were calculated assuming lighting levels which would meet the recommended lighting levels for various areas in the plant.

2. Average data based on 10 trials.

Appendix D. Electrical requirements for motors and pumps used in cheese manufacture

Motor #	Hrs./Day[1]	KW	Daily KWH	BTU/Day
1	0.5	3.22	1.6	5,000
2	7.7	0.2	1.36	5,300
3	7.5	0.77	1.82	19,700
4	7.7	0.64	1.4	16,900
5	0.75	2.3	1.7	6,000
6	1.0	2.6	2.6	9,000
7	0.75	2.2	1.7	6.000
8	0.3	2.3	0.7	2,000
9	3.2	0.1	0.32	1,000
10	0.4	3.2	1.3	4,500
11	2.25	6.25	14.1	48,000
12	0.1	0.4	0.04	100
13	2.0	2.6	5.0	17,000
14	2.0	2.4	4.8	16,000
15	2.0	2.5	5.0	17,000
Total				174,500

1. Average data based on 10 trials.

Appendix D_1. Electrical requirements for motors and pumps used in ice cream manufacture

Motor #	Hrs./Day[1]	KW	Daily KWH	BTU/Day
16	2.5	2.2	5.5	19,000
17	3.0	10.5	31.5	107,000
18	0.5	1.0	0.5	2,000
21	1.5	0.2	0.3	1,000
22	0.33	2.24	0.74	2,500
23	0.5	6.3	3.2	11,000
Total				142,500

1. Average data based on 3 trials.

Appendix D_2. Electrical requirements for motors and pumps used in yogurt manufacture

Motor #	Hrs./Day[1]	KW	Daily KWH	BTU/Day
17	2.0	3.6	7.2	24,500
18 (high)	0.5	6.0	3.0	10,000
18 (low)	0.5	1.0	0.5	2,000
19	0.5	6.25	3.1	10,500
20	0.75	0.24	0.18	1,000
21	1.5	0.2	0.3	1,000
Total				49,000

1. Average data based on 3 trials.

Appendix D_3. Description of motors and pumps

# 1	Creamery Package centrifugal pump with approximately 5.0 HP motor. No name plate available.
# 2	0.33 - 0.08 HP MASTER two speed gearhead motor which powers an agitator in a 200 gal. Creamery Package pasteurization vat. (Vat #1)
# 3	0.75 - 0.37 HP MASTER two speed gearhead motor which powers an agitator in a 300 gal Cherry Burrell pasteurization vat. (Vat #2)
# 4	0.33 - 0.08 HP MASTER two speed gearhead motor which powers an agitator in a 200 gal Creamery Package pasteuriztion vat. (Vat #3)
# 5	Marathon centrifugal pump used to circulate hot water through a pasteurization vat. HP rating equals 1.5.
# 6	Worthington centrifugal pump used to circulate hot water through a pasteurization vat. HP rating equals 2.0.
# 7	Westinghouse centrifugal pump used to circulate hot water through a pasteurization vat. HP rating equals 1.5.
# 8	Creamery Package centrifugal pump used to transport milk from the pasteurizing vats to the cheese vat. HP approximately 1.5. No name plate available.
# 9	0.75 HP, variable speed Stoelting motor used to power an agitator on a Damrow 800 gal. steam jacketed cheese vat.

#10 Creamery Package centrifugal pump used for circulating cleaning water on pasteurization vats. Approximate HP is 5.0. No name plate available.

#11 AMPCO centrifugal pump used for water agitation on portable Creamery Package parts washer.

#12 0.5 HP Leland gearhead motor used to power a cheese mill during cheddar manufacture.

#13 Worthington centrifugal pump used to circulate sweet water through a pasteurization vat. HP rating equals 2.0.

#14 Worthington centrifugal pump used to circulate sweet water through a pasteurization vat. HP rating equals 2.0.

#15 Westinghouse centrifugal pump used to circulate sweet water through a pasteurization vat. HP rating equals 2.0.

#16 0.75 - 0.37 Master two speed motor used to power an agitator in a 1000 gal Cherry Burrell ice cream mix storage tank.

#17 Cherry Burrell ice cream freezer. With a 10.0 HP dasher motor and a 0.75 HP pump motor.

#18 Cherry Burrell Superhomo Homogenizer. Capacity of 580 gal/hr., 3000 lb maximum pressure.

#19 Cherry Burrell portable pump used for mixing ingredients in yogurt manufacture. HP rating equals 0.75.

#20 0.25 HP, Master gearhead motor used to power agitator in portable 1000 gal. Cherry Burrell mixing vat.

#21 0.25 HP, Master gearhead motor used to power an agitator in portable 100 gal Creamery Package mix vat.

#22 Creamery Package centrifugal pump used for transport of ice cream mix to and from storage tank. Approximate HP rating equals 0.5. No name plate available.

#23 Creamery Package centrifugal pump used for circulate cleaning water through the ice cream mix storage tank. HP rating equals 1.5.

Appendix E. Heat input during cheese manufacture

Process	Times/ Week	Lbs./ Day	BTU/ Day	BTU/Week
Cheese Mfg. (reg.)	4	6,000	349,200	1,396,800
Cheese Mfg. (acid set)	1	6,000	843,900	843,900
Starter Mfg.[1]	1	86	51,800	51,800
Dipping[2]	5	570	24,200	121,100
Total[3]				2,519,900

1. Represents heating 100 gallons of water to 210°F
2. Represents heating 50 gallons of water to 200°F
3. Includes losses through steam lines while processing

Appendix E_1. Discarded warm solutions during cheese manufacture

Process	Times/ Week	Discarded Solns./Day Gal	Temp	BTU Loss/ Day	BTU Loss/ Week
Cheese Mfg. (reg.)	4	632	100°F	237,200	948,800
Cheese Mfg. (acid set)	1	632	185°F	726,900	726,900
Starter Mfg.[1]	1	100	210°F	44,000	44,000
Total[1]		632	100°F	237,200	
Total[2]		732	188°F	777,000	
Total[3]					1,760,700

1. Daily BTU loss 4 days/week
2. Daily BTU loss 1 day/week
3. Weekly BTU loss

Appendix F. Energy input for cleaning of cheese processing equipment

Equipment	Times/ Week	Volume/ Day (Gal.)	Temp. (^{o}F)	BTU/Week
Hoop cleaning	10	85	115	1,169,700
Past. Vats	5	85	160	788,100
Cheese Vat & Equip.	5	180	160	1,063,400
Tanker & Lines	2	300	140	255,200
Line Rinsing	3	120	140	141,800
Total[1]		100	140	3,908,200

1. Includes 15 percent for general plant clean-up

Appendix F_1. Recoverable hot solutions from cheese equipment cleaning

Equipment	Times/ Week	Vol. Discarded Wk. (Gal.)	Ave. Temp. Discarded Solns. (^{o}F)	BTU/Week
Hoop Cleaning	10	1,700	133	1,105,900
Past. Vats	5	340	150	269,400
Cheese Vat & Equipment	5	800	110	367,000
Tanker & Lines	2	200	130	125,100
Line Rinsing	3	360	120	195,200
Total[1]		3,400	128	2,062,500

1. Represents a weekly average

Appendix G. Energy input for cleaning of yogurt and ice cream equipment

Cleaning Operation	Times/ Week	Vol. (Gal.)	Temp. (°F)	BTU/Week
I.C. Storage Tank	1	180	160	157,600
Mix Vat & Filler (Y. & I.C.)	1	100	160	87,600
Homogenizer (Y. & I.C.)	1	150	160	131,400
Mix Vat (Y.)	1	100	160	87,600
Total[1]		250 to 280	160	241,600 (Ave.)

1. When the ice cream equipment is used during a given week the yogurt equipment is not and vise versa

Appendix G_1. Recoverable warm solutions during cleaning operations for yogurt and ice cream

Cleaning Operation	Times/ Week	Vol. (Gal.)	Temp. (°F)	BTU/Week
I.C. Storage Tank	1	150	145	112,600
Mix Vat & Filler (Y. & I.C.)	1	75	145	56,300
Homogenizer (Y. & I.C.)	1	50	135	33,400
Mix Vat (Y.)	1	75	145	56,300
Total[1]		200 (min)	142	145,100

1. When the ice cream equipment is used during a given week the yogurt equipment is not and vise versa. This total represents a minimum amount of discarded hot solutions per week

Appendix H. Cleaning data for all processing equipment

Cleaning Job	Prerinses		Cleaning Solutions		Post Rinses		Total	
	Used	Discarded	Used	Discarded	Used	Discarded	Used	Discarded
Hoop cleaning	-	-	85 gal 160°F	85 gal 155°F	85 gal 115°F	85 gal 110°F	75 gal 160°F 85 gal 115°F	170 gal ≈133°F
Past. vat cleaning	-	-	130 gal 160°F	35 gal 145°F	50 gal 160°F	50 gal 155°F	180 gal 160°F	85 gal ≈150°F
Cheese vat & equipment	-	-	160 gal 140°F	160 gal 110°F	140 gal 140°F	140 gal	300 gal 160°F	160 gal 110°F
Cleaning tanker & lines	-	-	60 gal 140°F	60 gal 115°F	60 gal 140°F	60 gal 115°F	120 gal 140°F	120 gal 120°F
Rinsing lines	-	-	-	-	100 gal 140°F	100 gal 110°F	100 gal 140°F	100 gal 110°F
Ice cream mix storage tank	60 gal 160°F	50 gal 145°F	60 gal 160°F	50 gal 145°F	60 gal 160°F	50 gal 145°F	180 gal 160°F	150 gal 145°F
Ice cream mixing vat and filler		-	50 gal 160°F	25 gal 135°F	50 gal 160°F	-	100 gal 160°F	75 gal 145°F
Mixing vat & homogenizer		-	100 gal 160°F	50 gal 135°F	50 gal 160°F	-	150 gal 160°F	50 gal 135°F
Mixing vat		-	50 gal 160°F	25 gal 135°F	50 gal 160°F	-	100 gal 160°F	75 gal 145°F

Appendix I. Discarded condensate from processing equipment

Operation	Times/Wk	Condensate Discarded Daily Gal	Temp °F	BTU/Day	BTU/Wk
Heating milk 40-88°F	4	41	125	23,936	95,744
Heating milk 40-145°F	5	85	136	57,421	287,105
Heating milk 40-185°F	1	119	170	114,133	114,133
Heating curd 88-102°F	4	5	142	3,628	14,512
Heating yogurt mix 40-185°F	1	39	170	37,405	37,405
Heating I.C. mix 40-145°F	1	28	143	20,550	20,550
Total[1]		131	133	84,985	339,940
Total[2]		232	154	191,553	191,553

1. Recoverable condensate daily, 4 days/week

2. Recoverable condensate daily, 1 day/week (minimum figure)

Appendix J. Heat loss through uninsulated steam lines

Nominal Pipe Size	Pipe Length (ft)	Hours Hot/Day	BTU Loss/ Week While Processing	Total BTU Loss/Week	Total BTU Loss/Year
3/4"	17.8	24	15,700	528,900	6,462,500
3/4"[1]	33.0	1	28,900	40,500	647,600
1.0"	18.0	24	19,100	642,500	10,279,300
1.0"[1]	5.0	1	5,200	7,300	117,439
1.5"	23.5	24	33,400	1,120,800	17,933,500
2.0"	2.5	24	4,100	136,000	2,176,100
Total[2,3]			106,400	2,476,000	39,616,500

1. Hot only during a certain process once per week

2. Steam pressure is 85 psig, temperature is 316^{o}F, and average air temperature in the plant is assumed to be 70^{o}F

3. Energy is only considered wasted 16 weeks per year, when space heating is not needed

Appendix K. Breakdown of total annual energy consumption and the potential for energy conservation

Operation	Present Demand (BTU)	Possible Saving (BTU)	Conservation Potential (%)
Lighting[1]	8.199×10^{7}	3.6×10^{7}	44%
Motors & Pumps	4.666×10^{7}	0	0
Total Electrical	1.2865×10^{8}	3.6×10^{7}	28
Steam Lines[2]	-	3.9616×10^{7}	29.1
Total Processing	1.36×10^{3}	3.9616×10^{7}	29.1
Disc. Condensate[3]	-	2.3905×10^{7}	11.4
Disc. Cleaning Solns.[4]	-	8.3065×10^{7}	39.8
Disc. Proc. Solns.[4]	-	2.9135×10^{7}	14.0
Total Clean-up	2.0875×10^{8}	1.3610×10^{8}	65.2
Total (Annual)	4.734×10^{8}	2.1172×10^{8}	44.7

1. Includes savings calculated as reduced total lighting levels and through an improved lighting management policy

2. Assumed 95% of heat lost through uninsulated pipes could be recovered (RAO et al., 1976). Ambient air temperature in the plant was taken as 70°F. Steam pressure was taken as 85 psig and a temperature of 327°F

3. Plant water supply was taken as 55°F. A 10% loss through condensate return lines was assumed

4. Plant water supply was taken as 55°F. A 75% heat exchanger system was assumed

Appendix L. Discarded hot solutions considered for heat recovery system

Discarded Solns.	Times/ Week	Vol. (Gal)	Temp. (°F)	BTU/Week
Condensate[1]	4	131	133	340,000
Condensate[1]	1	232	154	191,500
Cheese Equipment Cleaning[2]	5	680	128	2,070,000
Yogurt & I.C. Equip. Cleaning[2]	1	200	142	145,100
Disc. Whey from Casa Blanca[2]	1	632	185	655,600
Starter Mfg.[2]	1	100	210	129,300
Total[3]				2,744,200

1. 90 percent of the heat is recoverable

2. 75 percent of the heat is recoverable

3. Actual heat that is recoverable from the system on a weekly average basis

Appendix M. Sample calculation for economic evaluation of an energy conservation system

If

P = \$300.00 (Value of fuel saved through conservation for 1978 fuel prices)

j = 0.15 (expected annual increase in fuel cost)

i_{ann} = 0.10 (interest rate for loan)

t = 20 (life expectancy of the system)

$C_{h,tot}$ = \$7,600.00 (total cost of the energy conservation system)

then

$$i_{eff} = \frac{1+.10}{1+.15} -1 = -.0435$$

and

$$P = 300 \times \frac{(1+-0.0435)^{20}-1}{(-0.0435)(1+-0.0435)^{20}} = \$9,870.00$$

The maximum an owner could pay under these conditions would be \$8,005.00.

The N.P.V. would equal $P - C_{h,tot}$ or:

\$9,870.00 - \$7,600.00 = \$2,270

The owner would make \$2,270 dollars of the system over its life expectancy.

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