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DEMONSTRATION OF THE POTENTIAL FOR ENERGY CONSERVATION IN
SEVERAL FOOD PROCESSING PLANTS

Demonstration of the Potential for Energy Conservation in
Two Midwestern Pork Processing Plants

Final Report
for Period December 15, 1977-December 31, 1980

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Demonstration of the Potential for Energy Conservation in
Two Midwestern Pork Processing Plants

ABSTRACT

An energy study of two Midwestern pork processing plants was conducted to quantify present energy consumption and to determine potential energy savings with modification of existing processing equipment or adoption of alternative equipment. Process energy consumption was measured in each plant at each processing step or at each unit operation and pertinent costs obtained. Energy utilized was categorized by type such as gas, electricity, steam, etc. Process conditions such as temperature, pressure, flow rates, etc, were also measured so that they could be related to energy consumption.

Through measurement of operating parameters and the calculation of material and energy balances, patterns of energy loss in the major unit operations were determined. The major energy using unit operations in the two plants were; the scald tanks, the dehairing machines, the singeing operation, the smokehouses (sausage and smoked meats), the lard rendering operations, the inedible cookers, the blood drying operations and the hair drying operations. The total yearly steam and gas energy consumed by the processes studied in Plant A amounted to 133.6 billion Btu's and 207.8 billion Btu's in Plant B. Of that total, Plant A uses approximately 15.5% and Plant B uses 7.5% for sanitation and cleaning. The remaining energy is used to operate the various unit operations.

The energy used in the major unit operations can be broken down into lost energy and recoverable energy. Lost energy is that energy that will not effect production if eliminated. For the processes studied in Plant A, non-productive energy amounts to 48% of the energy supplied. The non-productive energy in Plant B amounted to 60.6% of the total process energy.

On the other hand, recoverable energy is that energy that was used for some productive purpose but still has value upon completion of the process. For the processes studied in Plant A, recoverable energy amounts to 40% of the energy supplied. The potentially recoverable energy for Plant B is 35.8% of the process energy supplied.

CHAPTER 1 - INTRODUCTION

Together, the activities of producing, processing, distributing and preparing food in the United States utilize over 10 percent of the entire national energy requirement. The major energy user of the nation's food system is the meat packing industry.

Background and Literature Survey

Several recent studies have analyzed energy use in the food system (SRI, 1972; Hirst, 1973; USDC, 1973; Conference Board, 1974; Hirst, 1974; Steinhart and Steinhart, 1974; USDA, 1974; Fritsch et al, 1975; FEA, 1976a). Depending on the source of information, the U.S. food industry uses 11.9 to 17 percent of the entire national energy consumption of 65 quadrillion BTU (Conference Board, 1974). Steinhart and Steinhart (1974) estimated that the food system consumes 12.8 percent, while Hirst (1973) suggested 11.9 percent and Fritsch et al (1975) stated that 12 percent of the U.S. total is utilized by the food industry. The 17 percent figure was presented by the FEA (1976a) from the summing of available estimates for each food system component. These estimates include all phases of the food industry; production, manufacturing, wholesale trade, retail trade, home preparation and transportation. Unger (1975) and Singh (1978) reviewed the currently available information concerning the energy used by the various food industries. Total energy used solely for manufacturing (processing) foodstuffs represents 4.1 to 4.8 percent of the U.S. consumption (Hirst, 1973; FEA, 1976a).

In 1963, a total of 2870 trillion BTUs were consumed by processors supplying food (Hirst, 1974). The total includes 51.3 billion kilowatts of electricity. The breakdown of energy supply to various food industry plants was studied by Morse and Proctor (1978). The authors determined that 11 percent of the energy supplied to the plants was in the form of electricity and 89 percent was supplied as heat (60 percent fuel oil, 17 percent coal, and 12 percent natural gas). Also noted was the fact that 70 percent of the heat was used at temperatures below 212°F.

Overall Energy Use in the Meat Industry

The meat products sector (production, processing and distribution) used 184 trillion BTU or 0.27 percent of the U.S. total according to a census report (USDC, 1972). Narrowing this amount further, the meat packing and sausage divisions consumed 132 trillion BTU (DPRA, 1974). This amount is shared by pork processing together with all other meat processing except fish and poultry. The meat packing industry is the largest energy user of the entire food industry and the processing section of the meat sector consumes 0.17 percent of the total U.S. energy use (Conference Board, 1974).

The meat packing industry can be separated into three broad divisions, slaughtering plants, processing plants and integrated plants which contain both slaughter and processing operations. Many of the meat packing plants, especially the larger facilities, also engage in rendering of meat by-products such as dried hydrolyzed hair, dried blood and meat and bone meal. In smaller meat packing operations the rendering processes are often performed outside the facility by independent firms.

Another FEA (1975) report analyzed the flow of natural gas in the different types of meat plants. In integrated plants 87 percent of the total gas was used as boiler fuel. The remaining 13 percent was used for processing. In plants that only manufactured processed meat products, 90 percent of the natural gas was used for the boiler. For plants with only pork slaughtering operations, the boiler consumed 95 percent of the total gas usage.

The previously mentioned studies were prepared using data obtained from diverse sources. The reports do not subdivide the total meat industry energy consumption beyond broad categories. Detailed analysis of the energy consumption by various plant types or meat products are limited. At the individual plant level, published analysis is also limited although the methodology has been presented (Stallburn, 1976).

Plant Level Energy Usage

Most plant level energy consumption information for food processing consists of correlating monthly or yearly utility flows with production. There has been some detailed energy utilization work in a few food processing areas. Several surveys have been done concerning the canning industry (Lund et al, 1977; Rao, 1977; Singh, 1977; Chhinnan et al, 1978), the coffee industry (Okado et al, 1980) and milk drying (Goel et al, 1979). For process specific information more closely related to the meat packing industry, there has been work done in poultry processing plants (Zwillenberg et al, 1976; Dwyer et al, 1977; Whitehead, 1978).

A limited number of energy auditing surveys have been conducted in meat packing plants, (DPRA, 1974; Pearson and Pilling, 1975; FEA, 1976b; Lund et

al, 1977; Brasington, 1978). The DPRA (1974) study revealed that for slaughtering plants, 750 to 1500 BTUs per pound, liveweight, were used for beef and 1400 to 1900 BTUs per pound were used for pork. The estimates for finished meat products in plants which only process meat, ranged from 1500 to as high as 10,000 BTUs per pound for some specialty smoked meat products. In small slaughtering plants (less than 125 head per week) Brasington (1978) found that electricity consumption averaged 88 kilowatt-hours per head, natural gas averaged 251 cubic feet per head and water averaged 241 gallons per head. Pearson and Pilling (1975) reported that energy use by New Zealand slaughtering plants varied from 3.8 to 12.8 megajoules per kilogram of meat processed. Of the total input energy to the plants, an average of 80 percent was input as coal or oil while 20 percent was due to electricity.

Meat packing plants vary considerably in size and in the types of products manufactured. In 1972, plants with fewer than 20 employees represented 66 percent of the total number of meat plants but only 4 percent of the total production. The larger plants (more than 250 employees) represent only 6 percent of the plants, but account for 60 percent of the output (Casper, 1977). The total number of hogs slaughtered in federally inspected plants during 1978 was 72,024,000 (Anonymous, 1980d). During that year, 1,562,000,000 pounds of bacon, 1,598,000,000 pounds of ham (all types), 1,509,000,000 pounds of frankfurters and 1,620,000,000 pounds of lard (rendered and refined) were produced in the federally inspected plants (Anonymous, 1979b).

As might be expected, energy used by meat plants also varies depending on size, age and product mix. On an industry wide basis, typical plants consume somewhere between 1000 and 3000 BTUs per pound of product (Rosoff and Ries, 1976).

Process Level Energy Usage

There has been some research which provides more detailed information than overall plant energy use per pound of all products produced. The FEA (1976b) report and Pearson and Pilling (1975) have categorized utility flow through several meat plants. The process energy consumption information provided by these authors was based on estimates. Process energy use was calculated as a percentage of total plant energy use. No actual process energy flow measurements were performed. For a large slaughter and processing plant (3500 to 4000 hogs and 400 to 450 cattle per day), the FEA study estimated that of the total annual gas input of 480 billion BTUs, 431 billion BTUs were used in the boiler for steam production. Of the remaining gas, 7 billion BTUs were use in hog singeing and 12 billion BTUs were used for the process ovens. The auditors estimated that, of the total 336 billion BTUs of steam produced per year, 15 billion BTUs were used in scalding and dehairing and 10 billion BTUs were used in process ovens. Of the remaining steam, 9 billion BTUs were used in the blood cookers, 17.8 billion BTUs were used in a continuous inedible renderer, 23.8 billion BTUs were used in batch inedible cookers, and 12 billion BTUs were used in the edible cookers. Brasington (1978) used actual flow rate measurement of water for the report on utility usage in small slaughtering plants but electricity and gas were monitored only at the overall plant level.

Some reports, such as the DPRA (1974) and the FEA (1975) studies give process specific information by default since the plants studied performed singular functions. For example, a plant which only slaughtered animals was evaluated. Another plant processed certain meat products but did no

slaughtering. In this way, fresh meat energy consumption data can be compared with the energy required for processing various meat products. A similar situation exists in a report by Jones (1980) which analyzed operations in poultry rendering plants.

For the most part, reports concerning utility consumption in meat packing present overall energy use of plants, make estimates of process energy usage and suggest methods of energy conservation. The surveys present very little information, however, as to the actual energy usage at the unit operations level within plants. Such detailed process audits are difficult to conduct, especially in integrated plants where an "energy use per pound of specific product" assessment is nearly impossible without actual measurement. Indeed, in the FEA (1976b) report, the authors expressly state that the investigation of energy savings did not include production equipment because of a lack of expertise, while at the same time stressing that processing is a major energy user. cursory audits usually emphasize housekeeping type energy savings as well as the use of generalized heat recovery. There are seldom any process specific analysis or recommendations. These housekeeping type energy savings should not be ignored, however. Considerable savings in energy can be realized with minimum capital expense.

Specific unit operation energy consumption information has been provided for a few meat plant processes. One report (Anonymous, 1980a) indicated that a typical singeing operation used approximately 13 million BTUs per hour. In a comparison of a conventional scald tub-double dehairer system with a vertical vapor scalding system, Nickels et al (1976) measured the utility flow for a scald tank and dehairers. They found that the conventional scalding system used 142 kilowatt hours of electricity, 1.3 tons (2,870 pounds) of steam and

94.7 cubic meters (25,000 gallons) of hot and cold water per 1000 head slaughtered. Kosak and Toledo (1980) found that for a 70 minute stepwise smoking operation of 45.5 kilograms (100 pounds) of fish, the amount of gas used was 125 megajoules (118,000 BTUs). An additional 89 megajoules (84,400 BTUs) of steam use was estimated based on material and energy balance calculations. No electrical input to the smokehouse was evaluated. The authors calculated that 95 percent of the heat loss was due to uninsulated ductwork in the air recirculation system.

Energy Conservation and Alternative Processing

There have been numerous suggestions and reports of energy conservation in manufacturing and food processing plants. Most of these reports stress housekeeping type energy saving techniques. Massey and Robe (1980) reported that considerable fuel savings were attained simply by reducing cooling-heating demand. The results were achieved by increasing temperature control dead band allowing wider temperature fluctuations. Such relatively simple techniques as repair of steam traps can provide good energy savings for a manufacturing plant (Miller and Lee, 1980). Through use of a continuous stack gas analyzer and combustion control system, large savings of boiler fuel have been obtained (Keifer, 1980). Another processing plant reduced the amount of steam use by 24 percent through improved steam traps, boiler controls and economizers (Lange and Kramer, 1978). A potato processing plant reduced drier energy use by one third through exhaust heat recovery (Bresley, 1978). One food processing plant uses ice builders running during off-peak hours to supply refrigeration demands during the production day. In this way, demand charges are avoided. The same plant uses computer controlled load shedding of

refrigeration compressors. The system paid for itself is less than six months. Through general housekeeping the plant boiler fuel requirement was reduced 38 percent (Anonymous, 1979a). Slater (1975) reported a 10 percent decrease in energy consumption by a food processing plant simply by common sense conservation activities. Rippen (1975) reported up to 50 percent reductions in certain dairy applications.

Specifically for meat type plants, Zwillenberg et al (1976) and Dwyer et al (1977) reported on the conservation potential in a poultry processing operation. Recommendations for energy recovery and alternatives included use of heat exchangers, heat pumps, solar energy collectors and on site electrical generation. An energy accounting model was developed. The FEA (1976b) report listed many housekeeping as well as more specific suggestions. The replacement of batch rendering cookers with continuous ones and the redesign of scald tanks were two of the recommendations. The report estimated that 9.7 to 22.7 percent of the annual energy costs could be saved using simple conservation and heat recovery techniques. Kaiser et al (1974) reported substantial savings at a fresh meat plant through improved boiler control, pipe insulation and allowing pressure drops during peak periods. Additional savings were realized by using cleaning water at reduced temperatures. Another meat plant reduced the steam demand for plant hot water by recovering waste heat from refrigeration equipment (Anonymous, 1970). The AMI (1978) has published many conservation guidelines for meat plants which provide suggestions for energy saving. A new product report (Anonymous, 1980a) indicated that a two stage singeing-polishing system reduced gas usage over a single stage system. Reduction was from 13 million BTUs per hour to 9 million BTUs per hour. The system was designed for plants processing hogs in excess of 600 head per hour.

Recently, there has been much discussion of processing various parts of the hog before chilling. In this way the energy used during the carcass chill could be reduced. The hot processing of pork has become most readily apparent in plants which produce fresh sausage. The entire process may last as little as two hours from kill to packaged product (Reynolds, 1971; Anonymous, 1973). A suggestion has been made for hot processing of smoked ham to reduce the smokehouse cycle and coincidentally energy requirements (Anonymous, 1980b). The hams would be pumped at 100°F instead of 38°F before heating to 137°F. The shortened smoking cycle allows continuous processing. In fact, such systems exist which use electrostatic deposition of smoke or liquid smoke spray together with rapid heating and cooling. The systems can process any type of smoked product (Hanley et al, 1955a; Hanley et al, 1955b; Varner, 1968; Gray and Devendorf, 1974). A continuous system also lends itself readily to recovery and recycling of heat. The attractive aspects of a continuous system must be weighed against the realization that it is difficult to produce a real continuous flow of product. It is common for machinery in a continuous system to be left operating while personnel are on breaks.

An alternative is known which would reduce energy consumption by the hog killing and evisceration process. Instead of scalding, dehairing and singeing, the hog carcass is immediately skinned as with cattle (Romans and Zeigler, 1974). This change in processing can result in considerable reduction of energy usage (Judge et al, 1978). Steam, electricity and water requirements by the scald tank and dehairers are eliminated as well as the gas usage by the singeing operation. It has been determined that as much as 65 percent of the refrigeration requirement for chilling can be saved by use of the skinning-hot processing method (Ferguson and Henrickson, 1979). Such a

radical alteration of an existing process may be economically prohibitive in an established plant but may be viable in new plants.

Another suggestion which has been made for heating operations in food processing is the use of microwaves. The more selective heating nature of microwaves can provide overall savings of energy for heating and drying processes (Minett and Witt, 1976; Shute, 1976). A smokehouse is an example of a heating and drying process. In fact a system for processing precooked bacon using microwaves has been described (Anonymous, 1980c). The possible use of this type of heating method is somewhat limited for drying since most moisture loss occurs during the constant rate period of drying at which time microwaves provide little benefit. For the initial heating and moisture loss phases, microwave heating provides economical use of energy. Shute (1976) suggests that it would be more energy efficient to achieve a fixed product temperature through the use of microwaves instead of hot air. In addition, a low flow rate of cold air, rather than hot, can be used to remove moisture. Some bakeries are currently using a combination of microwave and conventional hot air for cooking. A microwave rendering system has recently been introduced for processing inedible material at low temperatures (Morris, 1979).

Objectives of the Investigation

Little information is available that identifies energy use in meat packing on the level of a unit operation (basic process step). At present, food plant engineers must rely solely upon information supplied by the manufacturers of the processing equipment. As one might suspect, such information can be biased. Detailed process data would also be helpful in identifying energy intensive and energy efficient operations. This will focus attention on those

processes which use more energy than is necessary. Subsequent research can then be performed to reduce the energy use in these processes.

Meat Industry and Government Cooperation

Representatives of the meat industry proposed to the United States Department of Energy that an energy analysis of meat packing processes be performed. Ideally, the research was to be conducted by an organization which would provide unbiased results. In order for the results to be widely accepted, the work would have to be done by an organization which was not motivated by any potential economic benefits that might be derived from the subsequent recommendations.

Thus, an energy study of meat packing plants was undertaken in cooperation with two meat packing companies and the Department of Energy. It was believed that the data obtained would be applicable to not only a large segment of the meat industry but also to the entire food processing industry as well. Two companies agreed to open plants for such studies: Armour-Dial, a division of the Greyhound Corporation, and Wilson Foods, a division of LTV Industries. The facilities which were provided by these companies were: Wilson Foods - Logansport, Indiana and Armour Foods - Louisville, Kentucky. Both plants are integrated pork processing facilities with production rates from 400 to 800 hogs per hour. In addition to slaughter and preparation of fresh cuts for wholesale, both plants process several varieties of smoked meats and sausage type products. Two types of rendering are also performed in the plants, edible and inedible. Edible rendering is the production of prime steam rendered lard or rendered pork fat. The inedible rendering process consists of the production of inedible grease or tallow and meat and bone meal.

In addition, both plants produce an inedible dried blood product and an inedible dried hydrolyzed hair product. The plants differ in age and production methods with one plant being older and generally using batch type production methods. At the other plant, production is commonly by continuous methods. The difference in age and production methods provides a good opportunity for comparisons.

Specific Objectives

The overall object of this thesis was to determine present energy consumption for selected processes to the detail of unit operations (processing steps). Following this, the next step was to determine potential areas for energy savings through modification of existing equipment or adoption of alternative processing methods.

Through a discussion with officials of the two cooperating companies, a selection was made of the processes to be studied. The processes selected for analysis at the older plant included the production of bacon, frankfurter processing, dehairing (from stun to rinse), lard rendering, blood drying, hair hydrolysis and drying, and the rendering of grease, meat and bone meal. At the newer facility, the processes which were studied include the entire kill and cut processes, ham manufacture, frankfurter processing, blood drying, hair hydrolysis and drying and the processing of inedible grease and meat and bone meal.

CHAPTER 2 - MATERIALS AND METHODS

The data collection was conducted in two phases. . Because of the nature of such a large project, preliminary estimates first had to be made concerning approximate flow rates of utilities to the unit operations. Before purchase of any monitoring devices certain operating parameters of the process equipment had to be known.

Preliminary Audit

Information concerning "walk through" plant energy audits has come from many sources. Some of the techniques used specifically for meat plants were presented in the FEA (1976b) and Brasington (1978) reports. The initial steps of an audit usually consist of obtaining monthly utility billings for a year. In some larger facilities, power house or plant engineers may keep weekly, daily or even hourly records. This is usually true of more modern plants which may have installed flow monitoring devices (such as circular chart recorders) on main feeder lines. By obtaining concurrent production data, seasonal variations in utility flows can be separated from fluctuations due to production.

The next step of a plant audit consists of obtaining information concerning operating schedules of process equipment. This frequently requires several 24 hour visitation periods in the larger plants. It was found that the assumption of one or two 8 hour shifts is not adequate for defining equipment operation periods. Some equipment may be operated long after production

ceases and equipment can be shut down for long periods during the process day. The assumption of a continuous 8 hour sanitation period can lead to serious errors in water and steam consumption estimates. The use of continuous recording ammeters (Amprobe Instrument) temporarily attached to process equipment can be of great help in determining actual operating schedules. In addition, of course, the meters provide data relating to electrical input.

By obtaining hourly measurements of total plant utility flows (from plant personnel or taken directly while conducting a 24 hour visit) and comparing the flow patterns with the process equipment schedules, it is possible to gain insight into process utility flows. An example would be the steam flow pattern of the plant during the night when the major process operating was rendering. Weekend or holiday audits are also helpful in defining process utility criteria and base line plant energy use. Literature pertaining to processing equipment may also prove beneficial in estimating utility flows. However, caution is mandated here because frequently it was found that equipment had been intentionally altered after installation. This fact coupled with normal equipment wear can substantially change the way equipment uses energy. These changes will affect the utility requirements of the equipment and produce consumption patterns different from the original specifications.

To breakdown process patterns further requires another technique sometimes called "the bucket, thermometer, and stopwatch approach". For obtaining water flow measurements of unit operations or sanitation hoses, a bucket of known volume and a stopwatch can be used to obtain approximate flow rates. The flow rates can then be used with process equipment schedules, mentioned above, to provide daily water consumption. Also, if temperature information is obtained, steam requirements for water heating can be estimated using

simple material and energy balance calculations. A thermometer (hand-held digital types were used: William Wahl Corporation and Omega Engineering), a psychrometer or hygrometer (Abbeon-Cal) and an air flow measuring device, such as a hot wire anemometer, pitot tube-manometer, or Biram anemometer (Taylor Instrument, Davis Instrument Manufacturing) can be used to obtain refrigeration or heating information of air handling (HVAC) equipment. The air flow measurement technique is also useful in studying such meat packing unit operations as the smokehouses.

Following the collection of flow information as described above, there will still be some unknown utility flow rates. For example, gas and steam cannot be accurately measured at the unit operations level using the bucket, thermometer, and stopwatch technique. Therefore, when all the raw flow information has been obtained, the next step is the calculation of material and energy balances. Sources for methodology of these calculations are numerous. Many references are available which provide useful information for doing balances on food processing equipment (examples, Charm, 1971; Heldman, 1975). Psychrometric data (Zimmerman and Lavine, 1945), steam tables (Keenan and Keyes, 1936) and general reference books (Strock and Foxhall, 1959; ASHRAE, 1963; Perry and Chilton, 1973) are also useful. Through the use of balances, approximate utility flows can be determined for unit operations which cannot be directly measured by the bucket, thermometer and stopwatch method. In some cases, a detailed audit may stop at this level but, for determining exact utility usage, direct measurement by a monitoring device remains the most precise method.

Detailed Process Utility Measurement

For maximum flexibility and capability of data collection a central recording-remote sensing system was installed in each plant. From the rough flow estimates and balances of the preliminary audit step, utility flow parameters were obtained which permitted the specification of actual flow measuring devices. Vortex shedding meters (Neptune-Eastech) and turbine meters (Engineering Measurements Company) were selected for remote monitoring of steam and natural gas. Both types of meters provide high turn-down ratios for flow measurement. This means that accurate measurements can be obtained over a wide range of flow rates. Such a criterion was necessary because of wide variability in utility flow conditions to the unit operations. These conditions ranged from full open throttle to low standby or idle. Also there was some uncertainty concerning the flow predictions based on the balances. Both types of these remote sensing meters were specified to have a 4 milliamperes output at the no flow condition and 20 milliamperes output at the maximum flow condition. In addition, for safety reasons, all meters were powered with 12 volts direct current rather than 120 or 240 volt alternating current. After installation, the turbine meters suffered repeated breakdowns and were all eventually replaced with vortex shedding meters.

Water was measured in two ways using either direct reading totalizing meters (Rockwell International, Badger Meter Incorporated) or remote sensing turbine meters (Mead Instrument Corporation). The totalizing meters were used for less crucial measurements. For example, some sanitation hoses were monitored in this manner. The turbine water meters had the same operating specifications as the steam and gas meters.

Temperatures were monitored manually and also by remote sensing. Periodic temperature measurements were made using either a thermocouple based digital temperature probe (Omega Engineering) or a platinum resistance temperature device (RTD) based digital probe (William Wahl Corporation). The digital RTD temperature device proved far more reliable and accurate than the thermocouple based probes. This hand held temperature measuring equipment (together with anemometers and hygrometers) was used for measurements of the air handling refrigeration evaporators in the process rooms. In addition, the temperature probes were used to measure operating process equipment surface temperatures to provide information used for calculating heat losses.

For all remote sensing of temperatures, three wire RTD probes (HyCal Engineering) were installed in wells on process equipment. The RTD probes were wired to the recording equipment through a linear bridge amplifier (Rosemont Incorporated) which provided a signal output of 1.0 millivolt per degree Fahrenheit input. Several different types of RTD probes were used including immersion, weld-on and clamp-on. The type used in a given situation was dependent upon the characteristics of the process equipment.

All remote monitoring flow devices were provided with twin two-wire shielded cables (Belden), one for the 24 volt power supply and one for signal output. The RTD probes were wired using shielded three-wire cables (Belden). Power for the remote sensing flow meters was supplied by a 24 volt direct current regulated power supply (Solar Electric).

All remote sensing devices were wired to a central multiplexing and recording system. Figure 1 contains a representation of the data acquisition system. A data logger (Monitor Labs Incorporated) was used to scan all the

Figure 1. Energy Acquisition System

remote devices, condition the signals and perform an analog to digital conversion. The data logger printed instantaneous readings every scan period and transferred the data to a computer (Digital Equipment Corporation). The computer had the capability of performing rough data analysis (averaging, totaling, standard deviation) on line and storing the relevant information. Storage of information was accomplished through the use of a floppy disc drive system integral to the computer. This central multiplexing-recording system permitted sampling of data at any interval desired. During actual collection periods, a scan rate of every 10 or 20 minutes proved to be sufficient for detecting any changes in flow rates or temperature. It should be stated that considerable difficulty was encountered utilizing this system, especially with the data logger. Originally, it was believed that the system would be self supporting, permitting data collection in the absence of trained personnel. However, the system required considerable attention and it is apparent that such a collection system cannot be called "stand alone" by any means.

Serious problems developed with nearly all monitoring equipment. Most noteworthy was the repeated failures of the Engineering Measurements turbine steam meters. Although advertised as a steam flow meter, the delicate turbine of this device was easily destroyed by the presence of even minute amounts of condensate. After discussion of the problem with the manufacturer, steam traps were installed before each of these meters. Again, all meters failed. Because of the needless cost of repeatedly installing and removing these types of meters, other meters were purchased and installed. At this time, Purdue University and Engineering Measurements are in litigation.

The Neptune Eastech steam meters suffered a less serious problem. The electronics boards were highly susceptible to heat and corrosive atmosphere.

Both conditions abound in nearly all processes of a meat plant. Fortunately, breakdowns did not require removal of the meter, but only replacement of the electronics boards. The problem was alleviated by only inserting boards when readings were being taken.

The RTD probes, like the Eastech meters, suffered from corrosion problems. The stainless steel probes were fitted with aluminum terminals for the tinned-copper connecting wires. As can be imagined, when such a collection of dissimilar metals was subjected to a corrosive atmosphere, problems arose. The probes required constant cleaning and rewiring.

Very serious problems occurred in the operation of the Monitor Labs data logger. Since the data logger was the center of the data acquisition system, the repeated failures yielded serious lapses in information gathering. The problems were numerous including failure of the printer, failure of memory, failure of internal clocks, failure of analog to digital converter, and failure of RTD conversion boards. Fortunately, by having 4 other loggers on standby and sending the downed loggers back immediately, one operable logger was maintained at all times. Nevertheless, such incredible breakdown problems were inexcusable. In general, most of the monitoring equipment spent more time being repaired than recording data.

During energy data collection, production information was obtained from plant records. This information was later used for determining energy use per pound of specific product. Kill and cut process flows, as well as rendering process flows, are presented in terms of daily slaughter since there is a direct correlation between production by these processes and slaughter. For other processes the energy consumption was based upon the pounds of finished

product. Utility flow measurements from the recording system were also incorporated into the original material and energy balances which were performed at the beginning of the project. Some adjustments (considerable in some cases) were made to the balances in an attempt to explain variation between actual utility flows and the flows predicted by the original balances. In many cases, it was necessary to return to the plants several times before actual patterns of energy flows and losses were finalized.

CHAPTER 3 - RESULTS AND DISCUSSION

Detailed Process Energy Analysis for Plant A

The processes studied at Plant A were: the dehairing process; the bacon manufacturing process; the frankfurter manufacturing process; the lard rendering process; the inedible rendering process; the blood drying process; and the hair hydrolysis and drying process. The total plant layout is shown in Figures 2, 3 and 4. In a typical year, the plant uses 256 billion BTUs of gas and oil, 22 million kilowatt-hours of electricity and 328 million gallons of water to process 755,315 hogs. Figures 5, 6 and 7 and Appendix A1 contain data of production of hogs slaughtered, franks and bacon produced, lard produced, grease, blood, meat and bone meal produced. Figures 8-19 and Appendix A2 contain the typical monthly, daily and hourly energy utilization of electricity, water, production gas, and boiler fuel for a typical year. Process labor requirements and plant economic data are given in Appendices A3 and A4, respectively.

Dehairing Process

A simplified process flow diagram for dehairing appears in Figure 20. A layout of the process equipment is shown in Figure 21 and an operations schedule appears in Figure 22. A typical day for this process has a production of 3021 head.

Stun and Bleed Operation. The dehairing operation at this plant begins

FIGURE 2. Plant A - Layout of Basement

FIGURE 3. Plant A - Layout of First Floor

FIGURE 4. Plant A - Layout of Second Floor

Typical Monthly Slaughter

FIGURE 5

Typical Monthly Production

FIGURE 6

Typical Monthly Production

FIGURE 7

Typical Monthly Electrical Usage

FIGURE 8

FIGURE 9.

Typical Hourly Electrical Usage

FIGURE 10

Typical Monthly Water Usage

FIGURE 11

Typical Daily Water Usage

FIGURE 12

FIGURE 13

Typical Hourly Water Usage

Typical Monthly Production Gas Usage

FIGURE 14

Typical Daily Production Gas Usage

FIGURE 15

FIGURE 16

Typical Hourly Production Gas Usage

Typical Monthly Boiler Fuel Usage

FIGURE 17

FIGURE 18

Typical Daily Boiler Fuel Usage

FIGURE 19

Typical Hourly Boiler Fuel Usage

FIGURE 20

FIGURE 21

Plant A - Dehairing Process - Dehairing Area Equipment Layout

PLANT A - Dehairing Process - Operations Schedule

FIGURE 22

with the hogs being driven to the second story kill floor along an inclined ramp. Four to six hundred hogs per hour are brought from pens to the kill floor and put into holding pens. The animals are prodded into a lifting chute and stunned electrically by a 375 volt shock. The stunned hog falls from the chute onto a 1.0 horsepower conveyor where one of the animal's rear legs is attached to a shackle chain. The purpose of the 7.0 horsepower shackle chain is to move the animals through the next two unit operations, bleeding and scalding. The chain speed varies according to the number of hogs processed per hour. At 450 animals per hour, the chain speed is approximately 20 feet per minute.

The animal is carried to the bleed pit where it first passes in front of a sticking platform. The jugular vein is opened and the hog is transported over a bleed pit. Each hog loses 6 to 7 pounds of blood in 4 to 5 minutes while it is over the bleed pit area. The only utility used during production at this operation is steam. A small steam injected (90 psig) knife box is used by the sticker to sterilize his knife between hogs.

The stunning and sticking operations use a nominal amount of energy during processing. Electricity demand by the stunning operation amounts to 3.41 watt-hours per head or typically, 10.3 kilowatt-hours per day. A steam heated knife box in the sticking area requires a heat input of approximately 15,100 BTUs per day. There is no correlation between this steam demand and production although a typical use rate of 5.00 BTU per head can be estimated.

Scald Tank Operation. The actual dehairing process begins with the shackled hog entering a scald tank which is an L-shaped tub, 112 feet long by 5 feet wide and 3 feet deep filled with water. The water is maintained at a

temperature of 140°F by means of steam injection (90 psig) through sparging pipes running along the bottom of the tank. Sodium lauryl sulfate is added to the water to enhance the removal of hair. The water is constantly recycled from one end of the tub to the other by a 7.5 horsepower centrifugal pump. This aids in keeping the temperature constant throughout the tank and also assures constant movement of water around the hog. Three large oscillating presses (dunkers), each driven by a 2 horsepower motor, periodically force the animals into the water as they pass through the tank. This action keeps the hogs submerged for proper wetting and loosening of the hair. The animals remain in the scald tank for approximately 5 minutes.

Flow data obtained from the metered two inch water line flowing into the scald tub reveals that on the average 17,300 gallons are used per day (range 13,200 to 32,600 gallons). To fill the tank to operating level with 69°F water requires 10,100 gallons. The difference represents makeup water added during the day, estimated to be approximately 3,000 gallons, and cleanup water, 4,370 gallons. The total process water use was thus 13,100 gallons per day, typically. There was no linear correlation between amount of water used and number of animals slaughtered, since the tank must be filled to operate. For a typical day, however, the water use per head (for filling in the morning and for makeup) was estimated to be 4.34 gallons.

Steam consumption by the scalding operations can be divided into two phases, startup and maintenance. A sample day is shown in Figure 23. The time required to bring the water in the scald tub to operating temperature, 140°F , varied from 1.8 to 2.3 hours depending upon initial temperature and steam flow rate. The average requirement was 12,500,000 BTUs of steam at 90 psig. Of this amount, only 5,970,000 BTUs would be actually required to heat

FIGURE 23

SCALD TANK

10,100 gallons of 69°F water to 140°F. Thus half of the start-up steam consumption is lost to the atmosphere as combined losses from the water surface, as live steam, and as condensate overflow.

The total amount of maintenance steam is directly related to the length of time that the scald tank is operating. Usually, this steam consumption is also related to the number of hogs killed (more hogs longer workday) but this is not absolute. In several instances, the steam flow to the scald tank continued for some time after the last animal was put through. On a typical day, the total steam requirement was 26,500,000 BTUs. Total steam consumption per head during the monitoring period ranged from 6,940 to 10,100 BTUs, with an average 8,770 BTUs per head.

The electrical demand by the scalding operation is divided among five motors. There are three motor driven dunkers, one recirculation pump and one shackle chain drive motor. The electrical use by these motors correlates with the length of the workday and, in general, with the number of hogs slaughtered. The average use was 54.20 watt-hours per head. A typical day requires 164 kilowatt-hours.

Dehairing Machine Operation. At the end of the scald tank, the hog is unshackled from the chain and placed onto a 1.0 horsepower inclined conveyor feeding the first of two identical dehairers which are connected in inline. At the base of each machine is a 10 feet long by 6 feet wide by 3 feet deep tank which is filled with water maintained at 138°F by means of steam injection (90 psig) through spargers similar to those in the scald tank. The water in each tank is recirculated by a 7.5 horsepower pump. Within the dehairing machine, large rubber paddles driven by a 20 horsepower motor strike the hog

to remove hair and carry the carcass through the machine. A top mounted spray apparatus in each dehairer directs high pressure recirculated water down over the paddles and hogs to remove loosened hair. Hair is removed from the base of the machine by means of a skimmer. An auger conveyor system then transports the hair to the rendering area. A potable fresh water spray is required at the end of the second dehairer for sanitary purposes. For this reason, there is a constant overflow from the dehairers during operation. After passing through both dehairers, the hog is ejected onto the 5.0 horsepower gambrel table conveyor, where it is manually attached to a gambrel chain by piercing the tendons in both hind legs. The 5.0 horsepower gambrel or dressing chain is used to transport the hog through all remaining kill floor operations.

As with the scald tank, the two-stage dehairers are initially filled with cold water which is then heated by steam injection. When filled, the tanks in the base of the dehairers contain about 3,210 gallons total. In addition, during the process day, a constant fresh water overflow is maintained. The average daily overflow is 13,300 gallons with a range of 8,930 to 20,160 gallons. Total water requirement for the dehairing machine operation is estimated to be 5.47 gallons per head processed.

The startup period for the dehairers was highly variable lasting from 1.50 to 2.50 hours using from 2,960,000 to 12,300,000 BTUs, 90 psig steam to heat the water in the base tanks from an average of 70°F to 130°F. The average requirement was 8,380,000 BTUs in 2.03 hours of which only 1,970,000 BTUs was actually required just to heat all the water.

The total daily steam demand by the dehairers is directly related to

operating time. Unlike the scald tank which is usually operated about the same number of hours each day, the dehairers have considerable variability in operating times. From data collected at various times during the year, the operational day for the dehairers ranged from a total of 9.83 hours to as much as 22.33 hours, clearly in excess of the production day. For a typical day, the dehairers operated 13.5 hours (including the 2 hour startup time) using a total of 61,000,000 BTUs. The average steam demand obtained from monitored data was 20,200 BTUs per head with a range of 10,500 to 28,700 BTUs per head. Steam flow for a sample day is shown in Figure 24.

There are seven motors associated with the dehairing machines which contribute to overall electrical demand, two recirculation pumps, two main drives, one inclined conveyor, a gambrel chain drive, and one dressing chain drive. As with the steam flow, the total electrical demand is related to the length of the operating day. The average use was found to be 160 watt-hours per head. Typical daily electrical use was 483 kilowatt-hours.

Singeing Operation. The animal next passes through the singeing operation which burns off the few hairs remaining after dehairing. The singer is simply a wall of flame fueled by natural gas (15 psig) and directed at the overhanging hog from both sides along the direction of travel. A 2.0 horsepower blower is used to induce air flow through the operation. The animals remain in the flame for approximately 7 seconds.

Unlike steam flow to the two previous unit operations, the singer consumes natural gas at nearly a constant rate during the entire operating day, with very little fluctuation in flow. Day to day variations have been noted during the period of data collection, primarily because of adjustments per-

FIGURE 24

DEHAIRER

formed on the gas jet configuration. The average consumption was found to be 13,300 BTUs per head with a range of 12,800 to 14,000 BTUs per head. Typical flow was approximately 40,100,000 BTUs per day. The electrical input amounted to 2.63 watt-hours per head or 7.94 kilowatt-hours per day. It is assumed that the majority of the input energy to the singer is lost to the surroundings and as vented exhaust. Gas flow for a sample day is shown in Figure 25.

Polishing Operation. The next operation after singeing is polishing. The facility has two inline polishers. The first polisher has counterrotating brushes powered by a 10 horsepower motor. The second polisher contains rubber paddles driven by a 25 horsepower motor. The purpose of the polishers is to remove the small amount of singed hair. Both polishers utilize water sprays to remove debris from the brushes or paddles.

The polishers require electrical energy as well as water inputs. The total daily water consumption for this unit operation averaged 11,100 gallons during the study period. Daily flows ranged from 7,390 gallons to as high as 19,600 gallons. Water usage by the polishers was not linearly related to daily slaughter, however, a typical consumption during the study period was 3.68 gallons per head.

The electrical demand of the polishers was related to the operating time and not necessarily to production. An overall average electrical use was found to be 43.80 watt-hours per head with a typical usage of a total of 132 kilowatt-hours per 24 hour day.

Shaving Operation. The hog then passes in front of several people who inspect the carcasses and manually remove the last bits of hair and any irregularities. The workers stand on a raised platform along the gambrel chain

FIGURE 25

path and use sharpened knives for shaving operation. Each shaver has a steam injected knife box nearby for knife sterilization.

The shaving operation requires a nominal amount of steam input to heat the knife boxes used by the workers. A steam demand of 90,900 BTUs per day was calculated based upon heat loss from the boxes. For a typical day, the steam requirement was found to be 30.1 BTUs per head.

Rinsing Operation. The final operation is a rinse in preparation for evisceration. The rinse cabinet is merely a fresh water shower with aluminum side shields to direct the water to a drain. Multiple nozzles spray water at the passing carcass to remove any foreign matter left from the shaving operation.

The total daily water consumption for the rinsing cabinet averaged 6,770 gallons per day during the monitoring period. The range of flows was from 4,510 to 9,700 gallons per day. A typical consumption rate per head was found to be 2.25 gallons.

Sanitation and General Utilities. Sanitation water used for cleaning the scald tank and part of the dehairers was estimated to be 4,370 gallons as mentioned earlier. The hoses which are normally used for cleaning the process area use an average daily total of 58,000 gallons of water and 33,800,000 BTUs of steam. There is no correlation between sanitation utility requirements and production but a typical consumption of 19.2 gallons water per head and 11,200 BTUs of steam per head was found by overall averaging.

The electrical demands for lighting and ventilation associated with the dehairing process have been estimated to be 182 kilowatt-hours per day. As

with sanitation there is no direct correlation with production, but for a typical day it is estimated that the use per head is 60.2 watt-hours.

A summary of the utility requirements for each unit operation in the dehairing process is shown in Tables 1 and 2. The data is displayed using two bases, a per head basis and a per day basis.

The analysis of the dehairing process for this plant ends with the rinse cabinet and no other unit operations on the kill floor were evaluated.

Table 1

Plant A - Dehairing Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Gas BTU	Electricity WH	Water Gal
Stun and bleed	5.0		3.4	
Scald tank	8770.0		54.2	4.34
Dehairers	20,200.0		160.0	5.47
Singeing		13,300	2.6	
Polisher			43.8	3.68
Shaving	30.1			
Rinse				2.25
Sanitation and General Utilities	11,200.0		60.2	19.2

Table 2

Plant A - Dehairing Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Gas BTU	Electricity KWH	Water Gal
Stun and bleed	15,100		10.3	
Scald tank	26,500,000		164.0	13,100
Dehairers	61,000,000		483.0	16,500
Singeing		40,100,000	7.9	
Polishers			132.0	11,100
Shaving	90,900			
Rinse				6,770
Sanitation and General Utilities	33,800,000		182.0	58,000

Bacon Manufacturing Process

A simplified process flow diagram for the bacon manufacturing process appears in Figure 26. A typical daily production of finished product (sliced and slab bacon) during the monitoring period was 68,817 pounds. The operations schedule for bacon manufacturing equipment appears in Figure 27.

Cure Room Operation. The bacon process at Plant A begins as the hog bellies are removed from the carcass and conveyed to the bacon processing area by means of chutes. The bellies are separated by weight grade and placed into stainless steel containers. The bellies are transported in vats carried by electric dollies to the brine injection pumps. The injection machine is electrically powered by a 2 horsepower motor which pumps a brine solution into the bellies through needles which pierce the meat. The typical weight gain during pumping is 1.18 to 1.19 times the original (green) weight. Small stainless steel skewers (combs) are attached to the pumped bellies which permit hanging the product on racks (smoke trees). Filled smoking trees are moved to the smokehouses as they become available.

The injection room is maintained at an air temperature of about 50°F by three ceiling mounted ammonia refrigeration evaporators. Each of the evaporators contains two 0.5 horsepower fans for air circulation. A layout of the cure room appears in Figure 28.

Bellies from cut are transported to the cure area for pickling. The utility requirements for this operation include electricity for the injector machines as well as water for brine formulation. Since the cure area is chilled, refrigeration is also required together with electricity for the cooling units. The electrical demand for the brine pumps and the amount of

Plant A - Bacon Process - Flow Diagram

FIGURE 26

FIGURE 27. PLANT A - Bacon Manufacturing Process - Operations Schedule

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FIGURE 28

Plant A - Bacon Process - Curing Area Equipment Layout

brine used are both related to production. Refrigeration on the other hand operates independently of production for the most part.

The electricity required by the injector machine averages 0.095 watt-hours per pound of finished bacon. For a typical day the consumption amounts to 6.25 kilowatt-hours. The quantity of water used for pumping on a typical day was calculated to be 1200 gallons or 0.018 gallons per pound.

Room cooling is provided by three overhead air handling units (ammonia). The total load on these units for a typical day is 15,800,000 BTUs. The refrigeration requirement per pound of finished bacon during the monitoring phase was 239 BTUs absorbed. The electrical requirements for the evaporator fans for the three units was 79.7 kilowatt-hours. The average electrical demand by these fans in terms of pound of finished bacon was found to be 1.21 watt-hours.

Smoking Operation. The smoking operation lasts from 8 to 11 hours depending on the size and type of bacon being smoked. A typical smoke schedule for bacon begins with air flow at 140°F db, 115°F wb, for approximately 4.5 hours. The temperature is then reduced to 130°F db, 110°F wb, and the bellies are smoked for another 4 to 8 hours. The time that the bellies remain in the house is dependent upon the size of the product. The smoking continues until the product internal temperature reaches 125 to 130°F.

Smoke is produced from moist hardwood sawdust in a separate stoker (0.5 horsepower) and introduced into the smokehouse during the operation. Heat is supplied by a gas burner located above each smokehouse. The burners for the bacon smokehouses are rated at 1,570,000 BTUs per hour maximum. Fresh air is supplied to the burner by a 0.5 horsepower blower and the flow through the

house is controlled by a 1.0 horsepower damper motor. The heated air is recirculated within the house by means of a 30 horsepower blower. Steam (90 psig) is injected into the smokehouse in order to control humidity during the smoke. A layout of the smokehouse area for this plant appears in Figure 29.

The average period for gas flow during the smoke cycle was 7.73 hours with a typical total consumption of 2.951×10^6 BTUs (range 2.423×10^6 to 3.443×10^6 BTUs). The smokehouse is loaded with pumped bellies, total weight typically 11,900 pounds. An estimated daily gas flow total for all bacon smoking was 21,200,000 BTUs. The average gas consumption per pound of finished product based upon data collected from numerous smokehouse runs was 293 BTUs with a range of 271 to 315 BTUs.

From a material balance performed on a typical smokehouse run the amount of steam required was found to be 1260 pounds or 1,500,000 BTUs of 90 psig steam. This represents approximately 139 BTUs per pound of finished bacon and a total use per day of 11,800,000 BTUs.

Electrical consumption by the smokehouse operation averaged 13.1 watt-hours per pound. Four motors are used by the smokehouse including a recirculation blower, an inlet air blower, a damper motor and a stoker motor. For a typical day with four houses running, the electrical requirement was estimated to be 1080 kilowatt-hours.

Hot Skinning and Brine Chilling Operation. The cooked bellies leave the smokehouse and are immediately hot skinned by a 2.0 horsepower skinning machine. The bellies are then loaded into a brine cabinet having a normal capacity of 19,000 pounds. Brine water (6 percent) at 20°F showers the bacon for 1.5 to 2.0 hours lowering the internal temperature of the bacon to 25°F .

FIGURE 29

Plant A - Bacon Process - Smokehouse Area Equipment Layout

The brine cabinet uses two 7.5 horsepower pumps to spray brine over the bacon and to move brine over the ammonia chilling unit. A layout for the skinning and brine chilling area is shown in Figure 30.

The skinning machine requires electricity at an average consumption of 0.107 watt-hours per pound of finished bacon. A typical day of production requires 7.03 kilowatt-hours. Immediately after skinning, the smoked bellies are then quick chilled in a brine cabinet. Brine is circulated over the bacon at an average rate of 358 gallons per minute. The refrigeration requirement averaged 87.0 BTUs per pound of finished bacon. A typical daily total demand was 5,740,000 BTUs absorbed. The electrical demand for pumping including cleaning, averaged 2.66 watt-hours per pound finished bacon. A typical daily use was 175 kilowatt-hours.

Blast Chill Operation. From the brine chill, the bellies are moved to the blast chill room for approximately 30 hours. The internal temperature of the bacon falls to about 18°F. Two salt brine refrigeration units maintain air temperature at 16°F. Each of the floor mounted units has a 1.0 horsepower blower. A generalized process equipment layout of the blast chill area is represented in Figure 31.

The overall typical refrigeration requirement per pound finished bacon was 9.80 BTUs. The refrigeration load on the blast chill varied slightly with production but for the most part was independent of total pounds of bacon. In a typical day, the blast chill refrigeration demand amounted to 646,000 BTUs absorbed. The actual amount of heat absorbed from the bacon represents 169,000 BTUs of this total. The difference represents heat gained by infiltration and conduction through walls. The average amount of electricity used

FIGURE 30

Plant A - Bacon Process - Skinning and Brine Chill Area Equipment Layout

FIGURE 31

Plant A- Bacon Process - Blast Chill Area Equipment Layout

by the two refrigeration units was 0.806 watt-hours per pound of finished bacon. The requirement for a typical day was 53.1 kilowatt-hours.

Tempering Operation. From the blast chill the bacon is moved into the tempering room for 4 to 9 days. During tempering, the internal temperature of the bacon remains at 25 to 28°F for the entire period. Four ceiling mounted refrigeration evaporators maintain the air temperature of the room at 25°F. Each of the units has two 0.5 horsepower fans. The chilling operations firm the bacon fat allowing easier slicing. A layout of the tempering area appears in Figure 32.

The refrigeration requirement for a typical day during the period of study was found to be 679,000 BTUs. By assuming a constant throughput an approximate requirement per pound of product was 10.3 BTUs. Electrical demand by the fans in the refrigeration evaporators was typically 75.0 kilowatt-hours per day. This yielded a demand on a per pound basis of 1.14 watt-hours assuming a constant production. In reality of course, the electrical demand as with the refrigeration load, was nearly independent of production of both bacon products.

Slicing and Packaging Operation. Upon leaving the tempering area the bellies are formed into blocks by means of a hydraulic press powered by a 5.0 horsepower motor. The pressed blocks are placed into a 5.0 horsepower slicer which produces uniform strips of bacon. The slices are weighed, placed onto cardboard backings and fed into a 1.0 horsepower vacuum sealer. The complete bacon packages are formed in a 0.5 horsepower packaging machine. In the bacon packaging room there are three bacon presses and four slicers feeding three vacuum sealers and packaging machines. Two vacuum pumps (10.0 and 15.0 hor-

FIGURE 32

Plant A - Bacon Process - Tempering Area Equipment Layout

sepower) supply the vacuum required by the sealers. Bacon packages are then boxed, palletized and removed to cold storage.

The bacon packaging room is maintained at 48°F by means of three ceiling mounted refrigeration evaporators each with a 0.5 horsepower fan motor. Since the room is shared with a sausage slice and packaging line, the refrigeration demand for bacon was determined by the relative production rate of bacon as compared with the total production for this room. A layout of the bacon packaging area appears in Figure 33.

As with tempering, there is no actual heat absorbed from the bellies by the room refrigeration system, rather the cooling is done to maintain room conditions. The load is a combination of infiltration, conduction and generation provided by workers, lighting and processing equipment. During a typical day, the refrigeration requirement was 5,330,000 BTUs. Although there was no direct linear correlation with production, an overall cooling demand of 80.9 BTUs per pound was determined. The electrical demand to drive the refrigeration evaporator fans averaged 1.78 watt-hours per pound. For a typical day, the total requirement was 117 kilowatt-hours.

Since not all bacon is sliced and put through the vacuum packaging lines, the amount of slab type bacon was discounted from the determination of energy use per pound for the packaging lines. The energy demands for packaging are electrical, with motors driving bacon presses, slicers, sealers, packagers and vacuum pumps. For a typical day, the total electrical demand was 1020 kilowatt-hours. The average electrical requirement for packaging machinery per pound of packaged sliced bacon was 16.3 watt-hours.

FIGURE 33

Plant A - Bacon Process - Slicing
and Packaging Area Equipment Layout

Sanitation and General Utilities. The typical amount of water used per day for the four general areas of bacon processing (cure, smokehouse, skin, chill and temper, packaging) was 11,100 gallons. The steam requirement for heating this water from 70°F to 140°F was 6,480,000 BTUs. As noted earlier, sanitation requirements do not necessarily correlate with production but average requirements per pound of finished bacon have been estimated to be 98.2 BTUs steam and 0.168 gallons water.

The electrical requirement for lighting and ventilation for all areas connected with bacon processing was 883 kilowatt-hours. This corresponds to approximately 13.4 watt-hours per pound of finished bacon produced.

A summary of the utility requirements for each unit operation in the bacon manufacturing process is shown by Tables 3 and 4. The data is displayed in terms of a per head basis and a per day basis.

Table 3

Plant A - Bacon Process - Energy Usage per Pound

Unit Operation	Steam BTU	Gas BTU	Electricity WH	Water Gal.	Refrigeration BTU
Curing			1.30	0.018	239.0
Smoking	139.0	293.0	13.1		
Skin and Brine Chill			2.66		87.0
Blast Chill			0.806		9.80
Tempering			1.14		10.3
Slice and Package			18.1		80.9
Sanitation and General Utilities	98.2		13.4	0.168	

Table 4

Plant A - Bacon Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Gas BTU	Electricity KWH	Water Gal	Refrigeration BTU
Curing			86.0	1,200	15,800,000
Smoking	11,800,000	21,200,000	1080.0		
Skin and Brine Chill			181.0		5,740,000
Blast Chill			53.1		646,000
Tempering			75.0		679,000
Slice and Package			1140.0		5,330,000
Sanitation and General Utilities	6,480,000		883.0	11,100	

Frankfurter Manufacturing Process

A simplified flow diagram is presented in Figure 34. During the period of study, the typical daily production of franks was 47,276 pounds. The operations schedule of equipment used in the frank manufacturing process is shown in Figure 35.

Raw Materials Cooler Operation. The raw materials cooler as well as the sausage kitchen contain facilities for manufacturing all types of sausage products. For this reason, it was necessary to partition some of the energy measurements, for example room refrigeration load. The basis chosen for defining utility requirements was the ratio of frank production to total production of all sausage products. During the period of data collection, all varieties of franks represented an average of 63.4 percent of the total production and this factor was used in the calculations.

The refrigeration load in the raw materials cooler, for a typical day, was found to be 4,110,000 BTUs. That portion dedicated to franks was calculated to be 2,600,000 BTUs. On the basis of finished product the refrigeration required was 57.0 BTUs per pound. Since product temperature did not change appreciably, the total load was the result of infiltration, conduction through walls and heat, generated by lights, workers and equipment. As might be expected, there was no direct correlation between refrigeration load and production.

The electrical requirement of the three air handling (refrigeration evaporators), typically was 74.3 kilowatt-hours per day. In terms of electrical use per pound of finished franks, the requirement was 1.63 watt-hours per pound.

FIGURE 34

Plant A - Frankfurter Process - Flow Diagram

PLANT A - Frankfurter Manufacturing Process - Operations Schedule

FIGURE 35

Sausage Kitchen Operation. The entire sausage kitchen is maintained at an air temperature of 50°F by eleven ceiling mounted refrigeration evaporators each containing two 0.5 horsepower fans. Since other products are prepared in the sausage kitchen besides franks, the refrigeration requirement was partitioned based on relative production.

Frankfurters are prepared from beef or from a mixture of beef and pork. Fresh pork cuts are fed through a 50.0 horsepower grinder, and then transferred into storage bins by means of a 5.0 horsepower pivot screw conveyor. Frozen beef obtained from outside sources is fed into a 10.0 horsepower flaker where it is reduced to one quarter inch thick slices. The ground material is transferred by means of the pivot screw conveyor into storage bins. Each type of meat is stored separately in one of six bins or storage loaders which can hold 4000 pounds of fresh meat or 2800 pounds of frozen meat. Each storage loader has two motors, a 2.0 horsepower motor on top for settling the meat in the tank, and a 3.0 horsepower motor on the bottom for unloading the meat into the screw scale conveyor.

The 5.0 horsepower scale screw conveyor is used to weigh out the required amounts of each type of meat from the storage loaders. The scale conveyor transfers the material into a 5.0 horsepower pivot screw conveyor which can load either of the two blend tanks.

The blend tanks, typically, handle 5000 pound batches, but have capacities of 3000 to 4000 pounds in excess of this. Each blend tank has two motors, 20 horsepower each, to operate the twin mix blades inside the tank. Required amounts of each type of meat are weighed and deposited into one of the blend tanks. Remaining ingredients and spices are then added and the

material is blended.

A typical blend consists of 5000 pounds of meat of which 1200 pounds is frozen beef, 400 pounds of rework, 1700 pounds of water, 144 pounds of salt 222 pounds of spices, 7 pounds of cure and 153 pounds of corn syrup. Spices and meat are blended first. Since the temperature is to be lowered to 30°F water may be added as ice. This procedure, however, is usually not necessary if more than 1000 pounds of frozen meat is added. Following the blending, the mixture is heated to 60°F by means of a steam jacket (15 psig) in the blend tank. If any adjustments are necessary to achieve the desired blend of 30 percent fat, the appropriate material is added at this stage.

Next, the mixture is transferred into a 100 horsepower high speed grinder. The blades of the grinder partially emulsify the mixture which then passes down a 0.75 horsepower conveyor to a 125 horsepower high speed grinder for further emulsification. Flow rate through the emulsification step is 380 pounds per minute. The emulsion is conveyed to one of four holding tanks by a 0.75 horsepower belt conveyor. Each of the holding tanks has approximately 1900 pounds capacity. At this point the emulsion has usually reached a temperature of 70°F.

The emulsion is moved by an air pump from the holding tanks to the three continuous stuffer-linkers each powered by a 2.0 horsepower motor. These machines can handle up to 3500 pounds per hour of emulsion. The stuffer-linkers stuff the emulsion into a casing, twist, link and loop the franks. These loops are hung on racks (trees) to be smoked. A fully loaded tree varies in weight from 300 to 600 pounds depending on the type of frank. A layout of the entire sausage kitchen in this plant is shown in Figure 36.

FIGURE 36

Plant A - Frankfurter Process - Sausage Kitchen Area Equipment Layout

The refrigeration requirement for processing weiners in the sausage kitchen was calculated to be 12,200,000 BTUs per day based on the relative production of franks. In terms of the finished product, the average refrigeration requirement was 266.0 BTUs per pound. As with the raw materials cooler, the sole purpose of the refrigeration was maintenance of room temperature and thus not production related.

The electrical requirements for the eleven refrigeration evaporators amounted to 272.0 kilowatt-hours per day. On the basis of finished product, the utility demand was 5.97 watt-hours per pound.

The utility required by most of the processing equipment in the sausage kitchen is electricity, although the blend tank does use steam. The motor driven operations consisted of a grinder, a flaker, twelve storage loader motors, a scale screw conveyor, a pivot screw conveyor, two blend tanks each with two motors, two high speed emulsifiers with conveyors and three linking machines. Total typical daily electrical requirement was 912.0 kilowatt-hours. In terms of daily production of finished weiners, the average demand was 20.0 watt-hours per pound. The blend tanks commonly use steam for about 15 minutes per batch. Typical daily use was 4,370,000 BTUs. In terms of steam flow per pound of finished product, the average use was 95.6 BTUs per pound.

Smoking Operation. The trees are pushed on overhead racks into smokehouses and smoked for 1 to 2.5 hours depending on the type of hot dog. The franks cook for specified lengths of time at air temperatures ranging from 100 to 175°F until the internal temperature of the product reaches 155°F. The actual smoking-cooking process is performed by a combination of a gas fired

burner and smoldering hardwood sawdust. The gas burner is rated at 1,570,000 BTUs per hour maximum. A typical smoke schedule consists of 10 minutes at 100°F db, 50°F wb, followed by 20 minutes at 140°F db, 65°F wb, followed by 20 minutes at 160°F db, 50°F wb, and then finishing at 175°F db, 35°F wb, until the internal temperature of the franks is 155°F. Steam (90 psig) is injected into the smokehouse in order to control humidity.

Fresh air is supplied to the burner by a 0.5 horsepower blower and air flow through the house is controlled by a 1.0 horsepower damper motor. The heated air and smoke is recirculated through the house by means of a 30 horsepower blower. The smoke is produced in a separate 0.5 horsepower stoker and introduced into the house during operation. After the gas cook, the hot dogs are steam cooked for 2 to 4 minutes, or until the internal temperature reaches 165°F. The product is showered with fresh cold water to reduce the internal temperature to about 80°F and the franks are transferred into a holding cooler. A layout of the frankfurter smokehouse area is shown in Figure 37.

Smoke times vary for the different types of weiners. For regular franks, the average gas consumption per batch was 1,110,000 BTUs (range 880,000 to 1,550,000 BTUs). For dinner franks the average gas use was 2,040,000 BTUs per smokehouse run and for the small franks the smoke cycle required 557,000 BTUs of gas. For a typical day, the total daily consumption of gas by all frank smokehouses was estimated to be 8,670,000 BTUs. The average gas demand per pound of finished frankfurters was 190.0 BTUs per pound with a range of 150.0 to 246.0 BTUs per pound.

The results of a typical run indicate that the water in the exhaust air amounted to 720 pounds more than that removed from the weiners. Assuming that

FIGURE 37

Plant A - Frankfurter Process - Smokehouse Area Equipment Layout

the water represented steam injected for humidity control, the amount of steam was 846,000 BTUs at 90 psig. In addition, steam was used for a cook at the end of the smoke. Calculations for the amount of steam required for the cook yielded an estimate of 36,100 BTUs per batch. It was estimated that the total daily steam requirement for humidity control and cooking must be 5,480,000 BTUs or about 120.0 BTUs per pound of finished weiners.

The electrical demand by the frank smokehouses was typically 320.0 kilowatt-hours per day. In terms of finished product the electrical use by the smokehouse was 7.0 watt hours per pound on the average.

Frankfurters are usually showered in the smokehouse immediately after smoking. The typical consumption of water per batch is 564 gallons. In terms of daily consumption the amount of water used was estimated to be 3200 gallons. In terms of finished products the water used per pound was found to be 0.077 gallons.

Frank Cooler Operation. The link cooler is maintained at 38 to 40°F. Although the franks may be taken directly from the smokehouse to the frank chill tunnel, they are usually held in the cooler for several hours to overnight. The cooler is chilled by means of two ceiling mounted refrigeration evaporator each with two 0.5 horsepower fans.

In the link cooler the franks are chilled from about 80°F to 40°F. The typical daily requirement of refrigeration is 1,230,000 BTUs. The electrical load for the two refrigeration evaporators was 49.5 kilowatt-hours per day. In terms of pounds of finished franks, the requirements were found to be 26.9 BTUs and 1.08 watt-hours. Of the total daily refrigeration requirement, it was estimated that the amount of energy actually absorbed from the franks was

1,190,000 BTUs. The rest of the load was due to infiltration and generation by workers and equipment.

Brine Chill Tunnel Operation. The next step in the process is the frank chill tunnel. This is a 20 feet long tunnel which has a 20°F 6 percent brine solution recirculated through it by means of two 7.5 horsepower pumps. The frank loops are manually placed on the chiller chain which transports the product through the tunnel. The chain drive is powered by a 2.0 horsepower motor. The chilled brine spray cools the franks from 42 to 28°F typically in 12 minutes. Chain speed can be altered for different size franks.

The brine tunnel handles franks on a continuous basis. Chilled brine was recirculated through the tunnel at an average rate of 50.1 gallons per minute during the data collection period. The refrigeration requirement by the chiller for a typical day was found to be 996,000 BTUs. Franks are typically chilled from 42°F to 28°F. On a per pound of finished product basis the refrigeration demand was 21.8 BTUs per pound.

The total electrical demand for the brine tunnel for a typical day was 287.0 kilowatt-hours per day including cleaning time. On a per pound of product basis, the average electrical use was 6.29 watt-hours.

Prepack and Packaging Operation. The entire packaging area is maintained at 48°F by means of three ceiling mounted refrigeration evaporators each with two 0.5 horsepower fans. Since other products are packaged in this room, the refrigeration requirements were partitioned based upon relative production.

The brine chiller chain is manually unloaded and the franks are fed to a weiner peeler, driven by a 0.5 horsepower motor and a 3.0 horsepower vacuum

pump, which strips the casing from the frank. The peeler system consists of a rotating knife blade which slits the cellulose casing. The casing is then removed through vacuum action. Steam (5 psig) is injected onto the frank prior to the knife blade in order to facilitate loosening of the casing. There are five peelers available for use in the packaging area.

The franks exit from the peelers onto a belt and pass through a 0.75 horsepower collator which aligns the franks and drops the product into individual plastic dividers. The franks are deposited onto plastic film in the packaging machine which vacuum seals the package. The packaging machine has a 35.0 horsepower motor which drives the machine mechanism and two electrical heaters (20 and 17 amperes). Two 10.0 horsepower pumps provide the necessary vacuum for the sealing and packaging machines. The packages are then boxed and palletized and removed to cold storage until shipment. A layout of the packaging area is shown in Figure 38.

The principle utility demand for the equipment is electricity although a slight amount of steam is used for the peelers. As with the sausage kitchen, the working area is cooled by ceiling mounted refrigeration units.

The amount of total refrigeration required for the packaging area on a typical day was 5,840,000 BTUs. In terms of finished product, the load was 128.0 BTUs per pound. This total refrigeration is the result of infiltration, conduction and generation by workers, lights and equipment. The product does not change temperature appreciably and therefore there is no direct linear correlation between the refrigeration requirement and total production. The electrical use by the fans in the refrigeration evaporators for a typical day was 74.3 kilowatt-hours. In terms of production, the electrical consumption

FIGURE 38

Plant A - Frankfurter Process - Packaging Area Equipment Layout

was 1.63 watt-hours per pound.

The electrical use by the processing equipment for a typical day was 316.0 kilowatt-hours per day. On a per pound finished product basis, the electrical demand averaged 6.92 watt-hours per pound. The steam used by the peelers was estimated to be 121,000 BTU per day or about 2.66 BTUs per pound.

Sanitation and General Utilities. The amount of water used per day for the frankfurter processing areas of kitchen, smoke and pack was found to average 37,200 gallons. The steam required to heat the water was calculated to be 21,700,000 BTUs per day. The water and steam demands averaged 0.815 gallons and 475.0 BTUs per pound. Most water and steam was used in the sausage kitchen and packaging areas.

The electrical demand by the general utilities of lighting and ventilation amounted to a total of 765.0 kilowatt-hours per day. This yields a rough correlation of 16.8 watt-hours per pound was found.

A summary of the utility requirements for weiner manufacturing is shown by Tables 5 and 6.

Table 5

Plant A - Frankfurter Process - Energy Usage per Pound

Unit Operation	Steam BTU	Gas BTU	Electricity WH	Water Gal	Refrigeration BTU
Raw Materials					
Cooler			1.63		57.0
Sausage Kitchen	95.6		25.9		266.0
Smokehouse	120.0	190.0	7.0	0.077	
Frankfurter					
Cooler			1.08		26.9
Brine Chill			6.29		21.8
Packaging	2.66		8.54		128.0
Sanitation and General Utilities	475.0		16.8	0.815	

Table 6

Plant A - Frankfurter Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Gas BTU	Electricity KWH	Water Gal	Refrigeration BTU
Raw Materials					
Cooler			74.3		2,600,000
Sausage Kitchen	4,370,000		11980.0		12,200,000
Smokehouse	5,480,000	8,670,000	320.0	3,200	
Frankfurter					
Cooler			49.5		1,230,000
Brine Chill			287.0		996,000
Packaging	1221,000		390.0		5,840,000
Sanitation and General Utilities	21,700,000		765.0	37,200	

Lard Rendering Process

A simplified flow diagram of lard rendering is shown in Figure 39. The basis of this process is 3021 head slaughtered per day. A typical daily production of lard was 40,930 pounds. The operations schedule of equipment used during lard rendering can be seen in Figure 40.

Grinding and Loading Operation. For the batch type wet rendering of lard, fat is collect from trimming stations located on the cut and kill floors. The edible trim is transported to the rendering area in large wheeled carts and dumped into a 50 horsepower grinder-loader. Edible trim has a typical composition of 75.5 percent fat, 8.5 percent solids and 16 percent water. The total trimmings per head averages 23 pounds. A layout of the rendering vat filling area is shown in Figure 41.

The loading operation requires 223 kilowatt-hours of electricity per typical process day for the grinder-loader (25 horsepower). In terms of production of finished lard, the electrical demand was 59.0 watt-hours per head slaughtered. Since grinding is done only when raw material is present, there is a direct relationship between production and utility use.

Cooking Operation. The coarsely ground material is transfered into eight pressure vessels which use steam injection (40 psig) to melt the fat, denature protein and separate the water. Since steam is used for agitation also, a large amount of the steam input is vented and lost. The cook time varies between 3 and 5 hours and produces a three phase mixture. The water and solids phases are removed from the bottom of each rendering vessel. Pressure within the vessel moves these materials, known collectively as stick water, to stick water holding tanks in the inedible rendering area. The liquid fat is

FIGURE 39

FIGURE 40. PLANT A - Lard Rendering Process - Operations Schedule

FIGURE 41

Plant A - Lard Process - Cooker Loading Area Equipment Layout

at a temperature of about 260°F as it is removed from the pressure vessel. Figure 42 contains the layout of equipment in the lower rendering area (lard removal and clarification).

The loaded cookers are heated by direct steam injection at the bottom of the pressure vessel. The average time of steam injection for one cooker was 6.4 hours using 9,680,000 BTUs of steam at 40 psig. For a typical day, the total requirement of steam was estimated 64,800,000 BTUs. In terms of finished product, (average 17.8 pounds per hog), the steam consumption was found to be 17,200 BTUs per head (range 16,800 to 17,600 BTUs per head). Steam flow for a sample day is shown in Figure 43.

In one typical run of a cooker, which used 9,630,000 BTUs, the amount of heat lost through convection and radiation was found to be 802,000 BTUs. During the cook, a great deal of the steam was vented from the top of the cooker. By doing a complete material and energy balance, it was found that of the total steam injected, 4,480,000 BTUs were vented, almost half.

Separation and Clarification Operation. The liquid fat is drawn from the cooking vessel and forced by pressure to a 25.0 horsepower centrifuge. More solids and water are removed from the fat and the liquid lard is pumped (2.0 horsepower) upstairs to a settling tank. An agitated (1.0 horsepower) temporary storage tank is available but lard is usually moved directly to the settling tank. After settling, the clarified lard is transferred to storage tanks which contain steam coils to maintain the product in a liquid state. The debris removed from the lard during processing is moved to inedible rendering.

FIGURE 42

Plant A - Lard Process - Lard Clarification
and Storage Area Equipment Layout

FIGURE 43

LARD COOKER
(BATCH)

The centrifuge is electrically driven and consumes 102 kilowatt-hours in a typical day. In terms of production, the electrical demand represents 27.0 watt-hours per head slaughtered.

Sanitation and General Utilities. The average daily requirement of water for sanitation was found to be 10,700 gallons. To heat this water, the steam demand was estimated to be 6,690,00 BTUs. The water and steam consumption on a per head killed basis was 2.84 gallons and 1770 BTUs.

The electrical demand for lighting and ventilation during a typical day was found to be 198 kilowatt-hours. This quantity amounted to an average of 52.4 watt-hours per head.

The lard rendering process is summarized in Tables 7 and 8. Two bases are used, a per pound basis and a daily use basis.

Table 7

Plant A - Lard Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Electricity WH	Water Gal
Grinding and Loading		59.0	
Cook	17,200		
Purify		27.0	
Sanitation and General Utilities	1,770	52.4	2.84

Table 8

Plant A - Lard Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Electricity KWH	Water Gal.
Grinding and Loading		223	
Cook	64,800,000		
Purify		102	
Sanitation and General Utilities	6,690,000	198	10,700

Inedible Rendering Process

A simplified flow diagram for inedible rendering is shown in Figure 44. The operations schedule of equipment used in the inedible rendering process can be seen in Figure 45. The room layout (upper level) for the inedible rendering process is presented in Figure 46. The main process equipment is located in this area. Another room layout (lower level) is contained in Figure 47. This room contains tanks used for temporary storage of grease. The basis for reporting energy flow information concerning this process is the number of head slaughtered. The average daily kill during the study period was 3021 head. An average daily production of inedible grease was 16,616 pounds. At this plant, the meat and bone meal product is made from a mixture of inedible rendering solids and dried hydrolyzed hair. For this reason, production may not correlate with daily energy flow. A typical daily production of meat and bone meal was 22,739 pounds including the hair.

Grinding and Loading Operation. In the batch type grease rendering process, the inedible products consisting of inedible trimmings, bone and gristle are collected at trim stations throughout the plant and transported to a hopper in inedible rendering by a system of chutes and two conveyors (2.0 and 3.0 horsepower). A 3.0 horsepower auger conveyor moves the material from the hopper to a large grinder or prebreaker which uses a 75 horsepower motor to coarsely grind the material. Plant waste water is processed through a 1.5 horsepower skimmer. A 2.0 horsepower conveyor moves skimmed material to the prebreaker in addition to the above input. The input to inedible rendering is approximately 29 pounds of trim per hog slaughtered. The ground material from the prebreaker has an average composition of 59 percent water, 21 percent fat and 20 percent solids. The average temperature of this material is 80°F. One

FIGURE 44

FIGURE 45. PLANT A - Inedible Rendering Process - Operations Schedule

FIGURE 46

INEDIBLE RENDERING AREA - MAIN FLOOR

FIGURE 47

INEDIBLE RENDERING - BASEMENT

3.0 horsepower and six 2.0 horsepower conveyors move the ground material to six horizontal drum cookers.

The electrical demand for the conveyors and the prebreaker totals 273 kilowatt hours per day. In terms of the number of hogs killed the energy requirement is 72.3 watt-hours per head.

Cooking and Separation Operation. Each of the six cookers or melters is steam jacketed (60 psig) and equipped with a 30 horsepower agitator. In addition to inedible material, 500 to 1000 pounds of stick water from the edible lard process is pumped from holding tanks to each cooker by a 5.0 horsepower pump. The stick water has a composition of approximately 90 percent moisture and 10 percent solids. The ground material is cooked for 3 to 4 hours, denaturing the protein and separating it from the fat. Moisture evaporated from the material in the cookers is drawn through an ejector system which uses recirculated waste water to condense and remove the vapor to sewage treatment. Two 7.5 horsepower pumps move the water from the waste water pit to the ejectors. The final temperature of the grease after cooking is 250 to 260°F.

After the cooking period, the contents of each cooker are emptied into a 2.0 horsepower separation device, known as a percolation pan, where the grease is allowed to separate from the solid material or meat and bone meal by gravity. Grease from the percolation pans is drained to temporary holding tanks in the basement. The composition of the rendered solid material at this point is approximately 3 percent water, with 38 percent fat and another 59 percent solids.

For a typical day, the total steam requirement was estimated to be 146,000,000 BTUS based on the use for one cooker. Electrical consumption for

the entire day was found to be 491 kilowatt hours or roughly 130 watt-hours per head. The average steam flow for a single cooker was found to be 10,200,000 BTUs per batch run. In terms of head slaughtered, the average steam usage was 38,600 BTUs (range 32,300 to 42,900 BTUs).

Of the total steam used by a cooker during a typical run (10,800,000 BTUs), the total amount of energy actual used in heating the material and evaporating water was 6,550,000 BTUs. The condensate return was calculated to be 2,110,000 BTUs. The steam flow for a sample day is shown in Figure 48.

Expelling Operation. The rendered solid material from the percolation pans is transported to machines or expellers which remove more grease by mechanical pressure. One 3.0 horsepower and two 2.0 horsepower conveyors move the material from the percolation pans to the two 40.0 horsepower expellers. The grease separated from the rendered solid material is drained to temporary holding tanks in the basement.

The electrical demand for a typical day by the conveyors and expellers was 227 kilowatt hours. On a per hog slaughtered basis, the electrical requirement was 60.0 watt-hours.

Milling Operation. A 2.0 horsepower conveyor transports the pressed meat and bone meal from the expellers to a 40.0 horsepower hammermill. The mill grinds the material to a fine powder. The final composition of the product is about 6 percent moisture, 13 percent fat and 81 percent solids. The material is then transported by a system of seven 2.0 horsepower conveyors to a storage bin where it is mixed with dry hydrolyzed hair and is known as meat and bone meal. The total electrical usage by the mill and conveyor was 121 kilowatt hours per day. In terms of head killed, the requirement was 32.0 watt-hours

FIGURE 48

INEDIBLE COOKER
(BATCH)

per head.

Grease Clarification Operation. Grease is pumped (two 5.0 horsepower pumps) from separate holding tanks to the grease wash tanks. Each tank of grease is first washed with approximately 2000 pounds of water at 200°F. After settling for about 4 hours, the resulting water and sludge phase is drained from the bottom of the tank. The grease is then mixed with live steam (90 psig), raising the temperature from 140 to 200°F. Five pounds of caustic is then added to the tank and the material is agitated with air. The grease is later washed again with about 1000 pounds of water at 200°F and after a period of settling, approximately 8 hours, the sludge is again drained. The cleaned grease is pumped (5.0 horsepower) to storage tanks prior to shipping.

The electrical requirement on a typical day for pumping grease was 2.60 kilowatt hours. The total daily use of water for the tanks was about 960 gallons and the steam required to heat the grease mixture was 1,720,000 BTUs per day. In terms of the number of hogs processed the electrical, water and steam requirements were 0.69 watt-hours, 0.254 gallons and 456 BTUs.

Sanitation and General Utilities. Water meters were used to obtain the daily average consumption of water for cleanup in the general areas related to inedible grease; cookers, wash tanks and storage. The total water demand for a typical day was 19,600 gallons. The steam required to heat this water was estimated to be 11,400,000 BTUs. In terms of head killed, the water and steam demands were 5.20 gallons and 3020 BTUs per head.

The electrical load caused by lighting and ventilation due solely to the processing of grease and cracklings was 348 kilowatt hours per day or approximately 92.3 watt-hours per head.

Tables 9 and 10 contain the summaries of the utility demands by various unit operations of grease and crackling rendering.

Table 9

Plant A - Inedible Process - Energy Usage per Head Slaughtered

Unit Operations	Steam BTU	Electricity WH	Water Gal
Grinding and Loading		72.3	
Cooking	38,600	130.0	
Expelling		60.0	
Milling		32.0	
Grease Washing	456	0.69	0.254
Sanitation and General Utilities	3,020	92.3	5.20

Table 10

Plant A - Inedible Process - Daily Total Energy Usage

Unit Operations	Steam BTU	Electricity KWH	Water Gal
Grinding and Loading		273.0	
Cooking	146,000,000	491.0	
Expelling		227.0	
Milling		121.0	
Grease Washing	1,720,000	2.60	960
Sanitation and General Utilities	11,400,000	348.0	19,600

Blood Drying Process

A simplified flow diagram of blood drying is presented in Figure 49. The operations schedule for the blood drying process can be seen in Figure 50. The information of utility flows for blood drying are presented on a per head slaughtered basis, typically 3021 head per day during the study period. An average daily production of dried blood was 4,132 pounds. Figure 51 contains a layout of the blood drying process (as well as the other processes in the rendering area).

Loading Operation. Raw blood from the bleed pit area of the kill floor flows by gravity to the blood rendering area for drying. Blood can flow to one of two available driers or the material may be stored temporarily in a holding tank with a 5.0 horsepower agitator. From the holding tank blood can then be pumped to the driers by means of a 5.0 horsepower pump. Blood arrives at the rendering area at a temperature of 90°F. Approximately 7 pounds of raw blood is produced per hog slaughtered. The composition of the blood is 80 to 85 percent water with the remaining portion being solids.

Drying Operation. The driers are steam jacketed (60 psig) and agitated by 50.0 horsepower motors. Each drier operates for 12 to 15 hours per day with blood being added periodically as evaporation continues. Moisture which is lost from the blood is drawn off by a recirculating waste water ejector system as with the inedible cookers. Final moisture content of the dried blood ranges from 5 to 10 percent.

The batch drying run of one drier uses approximately 22,000,000 BTUs of 60 psig steam per day. Assuming both driers perform in a similar manner, the total daily steam use by the blood driers is 44,000,000 BTUs. The average

FIGURE 49

FIGURE 50. PLANT A - Blood Drying Process and Hair Hydrolysis and Drying Process - Operations Schedule

FIGURE 51

Plant A - Blood Process - Processing Area Equipment Layout

steam requirement was 11,700 BTUs per head (range 10,100 to 14,800 BTUs per head). The steam flow for a sample day is shown in Figure 52. The electrical requirements of the blood driers (agitators, each 50 hp, hopper, 10 hp) for a typical day was found to be 387 kilowatt-hours. In terms of production, the electrical demand was 112 watt-hours per head slaughtered.

Milling Operation. The dried material is transported from the driers to the 40.0 horsepower hammermill by two 2.0 horsepower conveyors. The mill reduces the dried blood clots to a fine powder. Seven 2.0 horsepower conveyors move the milled blood to a bin for storage. The hammermill input conveyors, output conveyors and the hammermill itself are the same units used for meat and bone meal and dried hair.

The total requirement for electricity by the hammermill and conveyors was found to be 18.7 kilowatt-hours per day. The demand in terms of production was 5.42 watt-hours per head slaughtered.

Sanitation and General Utilities. The water requirements for sanitation of the blood drying area was found to be approximately 2350 gallons per day. The steam requirement to heat this water was calculated to be 1,370,000 BTUs. In terms of head slaughtered, the water and steam requirements were 0.622 gallons and 363 BTUs.

The power requirement for ventilation and lighting due solely to blood drying was estimated to be 93.6 kilowatt-hours per day. The average use per head slaughtered was calculated to be 27.1 watt-hours.

The water and energy used by the blood drying process is summarized in Table 11 (per head basis) and Table 12 (per day basis).

FIGURE 52

Table 11

Plant A - Blood Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Electricity WH	Water Gal.
Drying	11,700	112.0	
Milling		5.42	
Sanitation and General Utilities	363	27.1	0.622

Table 12

Plant A - Blood Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Electricity KWH	Water Gal.
Drying	44,000,000	387.0	
Milling		18.7	
Sanitation and General Utilities	1,370,000	93.6	2350

Hair Hydrolysis and Drying Process

A simplified process flow diagram for hair hydrolysis and drying is shown in Figure 53. The operations schedule for equipment used in the hair hydrolyzed and drying process can be seen in Figure 54. The energy usage by this process is reported in terms of head slaughtered. During the monitoring period the average daily kill was 3021. The finished product is mixed with the solid material from the inedible rendering process and is known collectively as meat and bone meal. No separate production records were kept for hydrolyzed hair. Figure 55 contains a layout of the equipment used in the hair hydrolysis and drying process (as well as for other rendering processes).

Loading Operation. At Plant A, hair is dried in semi-continuous process. The hair is extracted from the dehairing machines on the kill floor and transported to a hair hydrolyzer in the rendering area by two 3.0 horsepower and two 2.0 horsepower conveyors. Approximately 2.5 pounds of wet hair is produced per hog slaughtered. The electrical requirement by the conveyors for a typical day is 17.2 kilowatt-hours. Electrical usage per head slaughtered averaged 4.7 watt-hours during the study period.

Continuous Hydrolyzing Operation. Hair enters the hydrolyzer at a temperature ranging from 70 to 90°F depending on whether the feed is direct from the dehairers or manually fed from the floor area near the hydrolyzer. The hair entering the machine contains approximately 60 percent moisture. The continuous hydrolyzer is steam jacketed (90 psig) and agitated with a 20 horsepower motor. The hydrolyzer operates at an internal pressure of 80 psig which is necessary for proper hydrolyzation of the hair. The hair itself forms a plug which maintains the internal pressure. Operating time for the

FIGURE 53

FIGURE 54. PLANT A - Blood Drying Process and Hair Hydrolysis and Drying Process - Operations Schedule

FIGURE 55

Plant A - Hair Process - Processing Area Equipment Layout

continuous hydrolyzer is 5 to 7 hours per day. Upon leaving the hydrolyzer, the wet hydrolyzed hair enters a hopper for the hair drier feed conveyor. At this stage, the hair is at a temperature of 280°F and contains about 57 percent moisture.

For a typical day, the amount of steam used was 7,130,000 BTUs at 90 psig. The electrical demand was about 45.6 kilowatt-hours per day. The average steam use on a per head basis 2060 BTUs and the electrical demand was 13.2 watt-hours. For a typical run, the amount of energy actually input to the hair in terms of temperature change was 852,000 BTUs. Since steam is supplied both to the jacket and as injection, a material and energy balance provided the breakdown. Based upon calculations, the amount of steam returned as condensate was 1,080,000 BTUs.

Drying Operation. Two 3.0 horsepower auger conveyors move the hair from the hopper to a steam jacketed (60 psig) cooker similar in design to the inedible cookers. This cooker or drier is a batch type operation which is started after a major portion of the daily output from the hydrolyzer has been transferred. Water is evaporated from the product and withdrawn from the drier by a recirculating waste water ejector system. The final product contains 5 percent moisture on the average, and leaves the cooker at a temperature of about 250°F.

The hydrolyzed hair drier is very similar to the blood driers. Since the steam flow was never actually monitored, the energy flow was estimated based upon the known efficiency of the blood drier. From this method of estimation, it was determined that the typical daily flow of steam to the drier was 8,030,000 BTUs per day at 60 psig. The steam requirement in terms of head

slaughtered was 2320 BTUs. The average electrical requirement for the 30 hp agitator during the drier run was found to be 29.0 watt-hours per head killed. For a typical day, the energy input as electricity was 102 kilowatt-hours.

Milling Operation. Two 2.0 horsepower conveyors move the dried hair from the cooker to the 40 horsepower hammermill where the material is reduced to a powder. A system of seven 2.0 horsepower conveyors move the milled material to the meat and bone meal storage bin where the hair is incorporated into the meat and bone meal. The hammermill input conveyors, output conveyors and the hammermill itself are shared by the dried hair process with inedible rendering and blood processing.

The electrical requirements of the conveyors and the hammermill together averaged 8.37 watt-hours per head slaughtered. For a typical day the total electrical demand for these unit operations was 28.9 kilowatt-hours.

Sanitation and General Utilities. Sanitation and general utilities requirements were assumed to be similar to those for blood drying in terms of daily totals. Thus, the daily total of water, steam and electricity was estimated as 2350 gallons of water, 1,370,000 BTUs steam and 93.6 kilowatt-hours per day. On a per head slaughtered basis the requirements were 0.622 gallons 363 BTUs and 27.1 watt-hours.

Tables 13 and 14 summarize the utility usage by the various unit operations of hair hydrolysis and drying.

Table 13

Plant A - Hair Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Electricity WH	Water Gal.
Loading		4.97	
Hydrolyzing	2,060	13.2	
Drying	2,320	29.0	
Conveying and Milling		8.37	
Sanitation and General Utilities	363	27.1	0.622

Table 14

Plant A - Hair Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Electricity KWH	Water Gal.
Loading		17.2	
Hydrolyzing	7,130,000	45.6	
Drying	8,030,000	102.0	
Conveying and Milling		28.9	
Sanitation and General Utilities	1,370,000	93.6	2350

Detailed Process Energy Analysis for Plant B

The processes analyzed at the Plant B facility were: the entire kill floor process; the cut floor process; the frankfurter manufacturing process; the ham manufacturing process; the lard rendering process; the inedible rendering process; the blood drying process; and the hair hydrolysis-drying process. The total plant layout is shown in Figure 56. In a typical year, the plant uses 434 billion BTUs of natural gas and fuel oil, 18 million kilowatt-hours of electricity, 384 million gallons of water and 94 billion BTUs of refrigeration to process 1,205,779 hogs. Figures 57-60 and Appendix B1 contain data on monthly production of hogs slaughtered, franks and hams produced, lard produced, inedible grease, meat and bone meal produced and blood and hydrolyzed hair produced. Figures 61-69 and Appendix B2 display typical monthly, daily and hourly energy utilization of electricity, water, natural gas and fuel oil. Monthly refrigeration loads are also given in Figure 70. Process labor requirements, plant economic data and preliminary product costs are given in Appendices B3, B4 and B5, respectively.

Dehairing and Evisceration Process

A simplified process flow diagram of the dehairing and evisceration process appears in Figure 71. A generalized layout of the kill floor, carcass chill area and cut floor is presented in Figure 72 and the operations schedule of equipment in the dehairing and evisceration process can be seen in Figure 73. A typical production day for this process is 4823 head slaughtered.

Stun and Bleed Operation. At Plant B, the dehairing operations handle from 500 up to 800 head per hour. The hogs are driven from the adjacent hold-

FIGURE 56. GROUND FLOOR

1. TOTAL PLANT SITE: 41,638 acers
2. TOTAL PLANT: 319,106 Sq. Fz.

Typical Monthly Slaughter

FIGURE 57

Typical Monthly Production

FIGURE 58

Typical Monthly Production

FIGURE 59

Typical Monthly Production

FIGURE 60

Typical Monthly Electrical Usage

FIGURE 61

FIGURE 62

Typical Daily Electrical Usage

FIGURE 63

FIGURE 64

Typical Monthly Water Usage

FIGURE 65

Typical Daily Water Usage

FIGURE 66

Typical Hourly Water Usage

FIGURE 67

Typical Monthly Total Gas and Oil Usage

FIGURE 68

Typical Daily Natural Gas Usage (Total Plant)

FIGURE 69

Typical Hourly Natural Gas Usage (Total Plant)

FIGURE 70

Typical Monthly Refrigeration Usage
(Ton = 288,000 BTUs)

CONTINUED ON NEXT PAGE

FIGURE 71

Plant B - Kill Floor Process - Flow Diagram

FIGURE 71 (cont')

FIGURE 71 (cont')

FIGURE 72
Plant 3 - Kill Floor Process - General Room Layout

FIGURE 73. PLANT B - Kill Floor Process and Cut Floor Process - Operations Schedule

ing pens into the sticking area where the animals are immobilized by means of an electrical stun. The animals are dumped onto a 3 horsepower bleed conveyor where the jugular vein is opened and bleeding begins. At the end of the conveyor the hogs are attached to the shackle chain carried across a bleed pit.

The stunning and sticking operations use a nominal amount of energy during processing. Electricity demand by the stunning apparatus, stun conveyor and bleed conveyor amounts to 7.33 watt-hours per head. A typical use per day is 35.2 kilowatt hours. Steam demand by a knife box is 2.20 BTUs per head or approximately 10,600 BTUs per day with little or no correlation to production.

Scald Tank Operation. The first major unit operation of the dehairing process is the steam injected scald tank. The scald tank is an L-shaped tub 146 feet long filled with water and divided into four heat zones each with steam injection and controls. The temperature of the tank is graduated from 135 to 140°F from one end to the other. Water for filling the scald tank is preheated and softened by means of the plant's waste heat recovery system. Heat from natural gas fired refrigeration compressors is used to heat water for general plant use. Depending on the amount of use for tempered water, the scald tank can be filled with water ranging in temperature from 70 to 160°F. The bled animals are pulled through the scald tank by means of a shackle chain powered with a 10 horsepower motor. Residence time is approximately 3 minutes and 50 seconds. The hog is kept submerged by six dunkers each driven by a 1 horsepower motor. Water is recycled in each of the four zones by a 7.5 horsepower pump. This plant facility is unique in that the scald tub is filled with softened water that has been preheated using waste heat recovery. Input temperatures of the water to the tank vary but often are above the daily operating temperature. Steam demand for startup is thus reduced. Some steam

is still required since the waste heat system only provides 110°F water. The amount of water required to fill the tank to operating level is 14,800 gallons. The amount is constant irregardless of production since tank depth must be maintained. The average amount of water per head is 3.08 gallons.

As noted earlier, the scald tank has little startup demand for steam. The typical heat requirement of the initial scald tank water was estimated to be 3,710,000 BTUs per day. Steam is required also for maintenance of proper water temperature during the workday. The total amount of maintenance steam is directly related to the length of time that the scald tank is operating. Usually, this steam consumption is also related to the number of hogs killed although this is not absolute since chain speed may vary and breakdowns occur. On a typical day, the amount of steam consumed was 56,900,000 BTUs. Average steam consumption per head during the monitoring period was 11,800 BTUs with a range of 9040 to 13,700 BTUs per head. A sample day is shown for two of the meters in Figures 74 and 75.

By comparing steam flow into the tank at operating temperature both in the presence and absence of hogs, the demand due to the hog carcasses was found. For periods when the tank contained no hogs but the water was being maintained at operating temperature, the steam flow averaged 2,420,000 BTUs per hour with a range of 2,060,000 to 3,110,000 BTUs per hour. When hogs were present, the maintenance steam flow averaged 6,210,000 BTUs per hour with a range of 5,790,000 to 6,640,000 BTUs per hour. The presence of animals in the tank more than doubled the steam demand. It should be noted, however, that very little of this energy is actually being absorbed by the hog carcass. Trial tests revealed that there was no appreciable temperature increase at the one inch depth as hogs were being scalded in 140°F water. Assuming that only

FIGURE 74. Plant B - Sample Steam Flow for Scald Tank - Meter 1

FIGURE 75. Plant B - Sample Steam Flow for Scald Tank - Meter 2

the outer skin was heated, the amount of energy which can be accounted for by the hogs (at 600 per hour) is only 412,000 BTUs per hour. The remaining amount of the increased steam demand must be due to the action of the animals disturbing the water surface and thus increasing heat loss.

The energy losses responsible for the maintenance steam demand consist of convective and radiant heat loss from the metal surfaces of the tank and piping, overflow of heated water and combined losses from the water surface. Of the total hourly flow of 2,420,000 BTUs per hour (no hogs), the heat loss from the metal tank surfaces and overflow account for only 506,000 BTUs per hour. The majority of the input energy is lost from the water surface through the combined effects of convection, radiation and evaporation and the direct loss of live steam. The presence of carcasses in the tank apparently increases water surface losses considerably as witnessed by the doubling of steam flow. All other losses remain relatively stable whether or not hogs are present.

The electrical demand by the scalding operation is divided among 11 motors. There are 6 motors powering the dunkers, 4 recirculation pumps and one shackle chain drive. The electrical use by these motors correlates with the length of the workday and, in general, with the number of hogs slaughtered. The average electrical use is 55.9 watt-hours per head. A typical daily demand was 2.69 kilowatt hours.

Dehairing Machines Operation. At the end of the scald tank the animals are guided into a 2 horsepower conveyor feeding the first dehairer. The hogs are propelled through the first dehairer then the second by means of beaters (30 horsepower) in each dehairer. Rinsing sprays wash the hair from the beaters down onto skimmers in the base of each dehairer. The hair conveyor is

powered by a 2 horsepower motor. The base of each dehairer consists of an open tank filled with water and maintained at the 138°F operating temperature through steam injection. Water is recycled in each dehairer from the base tank by a 25 horsepower pump. In addition to the recycle spray, the second dehairer has a fresh water constant spray near the outlet for sanitary reasons. The animals exit the dehairers and are attached to the gambrel chain (15 horsepower) at the gambrel conveyor table which is powered by a 5 horsepower motor.

As with the scald tank, the dehairers are usually filled with preheated softened water at startup. When filled, the tanks in the bases of the dehairers have a total combined capacity of 3210 gallons. During the workday, a fresh water overflow is maintained to the dehairing operation. The main water line which feeds the dehairers and polisher was monitored continuously during the data collection period. The average 24 hour total through this line was 91,200 gallons but this includes a good deal of post production cleanup flow. The average flow during the production day was 69.3 gallons per minute of which 22.4 gallons per minute was dehairer overflow, the remainder being due to the polisher.

For the production period during a typical day, the total water overflow was 20,500 gallons. The average water requirement for the entire unit operation during the production day was found to be 4.93 gallons per head with a range of 3.43 to 7.02 gallons per head.

Unlike the scald tank, the steam demand by the dehairers for temperature maintenance remained nearly constant, irregardless of the presence or absence of hogs. The average steam requirement was 15,200,000 BTUs per hour. Of this

total, only 3,970,000 BTUs per hour can be explained by losses from the metal surfaces of the dehairers plus overflow losses. The remaining heat is lost by the combined convective, radiant and evaporative heat transfer from water and the direct loss of live steam. The interior conditions of the dehairers consisting of fine sprays of heated water falling through flowing air provide ample opportunity for heat transfer.

The total daily steam demand by the dehairers is directly related to operating time. For a typical day, the dehairers used 109,000,000 BTUs. The average steam demand obtained during the monitoring period was 25,400 BTUs per head with a range of 20,300 to 29,000 BTUs per head.

There are 8 motors associated with the dehairers; 2 main drive motors, 2 recirculation pumps, a hog conveyor motor, a hair conveyor motor, a gambrel table motor and a gambrel chain drive motor. Typical daily electrical use was 3510 kilowatt hours per day. The average electrical demand per head was found to be 106 watt-hours.

Singeing Operation. From the gambrel table, the hogs are moved into a holding area prior to being started through the singer. Here the the hind toenails are removed. The singer consists of jets of flame fueled by natural gas (15 psig) directed at the hog carcass. The hog carcasses pass through the singer suspended on the gambrel chain. The singer at Plant B is variable controlled and serves the purpose of removing any remaining bits of hair which were not removed in previous operations.

When hogs are present, the singer consumes natural gas at nearly a constant rate during the entire operating day with very little fluctuation of flow. A typical daily consumption was 52,100,000 BTUs. Typical flow with

hogs present was 9,700,000 BTUs per hour. During idle, the flow dropped to 3,560,000 BTUs per hour. The average consumption was found to be 10,800 BTUs per head with a range of 10,100 to 12,100 BTUs per head. It is assumed that the majority of the input energy to the singeing operation is lost to the surroundings and as vented exhaust.

The electrical demand for the singer blower amounts to an average of 1.80 watt-hours per head. A typical consumption per day was 8.67 kilowatt hours.

Polisher Operation. The animal leaving the singer is moved into a polisher in which counterrotating brushes and water sprays remove singed hair. The brushes are driven with a 25 horsepower motor. The polishing operation uses water at an average rate of 5.78 gallons per head with a range of 3.79 to 6.80 gallons per head. The water consumption during production for a typical day was found to be 27,800 gallons.

The electrical demand for the motor powering the polisher amounted to an average of 12.9 watt-hours per head. A typical production day required 61.8 kilowatt hours.

Shaving Operation. The carcass next passes through a line of shavers whose jobs are to remove the hind toenails, shave the hams, sides, shoulders and jowls, and remove eyelids. Each of the shavers is provided with a steam injected knife box for sterilizing equipment between hog carcasses. The sole energy input to shaving is the modest amount of steam required by the knife sterilizers. The average steam demand was found to be 6.61 BTUs per head. Consumption for a typical day was 41,700 BTUs.

Rinse Cabinet Operation. The average flow to the rinsing operation dur-

ing the production day was found to be 4.95 gallons per head with a range of 4.21 to 6.93 gallons per head. During the production period of a typical day, the total water consumption was found to be 22,600 gallons.

Drop Head, Drop Bung and Split Carcass Operation. Evisceration begins with the head of the carcass being dropped by means of a pneumatic neck breaker. The head is then trimmed manually and inspected. The brisket is split with an electric saw and the carcass is opened. Next, the bung is cut and the carcass is spread by means of steel hooks. This combined operation requires a small amount of steam for knife sterilizers and electricity for a saw, a knife and a conveyor. The average steam demand was 60.7 BTUs per head with a typical daily consumption of 292,000 BTUs. The electrical usage by the operation averages 2.41 watt-hours per head and a typical daily demand was found to be 11.6 kilowatt hours.

Evisceration and Separation Operation. Viscera are removed from the carcass, placed onto pans, inspected and separated. Water demand by the pan washer and numerous spray heads averages 3.91 gallons per head. A typical daily requirement was found to be 18,800 gallons. Steam demand by the sterilizers and pan washer averages 1940 BTUs per head with a typical daily consumption of 9,380,000 BTUs.

For the general area of evisceration and separation of entrails, the plant has two six inch water mains, one cold water and one tempered. During actual production the flow rate of water through these mains averaged 31,400 gallons per hour. As described later, a large portion of this flow is used by the chitterling machines.

Stomach Line Operation. Water is used by the stomach cleaner, scalders and spray heads. An average usage was found to be .2.08 gallons per head. Typical daily consumption amounted to 9650 gallons per day. Steam usage by the batch type scalders was determined to be 155 BTUs per head. A typical daily requirement was estimated to be 748,000 BTUs. The average electrical demand by the cleaner, skinner and scalders was found to be 8.36 watt-hr found to be 8.36 watt-hours per head with a typical daily requirement of 40.4 kilowatt hours.

Casing and Chitterling Processing Operation. In this combined unit operation water is used for numerous spray heads, 3 chitterling machines, 2 casing crushers, 2 strippers and a finishing machine. The average flow for this operation was 83.8 gallons per head. The water consumption (cold and tempered) on a typical day was 404,000 gallons during the production period. This is the combined flow through the two six inch mains feeding the center of the kill floor area. Of this total, the majority of the water, 341,000 gallons, is used by the three chitterling machines. The steam required to heat all water to operating conditions from the waste heat recovery system temperature amounts to 85,400,000 BTUs per day or 17,700 BTUs per head slaughtered.

The electrical demand by this operation consists of 2 conveyors, 3 chitterling machine chain drives, 3 knife drives, 2 casing crushers, 2 strippers, a finishing machine and a slime pump. The average electrical usage per head was found to be 32.4 watt-hours. Consumption for a typical day amounted to 156 kilowatt hours.

Liver and Heart Line Operation. Water is used in this operation by spray heads and the heart scalders. The average consumption per head was found to

be 0.48 gallons. For a typical day, the total water use during production was 2260 gallons. Steam is used only by the heart scalding. It was estimated that the requirement for the scalding was 255 BTUs per head or 1,230,000 BTUs per production day. Electricity is used by a conveyor, 2 slashers and the scalding. The average electrical consumption per head was 10.1 watt-hours. On a typical day, the total consumption was 48.4 kilowatt hours.

Enucleate Kidneys, Split Back, Trim Hams and Inspection Operation. This combined operation uses steam for sterilizers and electricity for splitting saws. The average steam use per head was found to be 80.7 BTUs. For a typical day, the steam requirement was 389,000 BTUs. The electrical demand for the saws averaged 7.54 watt-hours per head or 36.2 kilowatt hours per typical production day.

Head Table Operation. The head is removed from the carcass and moved to a separate line where the tongue, ears and forehead are removed. The tongues are hand trimmed and placed into cold water holding tank prior to being chilled. The ears and forehead are separated each being placed on trays and removed to the cooler. The remaining portion of the head is moved to a station where the meat is loosened from the jawbone and the snout is pulled (1.3 horsepower). The snout is trimmed and chilled. The jaw is next pulled (1 horsepower) and meat is trimmed from the jaw. Cheek meat is cut from the head, trimmed and moved to a cooler. All remaining meat is trimmed from the skull and then the skull is split (15 horsepower). The brain and pituitary gland are removed and the skull is sent to inedible rendering. In this operation, water is used by numerous spray heads. Electrical demand consists of forehead meat slicer, snout stripper, jaw puller, jaw and skull meat trimmers and a hydraulic pump powering the skull splitter. The total water use for a

typical was found to be 1650 gallons. The average requirement per head was 0.34 gallons. The steam required to heat this water above the temperature of recovery heat was estimated to be 412,000 BTUs per day or 85.5 BTUs per head. Electrical demand for this operation averaged 17.1 watt-hours per head. The demand during a typical production day was 82.4 kilowatt hours.

Kidney and Leaf Lard Removal and Final Carcass Shower Operation. Water consumption for this combined operation is due to the three rinsing steps. The average water use per head was found to be 9.80 gallons. For a typical day, the water use during production was 47,300 gallons. Electrical requirements for this operation consist of a lard pump and auger and a cam motor. Total electrical demand for a typical day was 11.7 kilowatt hours. The average use per head was found to be 2.44 watt-hours.

Carcass Chill Operation. The carcass chill room has twelve air handling units for refrigeration. The refrigeration use at the evaporators was found to average 17,000 BTUs absorbed per head killed. The total room requirement for a typical day (summer) was found to be 81,980,000 BTUs absorbed. The electrical demand by the fan motors for a typical day was 891 kilowatt hours. The overall average electrical demand per head slaughtered was 185 watt-hours.

Sanitation and General Utilities. The variation in water flow after production hours (cleanup) was very large for all metered lines. The average post production flow in the line feeding the dehairing area (dehairers and polisher) was 38,800 gallons with flow continuing often until 3:30 the following morning. However, there were some days when the line was shut off promptly and as little as 4030 gallons were used. The upper limit recorded was 55,312 gallons used after production hours. Similarly, the water use in

the central kill floor area (fed by the 2 six inch mains) averaged 66,000 gallons post production with a variation of 43,700 to 85,800 gallons. The rinsing cabinets on the kill floor also ran well beyond the production period. For instance, the rinse cabinet after the carcass shave typically ran until midnight using an average of 8570 gallons.

Taken together, the water use by all portions of the kill floor during a typical cleanup period was estimated to be an average of 122,000 gallons. Although there is no direct correlation between cleanup water use and production rate, a typical per head use could be estimated from repeated measurements. In this case, approximately 25.3 gallons of water per head was used for cleanup on the kill floor for a typical day. Some of the cleanup water is heated beyond the temperature of water coming from the waste heat recovery system. It was estimated that 27,500,000 BTUs per day of steam was required or, in terms of hogs slaughtered, an average of 5710 BTUs per head.

The gambrel or dressing chain cleaner room contains a water filled tank similar to the scald tub. The chain with the gambrel hooks passes through the water tank, a water shower and then through an oil bath. The total steam requirement for this room which involves heating tank water, spray water and oil averages 2356 BTUs per head with a range of 988 to 2985 BTUs per head. The day to day variability of steam flow to this room is quite large, but choosing a typical day, the total daily flow was 11,400,000 BTUs.

A blower is used to ventilate fumes from the top of the cleaning tank. The average electrical demand was 7.53 watt-hours per head. For a typical day, the consumption was 34.7 kilowatt hours.

A series of water spray heads is used to clean the chain and hooks exiting from the cleaning tank. The average water usage is 0.3 gallons per head. For a typical day the total water consumption was 1380 gallons.

Electrical consumption by lighting and ventilation associated with the kill floor operations does not strictly correlate with production. In the same manner as sanitation water, the total electrical use depends solely on the length of time that these utilities remain turned on. For a typical day, the electrical requirement was estimated to be 374 kilowatt hours. On a per head slaughtered basis the consumption was estimated to be 77.7 watt-hours.

A summary of the utility requirements for each unit operation of the kill floor is shown in Tables 15 and 16. The energy and water flow data has been presented using two bases. Table 15 displays the energy usage information in terms of head slaughtered. Table 16 contains the energy consumption information on a per day basis.

Table 15

Plant B - Kill Floor Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Gas BTU	Electricity WH	Water GAL	Refrigeration BTU
Stun and Bleed	2.2		7.3		
Scald Tank	11,800.0		55.9	3.08	
Dehairers	25,400.0		106.0	4.93	
Singeing		10,800.0	1.8		
Polish			12.9	5.78	
Shave	6.6			4.95	
Rinse				4.95	
Head and Split	60.7		2.4		
Eviscerate and Separate	1940.0			3.91	
Stomach Line	155		8.4	2.08	
Casings and Chitterlings	17,700.0		32.4	83.80	
Livers and Hearts	255.0		10.1	0.48	
Split Backs and Inspect	80.7		7.5		
Head Table	85.5		17.1	0.34	
Leaf Lard & Rinses			2.4	9.80	
Carcass Chill			185.0		17,000.0
Sanitation and General Utilities	8070.0		85.2	25.3	

Table 16

Plant B - Kill Floor Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Gas BTU	Electricity KWH	Water GAL	Refrigeration BTU
Stick and Bleed	10,600		35.2		
Scald Tank	56,900,000		269.0	14,800	
Dehairers	109,000,000		510.0	23,700	
Singeing		52,100,000	8.7		
Polish			61.8	27,800	
Shave	41,700				
Rinse				22,600	
Head and Split	292,000		11.6		
Eviscerate and Separate	9,380,000			18,800	
Stomach Line	383,000		40.4	9,650	
Casings and Chitterlings	85,400,000		156.0	341,000	
Livers and Hearts	1,230,000		48.4	2,260	
Split Backs and Inspect	389,000		36.2		
Head Table	412,000		82.4	1650	
Leaf Lard and Rinses			11.7	47,300	
Carcass Chill			891.0		81,980,000
Sanitation and General Utilities	38,900,000		484.0	123,000	

Cut Floor Process

A layout of the process lines for the cut floor is depicted in Figure 76. The basis used for reporting energy use in this process was the number of head slaughtered per day, typically 4823 head.

Overall Room Refrigeration Operation. Chilled carcasses are removed from the chill room, brought into the cut area and lowered onto a conveyor from which four general lines branch; ham, shoulder, loin and belly. The room is maintained at approximately 45°F by 20 air handling units.

The electrical requirement for the fans in the air handling units are found to average 44.2 watt hours per head slaughtered during the monitoring period. At the time of study, the refrigeration system was operating approximately 13.5 hours per day using a total daily consumption of 212 kilowatt hours. The amount of energy absorbed from room air averaged 3590 BTUs absorbed per head slaughtered. For a typical day, the energy absorbed was 17,300,000 BTUs.

Carcass Rail and Main Conveyor Operation. The electrical demand for this operation is due to 4 motors. The average electrical consumption was determined to be 92.5 watt-hours per head killed with a typical daily usage of 444 kilowatt hours.

It should be noted that the carcass rail, main conveyor and room refrigeration operations are shared by all materials produced on the cut floor. Strictly speaking, they are not separate unit operations but are so treated for convenience.

FIGURE 76

Ham Line Operation. The utilities used by this operation include steam for knife sterilizers and more importantly, electricity. The average steam requirement for the sterilizers was found to be 3.85 BTUs. For a typical production day, the usage was estimated to be 18,500 BTUs.

Electrical consumption for this operation is due to 2 saws, 6 conveyors and 2 skinners. The average electrical usage per head slaughtered was found to be 50.2 watt-hours. For a typical day, the total requirement was 242 kilowatt hours.

Shoulder Line Operation. The steam requirement for the knife sterilizers used on the shoulder line averaged 24.4 BTUs per head killed during the period of study. In a typical day, the quantity of steam used by the boxes totaled 117,000 BTUs.

The electrical demand to this operation is due to 3 saws, 10 conveyors, 3 skinners, a mill and 4 trimmers. The average usage per head killed was determined to be 62.7 watt-hours. For a typical day, the total usage was 301 kilowatt hours.

Loin Line Operation. As before, the two utilities required are steam and electricity. The average steam consumption by the knife sterilizers was 5.14 BTUs per head killed with a typical daily usage being 24,700 BTUs.

The electrical requirement for the loin operation is due to 3 saws, 3 conveyors and a box closing machine. Typical daily electrical usage for this operation during the period of study was 124 kilowatt hours. An average use per head killed was determined to be 25.9 watt-hours.

Belly and Rib Line Operation. The steam requirement for the knife sterilizers used in this operation totaled 74,100 BTUs for a typical day. The average use per head was found to be 15.4 BTUs.

The electrical usage in this operation includes 8 conveyors, a roller, 4 knives, a skinner and 8 trimmers. The total electrical demand for a typical day was 244 kilowatt hours. The average usage per head killed was found to be 50.8 watt-hours.

Sanitation and General Utilities. The electrical requirement for lighting and ventilation for the cut floor averaged 45.3 watt-hours per head killed. For a typical day, the usage was 218 kilowatt hours. The water consumption by the cleanup hoses was found to average 1.85 gallons per head. For a typical day, the water use for sanitation was 8900 gallons. Steam is required to heat this water above the waste heat recovery system temperature. The daily total steam demand was estimated to be 2,220,000 BTUs. In terms of head slaughtered, this amounts to 461 BTUs per head.

A summary of the utility requirements for each unit operation of the cut floor is shown in Tables 17 and 18. The data is displayed using two bases, per head and per day.

Table 17

Plant B - Cut Floor Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Electricity WH	Water GAL	Refrigeration BTU
Cut Floor				
Refrigeration		44.2		3590
Carcass Rail and Main Conveyor		92.5		
Ham Line	3.8	50.2		
Shoulder Line	24.4	62.7		
Loin Line	5.1	25.9		
Belly & Rib Line	15.4	50.8		
Sanitation and General Utilities	461.0	45.3	1.85	

Table 18

Plant B - Cut Floor Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Electricity KWH	Water GAL	Refrigeration BTU
Cut Floor				
Refrigeration		212		17,300,000
Carcass Rail and Main Conveyor		444		
Ham Line	18,500	242		
Shoulder Line	117,000	301		
Loin Line	24,700	124		
Belly & Rib Line	74,100	244		
Sanitation and General Utilities	2,220,000	218	8900	

Ham Manufacturing Process

A simplified process flow diagram for the processing of ham-type products is presented in Figure 77. Typical daily production of cured ham-type products was 56,292. The operations schedule of equipment used in the ham manufacturing process is shown in Figure 78.

Cure Room Refrigeration Operation. Figure 79 contains a layout of the various process equipment lines in the curing room area of Plant B. This room is used for the curing of other products besides hams for instance, bacon. Graded hams, butts and picnics from the cut floor are moved to the cure area for pickling. The cure room contains lines for a variety of ham based products as well as for bellies. Some other products, such as loins, are also cured. Since only the ham-based products were to be studied, a method for discounting utilities used by bellies was required. All products, whether hams or bellies, enter the cure area already chilled and therefore the refrigeration load should not be portioned based on production weights. It was decided to segregate the refrigeration loads due to the bellies and hams based upon the number of workers and equipment necessary for the respective operation. In this way, the actual loads on the air handling system determine the refrigeration requirements. The ratio used for the refrigeration load (and also lighting and sanitation) due to ham processing in the cure room was 0.806. Unless otherwise noted, the word "hams" will be used, generically, to include such products as boneless, semi-boneless, bone-in, picnics, butts as well as such products as ham rolls, cooked hams, ham salad products, etc.

The cure room contains 14 air handling units which maintain the room air temperature at approximately 42°F. The electrical demand by the fan motors

FIGURE 77

Plant B - Ham Process - Flow Diagram

FIGURE 77, continued

FIGURE 78. PLANT B - Ham Manufacturing Process - Operations Schedule

FIGURE 79

Plant B - Ham Process - Cure Area Equipment Layout

for the air handling units was found to total 264 kilowatt hours per day. The fraction of this total due to hams was estimated to be 213 kilowatt hours per day. In terms of finished ham type products, the electrical consumption was determined to be 3.52 watt-hours per pound of finished product.

The room refrigeration load for the cure area was found to be 20,400,000 BTUs absorbed per day of which 16,400,000 BTUs was due to ham. The average refrigeration demand was found to be 272 BTUs per pound of finished product.

Boning and Injection Operation. The boning, trimming and pickle injection operation uses steam for sterilizers, water for brine makeup and electricity.

The amount of water use for cure injection varies depending upon the type of ham product. The estimated total use per day was 2290 gallons of water for the ham type products. For a bone-in ham, the amount of water used per pound of finished product was determined to be 0.035 gallons per pound. For other products, the range was 0.023 to 0.043 gallons per pound.

The electrical demand by this operation varies depending upon the type of product. The typical day total for electrical usage by a ham related machinery was 1120 kilowatt hours. For a bone-in ham, the average requirement was determined to be 10.3 watt-hours per pound of finished product. This is for hams which are not deboned, tenderized or massaged. For boneless and semi-boneless hams which had been tenderized and massaged, the electrical usage was as high as 52.8 watt-hours per pound of finished product.

For a typical day, the total steam usage by the knife sterilizers used by the trimming and deboning lines was 253,000 BTUs per day. The average use of

steam per pound for the boneless and semi-boneless hams was 12.0 BTUs per pound of finished product.

Holding Cooler Operation. The refrigeration usage by the holding cooler was found to be 9,600,000 BTUs absorbed per typical day. The average requirement per pound of finished ham type product was 159 BTUs per pound. The electrical demand by the air handling fans was found to total 101 kilowatt hours per day. In terms of finished product, the average usage was 1.67 watt-hours per pound.

Smokehouse Operation. Figure 80 contains a process equipment layout of the smoking area of the plant. Depending upon the type of ham product, the smoking period in the house varies. Consequently, the gas, steam and electrical usage will also vary. In a typical smokehouse run, with picnics, regular shank and T-65 hams the total run used 17,500,000 BTUs of natural gas, 659 kilowatt hours of electricity and an estimated 5,030,000 BTUs of steam. Since the varieties are pulled at different times, the amount of each utility which can be attributed to each type of ham is different. For picnics, which were pulled first, the average gas use was determined to be 606 BTUs per pound finished weight. The steam use was estimated to be 174 BTUs per pound and the electrical use was determined to be 7.93 watt-hours per pound. For the T-65 hams, the average gas use was determined to be 816 BTUs per pound. The steam usage was estimated to be 234 BTUs per pound and the electrical requirement was 10.7 watt-hours per pound. For the regular shank hams, the average gas use was determined to be 1040 BTUs per pound and the steam consumption was estimated to be 297 BTUs per pound. The electrical demand for the regular shank hams was found to be 13.6 watt-hours per pound of finished weight.

FIGURE 80

Plant B - Ham Process - Smokehouse Area Equipment Layout

A rough estimate of the total utilities used for all smoked ham type products based upon daily production was made. For a typical day, the gas consumption was determined to be 52,500,000 BTUs, the steam use to be 15,100,000 BTUs, and the electricity to be 1980 kilowatt hours.

The water usage for showering ham type products was found to average 0.065 gallons per pound finished product. A typical daily use was found to be 4000 gallons.

Blast Chiller Operation. After smoking and rinsing, the hams are moved to a blast chill area which is divided into 3 rooms. A total of 8 air handling units maintain the air temperature at approximately 30°F. The total daily requirements for electricity and refrigeration used in this process are 1660 kilowatt hours and 67,400,000 BTUs absorbed, respectively. On a per pound of finished product basis, the electrical requirement averaged 27.5 watt-hours per pound and the refrigeration requirement was 1110 BTUs per pound.

Tempering Operation. From blast chill, the hams are moved to tempering prior to entering the packaging phase. A total of 5 air handling units in 2 rooms maintain average air temperatures at approximately 35°F. The electrical usage for a typical day by the fan motors was determined to be 81.9 kilowatt hours. The amount of refrigeration required for a typical day was 5,515,200 BTUs. In terms of pounds of finished product, the electrical requirement was found to average 1.35 watt-hours per pound. The amount of energy absorbed by the refrigeration system was found to be 91.2 BTUs per pound.

Packaging Refrigeration Operation. Figure 81 contains a layout of the equipment in the general packaging area. Only the equipment in the lower

FIGURE 81

Plant B - Ham Process - Packaging Area Equipment Layout

portion of the figure is devoted to ham processing. As with the curing room, several products share the refrigeration requirement for the packaging area. For the immediate area of ham product packaging there are 5 air handling units. The total electrical use in a typical day for ham type products was found to be 75.6 kilowatt hours. The refrigeration load for ham products was determined to be 5,112,000 BTUs. The average electrical use in terms of pound of product was 1.25 watt-hours and the amount of energy absorbed by the refrigeration system was determined to be 84.5 BTUs per pound.

Packaging Equipment Operation. The electrical demand in the packaging area is due to a saw and seven motors associated with the vacuum packager. The typical daily electrical demand was found to be 68.7 kilowatt hours. An average usage per pound finished product was estimated to be 1.14 watt-hours per pound.

Sanitation and General Utilities. The electrical consumption for lighting and ventilation by all rooms associated with ham processing was found to be 517 kilowatt hours in a typical day. The average usage per pound of finished product was 8.55 watt-hours.

Water usage for sanitation in all process rooms related to ham processing was estimated to be 21,900 gallons per typical day. In terms of finished product, the water use was determined to be 0.36 gallons per pound. Since the water is preheated in the waste heat recovery system, the amount of steam required to heat the water to 140°F was estimated to be 5,470,000 BTUs per day or 90 BTUs per pound of ham produced.

A summary of the utility requirements for each unit operation of ham processing is shown in Tables 19 and 20. The data in Table 19 is based upon

information concerning a regular bone-in ham. For other types of ham products, the utility usages which are noted in the written discussion could be used where appropriate. The data in Table 20 is based upon a production day with all ham type products being produced.

Table 19

Plant B - Ham Process - Energy Usage per Pound

Unit Operation	Steam BTU	Gas BTU	Electricity WH	Water GAL	Refrigeration BTU
Cure Room					
Refrigeration			3.52		272.0
Cure Injection			10.3	0.035	
Holding Cooler			1.67		159.0
Smoking	297	1040	13.6	0.065	
Blast Chiller			27.5		1110.0
Tempering			1.35		91.2
Packaging					
Refrigeration			1.25		84.5
Packaging			1.14		
Sanitation and General Utilities	90		8.55	0.35	

Table 20

Plant B - Ham Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Gas BTU	Electricity KWH	Water GAL	Refrigeration BTU
Cure Room					
Refrigeration			213.0		16,400,000
Boning, Trimming and Injection	253,000		1120.0	2,290	
Holding Cooler			101.0		9,600,000
Smoking	15,100,000	52,500,000	1980.0	4,000	
Blast Chiller			1660.0		67,400,000
Tempering			82.0		5,520,000
Packaging					
Refrigeration			75.6		5,110,000
Packaging			68.7		
Sanitation and General Utilities	5,470,000		517.0	21,900	

Frankfurter Manufacturing Process

A flow diagram of the unit operations in frankfurter manufacturing is presented in Figure 82. The typical daily production of franks during the monitoring period was 71,345 pounds. The operations schedule for equipment used in the frankfurter manufacturing process is shown in Figure 83.

Green Meats Cooler Operation. The frankfurters, bologna and loaf meats at Plant B are prepared either from beef or a mixture of beef and pork. Fresh pork meat trim and specialty items which have been weighed on the kill floor are moved to the green meats cooler. Frozen meat which has been purchased outside of the plant is also moved to the cooler for storage. The utility requirements for this operation consist of refrigeration and electrical usage by the air handling units. For a typical day, the total energy absorbed by the air handling system was found to be 3,920,000 BTUs. The electrical requirements for the motors in the air handling units amounted to 39.5 kilowatt hours per day.

In order to partition the utility requirements, an analysis of material flow through the cooler was performed. In a given day, fresh meat, frozen meat, rework cotto and loaf materials pass through this operation. The proportion determined to be solely due to franks was 0.545. Therefore, in terms of frank production the total refrigeration and electrical demands were 2,140,000 BTUs and 21.6 kilowatt hours, respectively. In terms of pound of finished product, the electrical demand was 0.31 watt-hours. The refrigeration requirement averaged 31.1 BTUs per pound.

Sausage Kitchen Refrigeration Operation. As with the green meats cooler, other products besides franks are processed in this room. The total

CONTINUED ON NEXT PAGE

FIGURE 82

Plant B - Fränkfurter Process - Flow Diagram

FIGURE 32, continued

FIGURE 83. PLANT B - Frankfurter Manufacturing Process - Operations Schedule

refrigeration and electrical usage by the air handling units was 8,860,000 BTUs and 81.8 kilowatt hours per day. The total daily amounts of these utilities due solely to franks were estimated to be 5,580,000 BTUs and 51.5 kilowatt hours, respectively, using a proportion factor for franks of 0.63. The average electrical use per pound of finished frankfurter was determined to be 1.19 watt-hours. The refrigeration requirement was found to be 81.3 BTUs per pound.

Sausage Kitchen Equipment Operation. A layout of the sausage kitchen processing equipment is shown in Figure 84. Fresh meat trim is hydraulically loaded into a 127 horsepower grinder. Frozen meat is manually loaded into a 12 horsepower Hydroflaker. Five conveyors are used to move the ground and flaked meat to one of two blenders. Total horsepower for the conveyors is 3.75.

The blenders are used for the preparation of two types of meat blend, a lean blend and a fat blend. The mixture of these two blends controls the fat content in the finished product. One blender has a 30 horsepower motor, the other a 35 horsepower motor. The blended meat is removed from each blender by means of a screw conveyor into carts. The carts are weighed at each blender and carts with the two different blends are paired for processing. The carts are moved to a holding area and as required, hydraulically emptied into a vacuum chopper where spices and syrup are added. There are two choppers, one for franks and one for bologna. Each chopper contains three motors with ratings of 6, 10.2, 184 horsepower, respectively. In addition, a vacuum compressor is required for each cutter, driven by a 15 horsepower motor.

Following blending and chopping in the vacuum cutters, the material is

FIGURE 84 - PLANT B

SAUSAGE ROOM AREA

unloaded into an emulsifier or MinceMaster (100 horsepower). The emulsion from the emulsifier is placed into holding bins (bologna and franks) or into carts (loaf products). From this point onward the processing of the various types of products differ.

Emulsion for franks is pumped from the holding bins to the casing machines or FrankAmatics by pneumatic pumps. Four casers are used for franks each powered by a 2 horsepower motor. The output from the casing machines is fed to a chain loader or Julian loader (1.5 horsepower). This machine places ten strands of linked frankfurters onto the frank chain which moves continuously through the remaining unit operations.

The electrical demand by the frank processing equipment in the sausage kitchen is due to a flaker, a grinder, 5 conveyors, 2 blenders, a chopper, a vacuum pump, an emulsifying mill, 4 stuffer-linkers, a pump and a chain loader. The total electrical use for a typical day (two shifts) was found to be 1800 kilowatt hours per day. In terms of production, the electrical requirement was 26.2 watt-hours per pound of finished franks.

Water consumption by this unit operation consists mainly of water sprays used to keep equipment clean, water lines used for heating equipment or product lines, and water added to products. The total amount of water used for franks in the sausage kitchen was 11,800 gallons in a typical day. In terms of finished product, the water usage was 0.17 gallons per pound.

Smokehouse Operation. Franks which have been formulated, stuffed and linked in the sausage kitchen are loaded onto a continuous chain which passes through the two sectioned smokehouse. The continuous chain is driven by two controllable 1.5 horsepower direct current motors. The chain first moves

through a rinsing cabinet which sprays the frankfurters with diluted liquid smoke recycled by means of a 0.75 horsepower pump. The frank chain then moves to the second floor. Liquid smoke is sprayed onto the frankfurters prior to entering the smokehouse. Two 0.5 horsepower motors are used to spray the steam heated liquid smoke at 110°F.

The continuous smokehouse consists of two sections through which the frank chain passes in a looping arrangement. The residence time of the franks in each section is approximately 22 minutes depending on chain speed. The first section of the smokehouse operates at 160°F dry bulb and 130°F wet bulb. The second section operates under the conditions of 212°F dry bulb and 160°F wet bulb. Each section has two 20 horsepower blowers and two 0.25 horsepower vent controllers. Both sections are fueled with natural gas and steam injection is used to control humidity. The franks experience approximately a 0.5 percent shrink in the smokehouse and exit the house at an internal temperature of 160°F. Figure 85 contains a layout of the continuous smokehouse area including the chilling and peeling operations.

The electrical demand by this operation is due to 2 chain drive motors, 2 recycle pumps for liquid smoke, 2 smokehouse blower motors and 2 smokehouse damper motors. Total demand for a typical day (2 shifts) is 654 kilowatt hours. In terms of pounds of finished frankfurter product, the electrical requirement was 4.29 watt-hours per pound.

Water is used for rinsing the continuous chain. The total water used for this purpose during a typical day was 571 gallons. In terms of production, the amount of water used was 0.008 gallons per pound.

FIGURE 85

SMOKEHOUSE AND PEELER AREA

The two smokehouse burners are natural gas fired. For a typical day, the total gas used by this operation was recorded at 39,600,000 BTUs. In terms of final product, the natural gas use was 577 BTUs per pound.

Steam is required by this unit operation for maintaining smokehouse humidity and for heating the water used by the frank chain cleaner. The amount of steam which was used by the smokehouses was 43,000,000 BTUs in a typical day. The steam used for heating water to clean the continuous chain was 103,000 BTUs per day. The total daily requirement was thus, 43,100,000 BTUs. In terms of production, the steam demand was 628 BTUs per pound of finished franks.

Frank Shower and Brine Chill Operation. Immediately after smoking, the franks are initially cooled by a fresh water shower. A 5 horsepower pump moves the water. The chain then passes through a brine tunnel where recycled chilled brine lowers the temperature of the franks to approximately 30°F. The brine is chilled in a ammonia heat exchanger and pumped through the system by means of two pumps, 10 horsepower and 1.5 horsepower. The franks are rinsed upon leaving the smokehouse by a fresh water shower. The product then passes through a brine tunnel which further cools the product to approximately 30°F.

The electrical requirement for this operation consists of three pumps. The total electrical usage per day was found to be 183 kilowatt hours. The average demand per pound of finished product was 2.67 watt-hours. Water use by the shower after smoke was found to total 67,200 gallons in a typical day. The water use per pound of finished frankfurter product was determined to be 0.98 gallons per pound.

The refrigeration demand of the brine shower was determined by the recycle flow rate and the temperature difference across the chiller. For a typical day, the refrigeration requirement was calculated to be 13,300,000 BTUs absorbed. The average refrigeration use per pound of finished product was 194 BTUs.

Peeler Room Refrigeration Operation. The frankfurters next move into a refrigerated peeling room where the casings are removed. The electrical demand by the air handling units in the peeler room was determined to be 21.8 kilowatt hours per typical day. The refrigeration demand for these units was found to be 853,000 BTUs per day. In terms of production, the electrical and refrigeration requirements were 0.32 watt-hours and 12.4 BTUs, respectively.

Peeler Room Equipment Operation. Three motor driven conveyors (total 3 horsepower) remove links from the frank chain and move them onto tables feeding three peelers. The peeled franks are conveyed to a chute and drop through to the first floor at the packaging room. The electrical demand by the peeler room is due to 3 peelers, each with 2 motors and 3 conveyors. Total electrical demand for a typical day was approximately 221.0 kilowatt hours. In terms of the production of finished franks, the usage was 3.23 watt-hours per pound.

Water sprays for the peeler room use an estimated 8640 gallons per day or 0.126 gallons per pound. The steam requirement for the peelers was estimated to be 117,000 BTUs per day. In terms of production, the average use was 1.70 BTUs per pound of finished product.

Packaging Room Refrigeration Operation. The electrical demand by the air handling units associated with the frank packaging area was determined to be 94.5 kilowatt hours for a typical day. The refrigeration requirement for the

frank area of general pack was found to be 8,250,000 BTUs absorbed per typical day. In terms of production, the electrical and refrigeration requirements were found to be 1.38 watt-hours per pound and 120 BTUs per pound, respectively.

Frank Packaging Equipment Operation. A layout of the packaging room equipment layout can be seen in Figure 86. The process lines in the upper part of the figure are used for franks. The equipment in the lower part of the figure is used for ham packaging. The refrigerated packaging room contains two frank packing lines each with a separate frankfurter packer or War-rick loader. The two packaging machines together have nine motors (total 2.83 horsepower) and require two vacuum pumps (20 horsepower and 15 horsepower). In addition, the packagers have a total of 9045 watts of heaters for sealing the packages. Following packaging, the franks are boxed, palletized and moved to storage.

The electrical demand for the frank packaging line is due to two packaging machines and related equipment plus two vacuum pumps. Total electrical demand for a typical day was 598 kilowatt hours. In terms of production, the electrical requirement was approximately 8.72 watt-hours per pound. Water is used for cooling in the packaging machines. The total flow for a typical day was 7360 gallons or 0.107 gallons per pound of finished product.

Sanitation and General Utilities. The water used for sanitation of all the equipment and areas associated with frank process totaled 17,100 gallons for a typical day. In terms of production, the sanitation water requirement was 0.250 gallons per pound processed. Since the water is partially heated by the plant's waste heat recovery system only a small amount of additional steam

FIGURE 86
GENERAL PACKING AREA

is required. The estimated daily total usage was 4,270,000 BTUs or 62 BTUs per pound.

The electrical requirement by the lighting and ventilation of areas associated with frank processing was estimated to be 505 kilowatt hours per day. In terms of production of finished product, the average usage was 7.36 watt-hours per pound.

A summary of the utility requirements for each unit operation of the frank process is shown in Tables 21 and 22. The data is displayed using two bases, per pound of finished product and per day.

Table 21

Plant B - Frankfurter Process - Energy Usage per Pound

Unit Operation	Steam BTU	Gas BTU	Electricity WH	Water GAL	Refrigeration BTU
Green Meat					
Cooler			0.31		31.1
Sausage Kitchen					
Refrigeration			1.19		81.3
Sausage Kitchen					
Equipment			26.20	0.17	
Smokehouse	628.0	577.0	4.29	0.008	
Shower and Brine					
Chill			2.67	0.98	194.0
Peeler Room					
Refrigeration			0.32		12.4
Peeler Room					
Equipment	1.70		3.23	0.126	
Packaging Room					
Refrigeration			1.38		120.0
Packaging Room					
Equipment			8.72	0.107	
Sanitation and					
General Utilities	62.0		7.36	0.250	

Table 22

Plant B - Frankfurter Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Gas BTU	Electricity KWH	Water GAL	Refrigeration BTU
Green Meats					
Cooler			21.6		2,140,000
Sausage Kitchen					
Refrigeration			51.5		5,580,000
Sausage Kitchen					
Equipment			1800.0	11,800	
Smokehouse	43,100,000	39,600,000	654.0	571	
Shower and Brine					
Chill			183.0	67,200	13,300,000
Peeler Room					
Refrigeration			21.8		853,000
Peeler Room					
Equipment	117,000		221.0	8,640	
Packaging Room					
Refrigeration			94.5		8,250,000
Packaging Room					
Equipment			598.0	7,360	
Sanitation and					
General Utilities	4,270,000		505.0	17,100	

Lard Rendering Operation

A simplified flow diagram of the lard rendering process at Plant B is displayed in Figure 87. The operations schedule of equipment used in the lard rendering process is shown in Figure 88. Typical daily production of lard by this process was 62,548 pounds. The basis used for the presentation of energy usage was the number of hogs slaughtered, typically 4,823 head per day. Layouts of the process equipment on the lower and upper levels of the rendering room are shown in Figure 89 and Figure 90.

Collection and Transport Operation. Edible trim is collected on the kill and cut floors, ground and pumped to edible rendering. Electrical consumption by this operation is due to 2 grinders and 3 pumps on the kill and cut floors. The average usage per head slaughtered was found to be 82.0 watt-hours during the monitoring period. For a typical day, the total electrical demand was 390 kilowatt hours.

Steam is injected into the material going to rendering in order to facilitate movement. The average amount of steam used per head was estimated to be 341 BTUs. For a typical day, the total consumption was calculated to be 1,620,000 BTUs.

Surge Tank and Feed Operation. Edible material arriving in the rendering area is initially heated in one of two jacketed balance tanks. Material is then removed from the tanks, injected with steam and pumped to a chopper. The electrical requirement for this operation is due to 2 agitators motors and 2 pumps. The average demand for electricity by this operation is 19.1 watt-hours per head killed. For a typical day, the total amount of electricity required by this operation was determined to be 90.8 kilowatt hours.

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FIGURE 87
Plant B - Lard Process - Flow Diagram

FIGURE 37, continued

FIGURE 88. PLANT B - Lard Rendering Process - Operations Schedule

FIGURE 89

Plant B - Lard Process - Main Level Area Equipment Layout

FIGURE 90

Plant B - Lard Process - Upper Level Area Equipment Layout

The steam used by the surge tanks and injectors was found to average 2050 BTUs per head slaughtered based on metered data taken during the monitoring period. In a typical day, the amount of steam required by this operation was found to be 9,750,000 BTUs.

Grinding and Initial Separation Operation. Heated material is next ground, heated and separated. Solid material is transported from the separation to inedible rendering. The electrical consumption for this operation is due to 2 motor driven choppers, 2 separators each with 2 motors, a conveyor and a pump. The average electrical usage by this operation was found to be 87.4 watt-hours per head killed. For a typical day, the usage was 416 kilowatt hours.

Steam is used in heating material prior to separation. The average steam usage per head was estimated to be 577 BTUs based on the temperature rise of the material. For a typical day, the steam requirement was determined to be 2,740,000 BTUs.

Secondary Separation Operation. Liquid material, lard, from the initial separation is again steam injected and separated. The electrical demand by this operation is due to 3 pumps, 2 separators and a conveyor. The average consumption in terms of head slaughtered was 101 watt-hours per head. For a typical day, the usage was 480 kilowatt hours. The steam required to heat the material was estimated to average 696 BTUs per head. In a typical day, the total steam required was determined to be 3,310,000 BTUs.

Wash, Final Separation and Storage Operation. Lard is pumped to a steam injected wash tank where water is added and then the material is separated again. The electrical demand is due to 4 pumps and a separator. The average

demand per head was found to be 63.6 watt-hours with a typical daily consumption of 302 kilowatt hours. The amount of water use was variable depending on product quality arriving at this operation. The average usage during the monitoring period was 0.56 gallons per head. A typical consumption for a day was 2650 gallons.

The steam required to heat the material in the wash tank was estimated to average 514 BTUs per head. A slight amount of additional steam is used in the lard storage tanks to maintain a liquid state. The requirement here was estimated to be 136 BTUs per head slaughtered. Together, the steam use averaged 650 BTUs per head. In a typical day, the total amounts of steam used was determined to be 3,090,000 BTUs.

Sanitation and General Utilities. Water use for cleanup averaged 5.55 gallons per head slaughtered. In a typical day, the total consumption of water was 26,700 gallons. The steam required to heat sanitation water above the heat recovery temperature was estimated to be 6,670,000 BTUs per day or 1380 BTUs per head slaughtered.

The electrical consumption for lighting and ventilation averaged 23.7 watt-hours per head. For a typical production day, the total demand was 113 kilowatt hours.

A summary of the utility requirements for each unit operation in the lard rendering process is shown in Tables 23 and 24. The data is displayed using two bases, per head and per day.

Table 23

Plant B - Lard Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Electricity WH	Water GAL
Collection and Transport	341	82	
Surge Tank and Feed	2050	19.0	
Grinding and Initial Sep.	577	87.4	
Secondary Sep.	696	101	
Wash and Final Separation	650	63.6	0.56
Sanitation and General Utilities	1380	23.7	5.55

Table 24

Plant B - Lard Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Electricity KWH	Water GAL
Collection and Transport	1,620,000	390	
Surge Tank and Feed	9,750,000	91	
Grinding and Initial Sep.	2,740,000	416	
Secondary Sep.	3,310,000	480	
Wash and Final Separation	3,090,000	302	2650
Sanitation and General Utilities	6,670,000	113	26,700

Inedible Rendering Process

A flow diagram of the inedible rendering process is presented in Figure 91. The operations schedule of equipment used in the inedible rendering process is shown in Figure 92. The basis used for the presentation of energy usage by this process is head slaughtered. During the period of study, the typical daily kill was 4,823 head. The average daily production of inedible grease by Plant B was 31,509 pounds. The production of meat and bone meal amounted to 44,747 pounds per day on the average. The layout of the equipment for the inedible rendering process can be seen in Figure 93.

Transport and Grinding Operation. Inedible scraps from the kill floor collection area are transported by conveyors to a grinder in inedible rendering. The sole utility required is electricity for the 8 motors involved. There are 6 augers or conveyors, a drain pump and the grinder. The electrical demand for a typical day was 173 kilowatt hours. The average requirement per head slaughtered during the monitoring period was found to be 36.3 watt-hours.

Cooker Operation. The method used is a continuous dry renderer with exhaust scrubber. The electrical demand by this operation consists of the cooker drive, grease agitator, control wheel, solid material auger, 2 pumps for the cooling tower-scrubber. Electrical demand for a typical day was 1220 kilowatt hours. The average consumption on a per head basis was 256 watt-hours.

The cooker uses steam at a relatively constant rate during the production day. The total steam used is dependent upon the total operational time which includes preheating, actual production and run on period after production ceases. During the monitoring period, the cooker steam requirement averaged

CONTINUED ON NEXT PAGE

FIGURE 91

Plant B - Inedible Process - Flow Diagram

FIGURE 91, continued

FIGURE 92. PLANT B - Inedible Rendering Process - Operations Schedule

FIGURE 93

Plant B - Inedible Process - Processing Area Equipment Layout

39,600 BTUs per head slaughtered with a range of 34,200 to 43,300 BTUs per head. Steam usage for a typical day was found to be 188,000,000 BTUs.

Steam is used by the cooker at an average of 13,000,000 BTUs per hour. A sample day is shown in Figure 94. Of this total, 9,630,000 BTUs per hour are used to heat and melt fat and to evaporate water. Another 3,340,000 BTUs per hour are returned as condensate. The convective and radiant losses are estimated to be approximately 52,200 BTUs per hour.

Expelling and Milling Operation. The solid material which is removed from the cooker is pressed, milled and moved to storage. The electrical consumption by this operation includes a press, input and output augers for the press, a return grease pump, an elevator, a hammermill, input and output conveyors for the mill. The total electrical demand for a typical day was found to be 997 kilowatt hours. In terms of hogs killed, the average usage by this operation was 210 watt-hours.

Grease Clarification Operation. The liquid fat from the rendering cooker is centrifuged and pumped to a settling tank. Electricity is used by a centrifuge, a centrifuge feed pump, 2 transfer pumps and 2 agitators. Total demand for a typical day was 166 kilowatt hours. During the monitoring period, the average electrical requirement per head was 34.9 watt-hours.

Sanitation and General Utilities. Water use for cleanup was not linearly correlated to production. For a typical day the consumption of water for sanitation associated with grease and meat and bone meal was found to be 9020 gallons. The average water use per head slaughtered was 1.90 gallons as found by averaging the data from numerous production days. The steam required to heat this water above the waste heat recovery temperature was estimated to be

2,250,000 BTUs per day of 467 BTUs per head slaughtered.

The electrical demand for lighting and ventilation associated with the inedible grease and meat and bone meal process was 164 kilowatt hours per day. This figure includes the area surrounding the cooker and the sunken collection area below the kill floor. An electrical use per head killed figure based on several data points was found to be 34.4 watt-hours.

A summary of the utility requirements for each unit operation in this rendering process is shown in Tables 25 and 26. The data is presented using 2 bases, per head killed and per day.

Table 25

Plant B - Inedible Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Electricity WH	Water GAL
Transport and Grinding		36.3	
Cooker	39,600	256.0	
Solids Press and Grind		210.0	
Grease Clarify		34.9	
Sanitation and General Utilities	467	34.4	1.90

Table 26

Plant B - Inedible Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Electricity KWH	Water GAL
Transport and Grinding		173	
Cooker	188,000,000	1220	
Solids Press and Grind		997	
Grease Clarify		166	
Sanitation and General Utilities	2,250,000	164	9020

Blood Drying Process

A simplified flow diagram of the blood drying process is presented in Figure 95. The operations schedule of equipment used in the blood drying process is shown in Figure 96. The basis for analyzing energy data in this process is the number of head slaughtered. A typical daily slaughter was 4,823 hogs. The average daily production of blood during the data monitoring period was 6,067 pounds. The layout of the blood drying equipment can be seen in Figure 97.

Collection and Transport Operation. Blood from the sticking area flows to a basement holding tank and then is pumped to the inedible rendering area. The electrical consumption for this operation is due to a holding tank agitator, a transfer pump, a silo agitator and a work tank agitator. For a typical day, the total electrical usage was 57.9 kilowatt hours. In terms of production, the requirement was found to average 12.2 watt-hours per head slaughtered.

Coagulation Operation. Blood from the work tank is pumped through a steam heated coagulator. Electrical usage for this operation is due to a transfer pump and the coagulator drive. A typical daily requirement was 22.8 kilowatt hours. The average use per head was found to be 4.80 watt-hours.

Steam consumption during production was fairly uniform but the total daily consumptions varied. This was due to incomplete shutdown with steam often flowing at reduced rates for nearly 24 hours. The average steam demand found during the monitoring period was 4640 BTUs per head killed with a range of 3950 to 5320 BTUs per head. On a typical day, when the steam was shut off promptly, the total daily consumption was 18,800,000 BTUs but with incomplete

FIGURE 95

Plant B - Blood Process - Flow Diagram

FIGURE 96. PLANT B - Blood Drying Process and Hair Hydrolysis and Drying Process - Operations Schedule

FIGURE 97. PLANT B - Blood Process - Processing Area Equipment Layout

shutdown the usage for one day was as high as 25,300,000 BTUs.

During production, the typical hourly flow of steam was 1,380,000 BTUs. The amount of energy required to heat the blood to the outlet temperature of 300°F was only 672,000 BTUs per hour. The condensate returned takes 316,000 BTUs per hour and convective and radiant losses from the tube were estimated to be 17,600 BTUs per hour. The remainder of the input energy is most likely lost as evaporating water although theoretically, only coagulation occurs in the tube with no water loss.

Pressing and Grinding Operation. Coagulated blood is separated from serum by mechanical means. The clots are then washed and ground in preparation for the ring drier. The electrical consumption by this operation is due to an auger, a press drive and a grinder. The average usage is 22.9 watt-hours per head. For a typical production day, the electrical demand was 109 kilowatt hours. Water usage for washing the clotted blood averaged 0.37 gallons per head. A typical day's total was 1750 gallons.

Ring Drier Operation. Blood entering the drier is mixed with air which has been heated in an external furnace. The electrical demands in this operation are due to a furnace blower, an air lock motor and an exhaust blower. The average electrical usage was determined to be 33.9 watt-hours per head slaughtered. For a typical day, the electrical use was 161 kilowatt hours.

The natural gas fired furnace uses an average of 5230 BTUs per head slaughtered with a range of 4670 to 5664 BTUs per head. For a typical day, the total gas requirement was 25,700,000 BTUs. A typical hourly flow of gas was 2,140,000 BTUs. A sample day is given in Figure 98. Of this total, 655,000 BTUs per hour were used to evaporate water. Combined convective and

radiant loss from the drier and cyclone was estimated to be 1,000,000 BTUs per hour. The remainder of the input energy was used to heat the incoming blood and air.

Transfer to Storage Operation. After drying, the blood is pneumatically pumped to storage. The electrical demand for this operation is due to a blower. The average electrical usage was 4.08 watt-hours per head slaughtered. In a typical day, the blower consumes 19.4 kilowatt hours of electricity.

Sanitation and General Utilities. Water use for cleanup of the area associated with blood drying is typically 4510 gallons per day. The average water usage in terms of hogs slaughtered is 0.95 gallons although this amount is not strictly correlated with production. The steam required to heat the water above the waste heat recovery temperature was estimated to be 1,130,000 BTUs per day or about 234 BTUs per head slaughtered.

The electrical demand by lighting and ventilation in the blood drying area was estimated to be 40.5 kilowatt hours per day. A rough average usage per hog killed was found to be 8.52 watt-hours.

A summary of the utility requirements for each unit operation in the blood drying process is shown in Tables 27 and 28. The data is presented using two bases, per head slaughtered and per day.

Table 27

Plant B - Blood Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Gas BTU	Electricity WH	Water GAL
Collection and Transport			12.2	
Coagulation	4640		4.8	
Press and Grind			22.9	0.37
Dry		5230	33.9	
Transfer to Storage			4.1	
Sanitation and General Utilities	234		8.5	0.95

Table 28

Plant B - Blood Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Gas BTU	Electricity KWH	Water GAL
Collection and Transport			57.9	
Coagulation	18,800,000		22.8	
Press and Grind			109.0	1750
Dry		25,700,000	161.0	
Transfer to Storage			19.4	
Sanitation and General Utilities	1,130,000		40.5	4510

Hair Hydrolysis and Drying Process

A simplified flow diagram of the hair hydrolyzing and drying process is displayed in Figure 99. The operations schedule of equipment used in the hair hydrolysis and drying process is shown in Figure 100. Energy usage by this process is reported on a per head slaughtered basis. A typical daily kill was 4,823 head with the production of 4,219 pounds of hair. The layout of process equipment can be seen in Figure 101 along with two other processes, inedible rendering and blood drying.

Collection and Transport Operation. Hair which has been removed from the dehairers on the kill floor is pumped to inedible rendering. The electrical consumption by this unit operation is due to a blower pump, a hair hopper drive and a feed auger. The average electrical use in terms of hogs slaughtered is 51.3 watt-hours. For a typical day, the total electrical requirement was 244 kilowatt hours.

Hydrolyzing and Drying Operation. Hydrolysis and drying takes place in the same unit which is both steam injected and steam jacketed. The electrical demand is due to the motor driven agitator in each of the three driers and a scrubber pump. The average electrical consumption was found to be 291 watt-hours per head slaughtered. A typical day required 1380 kilowatt hours of electricity.

Steam consumption was monitored for this operation by a meter installed in the main header supplying all three driers. All steam use by jackets, injection or leaks was therefore included. The average steam usage per hog slaughtered for the monitoring period was 6160 BTUs. The total steam consumption for a typical day was 29,300,000 BTUs. Of this total, it was estimated

FIGURE 99

Plant B - Hair Process - Flow Diagram

FIGURE 100. PLANT B - Blood Drying Process and Hair Hydrolysis and Drying Process - Operations Schedule

FIGURE 101

Plant B - Hair Process - Processing Area Equipment Layout

435,000 BTUs was due to convective and radiant losses from the driers. Condensate returned from the jackets accounted for an additional 3,160,000 BTUs. The energy requirement necessary to evaporate the water present in the hydrolyzed hair was calculated to be 22,200,000 BTUs. The remainder of the total input is assumed to have been lost as pipe leaks and venting.

Transfer to Storage Operation. Dried hydrolyzed hair is removed from the driers and conveyed to storage. The electrical demand in this operation is due to 2 transfer augers, an airlock motor and a pneumatic blower. The average electrical consumption was determined to be 6.04 watt-hours per head killed. For a typical day, the usage was 28.7 kilowatt hours.

Sanitation and General Utilities. Water usage for sanitation was found to average 0.84 gallons per head slaughtered. Consumption for a typical day was 4000 gallons. The steam required to raise the temperature of this water above the waste heat recovery temperature was estimated to be 1,000,000 BTUs per day or 207 BTUs per head slaughtered.

The electrical requirements for lighting and ventilation associated with the hydrolyzing and drying process was found to average 9.85 watt-hours per head. In a typical day, 46.8 kilowatt hours of electricity was used.

A summary of the utility requirements for each unit operation of this process is shown in Table 29 and 30. The data is displayed using two bases, per head slaughtered and per day.

Table 29

Plant B - Hair Process - Energy Usage per Head Slaughtered

Unit Operation	Steam BTU	Electricity WH	Water GAL
Collection and Transport		51.3	
Hydrolyze and Dry	6160	291.0	
Transfer to Storage		6.0	
Sanitation and General Utilities	207	9.8	0.84

Table 30

Plant B - Hair Process - Daily Total Energy Usage

Unit Operation	Steam BTU	Electricity KWH	Water GAL
Collection and Transport		244.0	
Hydrolyze and Dry	29,300,000	1380.0	
Transfer to Storage		28.7	
Sanitation and General Utilities	1,000,000	46.8	4000

CHAPTER 4 - SUMMARY AND CONCLUSIONS

Summaries of energy use by the processes investigated at the respective plants are presented in Tables 31 and 32. Through measurement of operating parameters and the calculation of material and energy balances, patterns of energy loss in the major unit operations were determined. By using a current value for energy of 5 dollars per million BTUs, the economic incentives for reducing energy waste can be determined. The major energy using unit operations in the two plants were: the scald tanks; the dehairing machines; the singeing operation; the smokehouses (sausage and smoked meats); the lard rendering operations; the inedible cookers; the blood drying operations; and the hair drying operations.

The total steam and gas energy consumed by the processes studied in Plant A amounted to 133.6 billion Btu's and 207.8 billion Btu's in Plant B. Of that total, Plant A uses approximately 15.5% and Plant B uses 7.5% for sanitation and cleaning. The remaining energy is used to operate the various unit operations.

As shown in Tables 33 and 34, the energy used in the major unit operations can be broken down into lost energy and recoverable energy. Lost energy is that energy that will not effect production if eliminated. Examples include heat loss from metal or water surfaces, operation of the unit during non-production periods, overventing, loss of uncondensed steam and leaks. For the processes studied in Plant A, non-productive energy amounts to 48% of the energy supplied. The non-productive energy in Plant B amounted to 60.6% of

Table 31
Plant A - Process Energy Use Summary

	Basis	Steam BTU	Gas BTU	Electricity WH	Water Gal	Refrigeration BTU (absorbed)
A. Slaughtering and By-Products Head Killed						
1. Dehairing (no evisceration)		40,200	13,300	324	34.90	
2. Lard Rendering (batch cooker)		19,000		138	2.84	
3. Blood Drying (batch cooker)		12,100		144	0.620	
4. Hair Hydrolyzing (semi-continuous)		4,740		82.6	0.622	
5. Inedible Rendering (batch cooker)		42,100		387	5.45	
B. Meat Processing # Finished Prod.						
1. Franks (batch smoke)		693	190	67.2	0.892	500
2. Bacon (batch smoke)		237	293	50.5	0.186	427

Table 32
Plant B - Process Energy Use Summary

Process	Basis	Steam BTU	Gas BTU	Electricity WH	Water Gal	Refrigeration BTU (absorbed)
A. Slaughtering and By-Products Head Killed						
1. Dehairing and Evisceration		65,600	10,800	534	144	17,000
2. Lard Rendering (continuous)		5,690		377	6.11	
3. Blood Drying (continuous)		4,870	5,230	86.4	1.32	
4. Hair Hydrolyzing (batch cooker)		6,370		358	0.84	
5. Inedible Rendering (continuous)		40,100		572	1.90	
B. Meat Processing # Finished Prod.						
1. Franks (continuous smoke)		692	577	55.7	1.64	439
2. Ham (batch smoke)		387	1040	68.9	0.45	1717

Table 33

Plant A - Process Energy Losses and Recovery Potential

Unit Operation	Yearly Energy Use Billion Btu's (Steam & Gas)	% Lost	% Potentially Recoverable
Scald Tank	6.6	70	24
Dehairer	15.3	86	10
Singer	10.0	20	80
Frank Smokehouse	3.7	54	46
Bacon Smokehouse	7.4	77	23
Lard Cooker	13.0	54	—
Inedible Rendering	29.2	24	63
Blood Drying	8.8	46	54
Hair Hydrolysis	1.6	83	—
and Drying	1.8	46	54

Table 34

Plant B - Process Energy Losses and Recovery Potential

Unit Operation	Yearly Energy Use Billion Btu's (Steam & Gas)	% Lost	% Potentially Recoverable
Scald Tank	14.2	85	10
Dehairer	30.6	90	10
Singer	13.0	20	80
Frank Smokehouse	21.5	80	20
Ham Smokehouse	18.8	90	10
Lard Rendering	5.2	58	—
Inedible Cooker	47.7	24	72
Blood Drying	6.3	46	54
Hair Hydrolysis			
and Drying	7.4	20	67

the total process energy.

On the other hand, recoverable energy is that energy that was used for some productive purpose but still has value upon completion of the process. Examples include hot water from scald tank and dehairer, hot gas off singer, and evaporated water from smokehouses and rendering cookers. For the processes studied in Plant A recoverable energy amounts to 40% of the energy supplied. The potentially recoverable energy for Plant B is 35.8% of the process energy supplied.

Scalding Operation

The scald tank at Plant A is initially filled with cold well water. Over a third of the total daily steam flow is used during the 2 hours required to bring the water to operating temperature. Only one half of the energy in the steam injected appears as a temperature rise in the water. The rest is lost during the heating period. After the water in the tank is at the proper temperature, the scald tank loses 8 percent of the total daily input simply by operating outside the production period. Typically, the water in the tank is brought up to operation temperature 1.3 hours before production begins. On the average, the tank also remains operating 1.5 hours after production ceases. Through better scheduling it is estimated that the plant could save 0.7 billion BTUs annually or 3,400 dollars. During production, 5 percent of the daily energy input to the scald tank is lost as convection and radiation from the metal tank surfaces. Another 19 percent is removed by combined radiant, convective and evaporative losses from the water surfaces. The total value that these losses represents annually is 9,900 dollars which provides an incentive for insulating and covering the scald tank. Surprisingly, the

largest energy loss for the scald tank was the release of uncondensed steam from the water in the tank. Confirmation of this phenomenon has been received from Pick (1980). It was found that a steam injected vat of water at 130°F lost almost half of the steam input as vapor escaping from the water surface. The annual loss for the live steam loss at Plant A was estimated to be 38 percent or 15,000 dollars at current values for energy. Clearly a better method of water heating is mandated. In order to reduce the steam loss, a steam injection water heater could be used in the recirculation lines of the scald tank. This would provide to the water the total energy available from the condensing steam plus some sensible heat. Another method which would provide an efficient mode of water heating is the use of a heat exchanger. The benefit here, in addition to elimination of steam loss, is the return of hot condensate to the boiler. Less cold boiler makeup water would be required if this method were adopted.

The scald tank at Plant B is usually filled with preheated water prior to production. There is no period of startup in the scald tank. All production water at this plant is heated using a waste heat recovery system and efficient steam water heaters. The waste heat is recovered from natural gas driven refrigeration compressor engines. City and well water is tempered to approximately 110°F. When water is needed at a higher temperature, the steam heaters are used. Thus, while technically there is no startup in the scald tank, there is some steam preheating of water prior to the operation day.

During the day, the scald tank at the Plant B plant loses 4 percent of the total input energy as heat dissipating from the metal surfaces of the tank through convection and radiation. This represents an annual loss of 3,800 dollars. Another 21 percent of the input is lost as combined radiant,

convective and evaporative losses from the water surface. This represents 19,000 dollars annually. The major energy loss from the scald tank (as in Plant A) is as steam which has not condensed. It was estimated that 38 to 60 percent of the total daily energy input was lost as steam which did not condense. The reason for the range of values was because of the steam monitoring method used. There are four steam inputs to the tank at Plant B but only two were metered. The lower figure results when it is assumed no steam flowed through the middle two lines. The higher figure results when flow through the two non-metered lines is assumed to be equivalent to one of the metered lines. The flow through the metered line nearer the dehairers (lower flow) was used as the basis rather than the line nearer the bleed area (higher flow).

From the above discussion, it can be seen that both scald tanks behave in a similar manner. The steam use for the tanks at the two plants could easily be reduced by using a better heating method and through covering and insulating the tank.

Dehairing Machine Operation

The dehairing machines at Plant A are initially filled with cold water and require a startup demand of steam. Approximately 10 percent of the daily total steam is used during the 2 hour startup period. Only about 4 percent of the input appears as a temperature rise in the water. The operation of the dehairing machines at the plant was very energy wasteful. Loss which occurred by operation outside production periods accounted for 29 percent or 28,000 dollars annually. The dehairers were observed operating during cleanup for up to 7 hours after the end of production. During production, losses from the metal surfaces and water surfaces in the base tanks accounted for 6 percent or

5,400 dollars annually. An additional 10 percent of the input energy representing, 10,000 dollars annually, is lost through the mandated water overflow. Since a fresh water rinse is required some energy to the dehairers could be saved by using discharged water to preheat incoming water.

The largest energy loss in the dehairing operation is live steam and water vapor loss. Over 80 percent of the total input energy to the dehairers at Plant A is lost to the air passing through the machines. The design and operation of present dehairers is such that a large amount of air passes through the machines during operation. Internal conditions of the equipment is one of very high humidity since the air is saturated by the action of the overhead water sprays. The air movement displaces escaping live steam and encourages evaporation of water from the spray droplets. The net result is the removal of a large amount of energy which is vented to the atmosphere.

It may be possible to reduce air flow through the dehairers by enclosing the base tanks in the machines and adding shield curtains (or airlocks) to the inlet and outlet openings. By reducing the size of the openings the amount of venting could be reduced while still maintaining satisfactory working conditions for workers in the area. If the air flow through the dehairers was completely eliminated, the annual savings would be 82,000 dollars at present energy costs.

The dehairing machines at the Plant B facility lose 5 percent of the input energy as heat loss from metal surfaces and combined losses from the water surfaces of the base tanks. This represents 8,100 dollars. As in the case of Plant A, the largest loss from the dehairers is the loss to air passing through the dehairers. In this plant 95 percent of the input energy was

lost representing 145,000 dollars annually. The dehairers at this plant are much larger than those in Plant A and have a water overflow rate about three times greater. In addition, water temperature during the operating day averages 10°F warmer.

Singeing Operation

The singeing operation is the most obvious loss of energy at a hog processing plant. Typically, greater than 99 percent of the input energy passes through the stacks to the atmosphere. At Plant A this represents an annual loss of 60,000 dollars. Of the total loss a certain amount is nonrecoverable due to the requirement of maintaining sufficient flue gas temperature. However, it was estimated that energy worth 44,000 dollars could be recovered.

The singer at Plant B consumes (passes up the stack) energy worth 78,000 dollars annually. Of this, a major portion could be saved without reducing stack gas temperature below critical value. The approximate savings per year which could be realized is 56,000 dollars.

For existing plants, singeing heat recovery seems to be an attractive process modification which should be considered. The energy recovered could be used to heat process and sanitation water. A better use may be to reduce (or eliminate) the steam demand by the scald tank and dehairers. If the scald tank at a plant was covered and insulated and the air flow through the dehairers was stopped, then all heat energy to these two operations could be supplied by the singer. The use of a singer heat exchanger would at the same time solve the problem of live steam loss from these operations, since little or no steam injection would be required.

Clearly much can be done within existing systems to reduce energy consumption. However, as discussed in Appendix C, by eliminating the dehairing process and adopting a hot skinning procedure at Plant A, the scald tank, dehairer and singer are eliminated, representing an annual savings in energy of 198,000 dollars. Eliminating the dehairing system at Plant B in favor of hot skinning would represent a potential savings of 326,000 dollars annually over present operations in terms of energy cost. Unfortunately, the retrofit of a skinning process to a former dehairing type plant may be economically prohibitive. It is the opinion of meat industry representatives, however, that all new hog slaughtering plants built in the future will probably have the skinning process.

Smokehouse Operations

The frank smokehouses at the Plant A plant use 54 percent of the input energy as non product-related loss. This energy represents heat loss from the metal surfaces of the house and for the most part, heat loss due to conditioning air which is exhausted. Economically, those losses represent 16,000 dollars annually.

The bacon smokehouses use 73 percent of the energy input as non product-related loss, mostly in heating and humidifying the air (66 percent). This energy loss represents an annual value of 30,000 dollars.

The frank smokehouse at the Plant B facility is a continuous processing unit. During the energy audit, the house was operating at excess exhaust conditions. Through greater control of this parameter a savings of 16,000 dollars per year could be realized. While operating during production, the smokehouse

loses 80 percent of the input energy as non product-related losses. This represents 87,000 dollars per year at current prices. The principle non product related loss is the energy used to heat and humidify air which is subsequently exhausted.

The ham smokehouses at the plant are batch type houses. The energy lost as non product related losses represents 90 percent of the input energy. This represents 96,000 dollars annually.

The smokehouses at both plants suffer from problems of excess venting of exhaust air. Better controls of exhaust venting in the houses would provide substantial savings in energy use. Serious problems of smokehouse control occur due to changing conditions of inlet air. Wang (1976) suggested adding an extra set of humidifying-exhausting controls to the smoking system. By monitoring inlet air conditions as well as in-house air conditions, reduction of excess exhaust is possible. The extra set of controls prevents fluctuating inlet air conditions from "confusing" the in-house controls which causes greater steam and gas use.

All houses use a fresh air inlet to supply combustion air to a natural gas fired burner. This air must subsequently be vented. There is apparently no valid reason for the high air flow to the smokehouse burners in the plants. A typical specification for air delivery to a smokehouse burner was 175 percent excess air. Excess air is usually specified for safety sake to prevent accumulation of unburned explosive gas. The air recirculating in the smokehouse, however, at all times contains more than sufficient oxygen to support combustion. For this reason, it is believed that a more logical location for a burner would be inside the house using the available oxygen in the air which

is already present.

A great deal of energy is expended in the smokehouses as steam injected to control humidity. In some cases, more than 50 percent of the total input energy to a house was in the form of steam. All steam must subsequently be vented. An alternate method of introducing water to humidify air is possible. By using a water injection before the gas flame it would be possible to eliminate the steam requirement. More gas would be required for evaporation of the water but the conversion efficiency of the boiler and all steam line heat losses would be eliminated. Theoretically, the gas would be used more efficiently.

The continuous smokehouse at Plant B suffered from improper mixing of hot air and steam. It was observed that both sections of the house were exhausting air at dry bulb and wet bulb conditions above those present in the house. This clearly indicates improper mixing conditions. Another phenomenon occurring with this smokehouse was the exhausting of hot humid air from section one while at the same time heating and humidifying cold room air for section two. The first section is used to dry the product while the second section is used for cooking. A simple ducting modification would be quite suitable for recovering the energy presently being lost. Both sensible and latent heat could be recovered in this manner in contrast to most heat recovery techniques (for example, a heat wheel) where only sensible heat can be recovered. In addition, the exhaust from section two in this plant is of sufficiently high temperature that some energy could be recovered for heating a liquid smoke spray chamber which is now steam heated.

Alternative heating methods for the smokehouse were discussed in the

introduction. Efficient methods of heat transfer include microwave and infrared heating. However, the overall efficiency of such systems must include the conversion and line losses of electrical production. In like manner, electrically heated or indirect steam heated smokehouses can be used in place of the gas fired houses, but overall efficiency should be taken into account in any analysis.

Lard Rendering Operations

The lard rendering cookers at Plant A lose 8 percent of the input energy as heat loss from non-insulated rendering vessels. This represents 8,000 dollars annually at current energy prices. The major energy loss in this operation is excess venting of steam. Steam flow rather than mechanical agitation is used to mix the vessel contents during cooking. The steam lost in this manner represents 46 percent of the input energy or 45,000 dollars annually.

The continuous edible rendering system at Plant B Foods loses 15 percent of the input energy as rejected condensate to the sewer. An additional 43 percent of the input energy is lost as non product loss, mostly radiant and convective losses from equipment. This loss represents 13,000 dollars in terms of energy.

The efficiency of the batch lard rendering vessels was very poor especially with the steam agitation method rather than mechanical. The low temperature continuous rendering system used in Plant B was much more efficient in contrast using about 20 percent of the energy expended by the batch system to produce a pound of lard. The continuous system could be improved further by recovering the heat from rejected condensate. At the present time, the

water removed from the separators is transferred to the waste water system. This material could be used to heat incoming edible trim. In addition, there is a potential benefit from insulation in this process.

Inedible Cooking Operation

The batch inedible cookers at Plant A are steam jacketed. The steam condensate is returned to the boiler. The heat loss in the water evaporated from inedible trim which is drained to the sewer represents 63 percent of the input energy. The potential for recovery represents 106,000 dollars annually.

The continuous inedible renderer at Plant B loses 72 percent of the total energy energy input as energy in the evaporated water. This represents an annual loss of 128,300 dollars which is presently going down the sewer.

Both the batch and continuous inedible cookers use approximately the same amount of energy per pound of finished product. No attempt has been made at either plant to recover the latent and sensible heat present in the evaporating water. It would be possible to use the waste heat for sanitation or production water. A better suggestion would be to use the waste heat to preheat incoming material. Both the multiple batch (overlapping cycles) and the continuous cooking systems operate in such a manner that heat could be more or less continuously recovered throughout the production day.

Ideally, the most efficient inedible rendering system would be a low temperature process similar to the edible process now being used at Plant B. Since there is really no need to heat the material to 260 to 280°F a continuous low temperature system would be more energy efficient.

Blood Drying Operations

At Plant A the blood driers are very similar to the inedible cookers in design and operation. The energy loss from the driers as evaporated water represents 54 percent of the input energy. This energy is drained to the sewer and represents a potential recovery opportunity of 32,000 dollars annually.

The blood drying process at Plant B is more efficient than the simple cooker arrangement at Plant A. A coagulator-press operation uses mechanical means to remove a good deal of the water from the blood. Unfortunately, at the present time, a cold fresh water rinse is used to drain serum from the clotted blood. Because of this, the blood enters the ring drier at a lower temperature than is ideally possible. In addition, the hot serum is sent to the wastewater treatment process, thus losing both energy and recoverable product. The valuable proteins in the serum could be recovered by ultrafiltration or reverse osmosis. These operations would remove a great deal of the serum water prior to a final drying step. Elimination of the cold water spray on the coagulated blood would permit higher input temperatures at the ring drier saving a slight amount of energy.

The blood ring drier loses 46 percent of the total input energy as radiant and convective losses from uninsulated ductwork. The ductwork was originally insulated but due to poor maintenance most of the insulation has been removed. The estimated annual loss is 15,000 dollars. An additional 30 percent of the input energy is lost as water vapor removed from the product. At present this energy is exhausted, representing a loss of 9,800 dollars per year. The exhaust air from the drier could be used to heat either incoming

air or blood flowing to the coagulator.

Hair Hydrolysis and Drying Operations

The continuous hydrolyzer in Plant A uses steam injection into the product for heating as the hair passes through this operation. Some of the injected steam is released with the output. It was estimated that 83 percent of the input energy is lost in this manner, representing 7,600 dollars annually. The hair is then transferred to a drier similar in construction to the inedible cookers. The amount of energy lost as vapor from this operation represents 5,400 dollars annually.

The batch hair hydrolyzer-driers at Plant B use steam injected into the cooker and also in a jacket. The energy present in the evaporated water which is presently scrubbed and removed to the sewer represents 67 percent of the input energy or 28,000 dollars. An additional 8,000 dollars worth of energy is lost during the steam injection due to venting.

The semi-continuous system at Plant A is only slightly better than the batch system at Plant B. Hair entering the systems at both plants is already high in moisture and then steam is injected for hydrolyzation. The water then must be removed. A more energy efficient system might include a continuous hydrolyzer (similar to the one at Plant A) followed by a mechanical expeller (similar to the grease and blood presses) and then a ring drier (similar to the continuous blood drier at Plant B).

Clearly there is a great potential for energy conservation in both plants. The economic incentive in some cases is very good, while in others, it is marginal. In any case, potential for conservation is there. Further work

is needed to evaluate the actual costs to implement the actual energy conservation measures.

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APPENDIX A1 - PLANT A

PRODUCTION DATA

PLANT A

TYPICAL YEAR HOG SLAUGHTER

Month	Number of Hogs Killed	Weight of Hogs Killed (Pounds)
January	52,544	11,867,069
February	54,334	12,313,667
March	78,278	17,829,693
April	63,703	14,672,623
May	49,799	11,515,105
June	60,965	14,125,401
July	48,079	10,720,498
August	51,487	11,606,064
September	72,681	16,454,963
October	71,429	16,397,484
November	66,750	15,447,612
December	85,226	19,327,690
TOTAL	755,315	172,277,850

Average Slaughter
Per Day (250 days/year) - 3021 Head

Average Liveweight
Per Head Slaughtered - 228.1 Pounds

PLANT A
TYPICAL YEAR BY-PRODUCTS PRODUCTION

Month	Lard (pounds)	Inedible Grease (pounds)	Dried Blood (pounds)	Meat and Bone Meal (pounds)
January	677,720	267,173	93,000	354,520
February	709,260	265,957	91,420	357,320
March	881,970	390,720	138,480	575,560
April	707,120	355,260	96,820	447,920
May	688,720	304,760	84,600	344,480
June	856,200	353,220	97,300	429,000
July	651,321*	264,430*	65,758*	361,862*
August	730,780	267,500	59,680	455,920
September	1,012,980	407,094	86,600	593,260
October	1,140,880	398,980	65,300	583,780
November	976,980	398,370	67,500	547,030
December	1,198,220	480,665	634,170	
TOTAL	10,232,151	4,154,129	1,033,058	5,684,822

Average Production Per Day (250 days/year)	40,929	16,616	4,132	22,739
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Average Production Per Head Killed	13.55	5.50	1.37	7.53
--	-------	------	------	------

*Data not available - estimate based on number of hogs killed.

PLANT A
TYPICAL YEAR
FRANKFURTERS AND BACON PRODUCTION

Month	Pounds of Franks	Pounds of Bacon*
January	751,322	1,516,880
February	1,041,400	1,708,461
March	796,330	1,267,850
April	1,037,678	1,310,546
May	1,513,376	1,591,662
June	1,120,738	1,425,917
July	914,338	1,356,091
August	1,053,678	1,890,520
September	1,071,272	1,394,308
October	964,742	1,397,837
November	970,900	1,305,410
December	583,362	1,038,751
TOTAL	11,819,136	17,204,233

Average Production Per Day (250 days/year)	47,276	68,817
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*Includes sliced, slab and Institutional prepared bacon.

APPENDIX A2 - PLANT A

UTILITY FLOW DATA

PLANT A.

TYPICAL YEAR UTILITY USAGE

Month	Water Million Gal.	Electricity Million KWh	Production Gas* Billion BTU's	Boiler Fuel* (#6 oil and gas) Billion BTU's
January	27.069	1.6113	4.6408	21.117
February	19.608	1.5168	3.9948	20.023
March	18.725	1.7531	3.9739	20.783
April	32.790	1.8144	2.7880	20.613
May	33.618	1.8272	2.3024	17.604
June	32.120	2.0321	2.6145	14.517
July	24.018	1.9343	1.9316	13.174
August	27.471	2.0893	2.1416	17.786
September	39.394	1.9415	2.2986	16.581
October	34.141	1.784	2.5675	16.795
November	17.106	1.8702	3.1185	20.161
December	22.224	1.7894	3.5700	21.418

*Conversion - cubic feet gas = 1000 BTU's
 - gallon #6 oil = 152,000 BTU's

PLANT A

BASELINE ENERGY REQUIREMENTS
AVERAGE WEEKEND USAGE 1979

Month	Water Gal./Day	Electricity KwH/Day	Production Gas Million BTU's/Day	Boiler Fuel Million BTU's/Day
January	741,300		57.0	384
February		48,000	35.1	453 (oil)
March	248,900	46,000	23.2	146
April	395,900	56,700	17.5	317
May	397,600	54,900	37.4	206
June	411,600	66,500	14.2	253
July	620,600	70,200		328
August	602,200	71,100	83.0	333
September	546,100	73,200	52.5	331
October	472,400	64,800	41.0	361
November	602,300	63,600	57.6	474
December	392,200	54,900	57.8	355

PLANT A

TYPICAL DAILY UTILITY USAGE (3-1 to 4-1-79)

Day	Water Million Gal.	Electricity KwH	Production Gas Million BTU's	Boiler Gas Million BTU's
Thursday	0.63072	72,000	64.60	714.3
Friday	0.77565	57,600	64.30	815.8
Saturday	0.32670	42.2	22.00	14.9
Sunday	0.09299	50,400	22.00	280.9
Monday	0.77870	43.2	60.5	899.1
Tuesday	0.85400	64,800	64.5	873.6
Wednesday	0.73677	72,000	69.8	886.7
Thursday	0.83764	72,000	67.1	869.0
Friday	0.86995	72,000	65.9	833.0
Saturday	0.17048	64,800	39.5	273.0
Sunday	0.15048	36,000	19.3	35.0
Monday	0.93452	57,600	56.4	872.4
Tuesday	0.79599	72,000	78.7	866.0
Wednesday	0.87497	72,000	63.4	821.0
Thursday	0.98518	72,000	79.6	865.0
Friday	1.02974	72,000	69.9	782.0
Saturday	0.16900	36,000	39.6	175.0
Sunday	0.17200	36,000	19.8	175.0
Monday	1.08487	72,000	53.1	853.5
Tuesday	1.09863	86,000	65.6	759.8
Wednesday	1.17564	64,800	68.6	851.8
Thursday	1.05568	79,200	59.3	853.8
Friday	1.17296	72,000	59.7	797.0
Saturday	0.60077	64,800	26.3	18.1
Sunday	0.20798	36,000	11.7	30.2
Monday	1.09723	57,600	52.5	693.0
Tuesday	0.98388	72,000	59.8	833.5
Wednesday	0.97891	72,000	60.3	791.0
Thursday	0.98886	72,000	56.9	800.6
Friday	1.142680	72,000	57.9	781.4
Saturday	1.73200	57,600	24.6	118.3
Sunday	0.33901	36,000	6.7	338.6

PLANT A
AVERAGE HOURLY UTILITY FLOWS
6-26-80

City Water		Well Water		Electricity	
Time*	Gal/Hr.	Time	Gal/Hr.	Time	Kw/Hr.
11:40	8,428	11:45	60,000	12 MIDNT	----
12 MIDNT	----	12 MIDNT	----	12:40	2673
12:30	9,688	12:30	56,326	2:15	3438
1:30	15,815	1:35	61,579	4:00	3352
2:45	8,384	2:50	56,512	5:35	3789
4:15	6,979	4:45	51,428	7:20	3420
7:00	9,020	7:05	55,683	9:15	3517
8:45	9,368	8:40	64,932	10:45	3644
9:45	10,243	9:45	65,000	12 Noon	5502
10:35	10,649	10:35	67,792	1:40	3824
11:45	9,962	11:45	67,869	2:30	2400
12 Noon	----	12 Noon	----	3:30	3396
1:05	10,238	1:10	68,648	4:25	4022
2:30	9,500	2:30	68,889	6:30	3676
3:30	6,970	3:30	49,355	9:45	3600
4:25	6,338	4:25	48,261	12 MIDNT	----
6:40	8,742	6:45	55,046	1:30	3301
9:30	10,370	9:30	59,504	----	----
12 MIDNT	----	12 MIDNT	----	----	----
1:15	10,939	1:10	57,522	----	----

*Time indicates midpoint between two successive readings.

PLANT A

AVERAGE HOURLY UTILITY FLOWS
6-26-80

Production Gas		Boiler Gas	
Time*	Million BTU/Hr.	Time	Million BTU/Hr.
12 MIDNT	----	12 MIDNT	----
12:15	2.266	12:05	22.687
2:05	1.487	2:05	20.666
3:35	1.460	4:00	21.744
4:20	1.767	5:35	18.944
5:25	1.286	6:30	34.595
7:00	2.423	7:50	28.211
8:30	3.075	9:20	32.100
10:00	0.828	10:30	37.278
11:30	5.390	12 Noon	38.148
12 Noon	----	1:30	39.513
1:00	1.931	2:40	42.922
2:30	9.122	3:30	38.865
3:30	7.119	4:20	33.500
4:20	2.440	6:30	26.753
6:20	2.453	9:35	22.018
9:40	1.889	12 MIDNT	----
12 MIDNT	----	1:15	22.776
1:20	1.660	----	----

*Time indicates midpoint between two successive readings.

Plt1

TIME 0-24 HR	DEHAIR	DEHAIR	SINGER	(256)
	WATER	STEAM	GAS	CLEANUP
	GPM	PPH	SCFH	WATER GPM
.0	15.11	6.50	3.23	0
1.0	15.25	5.42	3.05	21.21
2.0	15.02	6.73	3.05	5.93
3.0	13.49	6.62	2.87	0
4.0	14.41	6.73	3.23	0
5.0	14.96	2669.75	3.23	0
6.0	14.25	2481.67	3.23	0
7.0	13.97	2215.12	6786.83	0
8.0	14.04	2733.00	6772.83	0
9.0	14.10	3033.50	4484.15	0
10.0	13.99	3260.17	6600.33	.03
11.0	7.06	1603.83	3295.67	.11
11.0	14.06	2562.54	3304.03	5.32
12.0	13.89	2801.12	6620.83	2.81
13.0	14.53	3170.67	6623.83	.34
14.0	14.00	2035.30	6619.83	.34
15.0	13.73	6.00	3210.17	6.93
16.0	14.23	6.30	3.85	8.64

Plt2

TIME 0-24 HR	F BLEND	F BRN CHL	L COOKER	(256)
	STEAM	BRINE	STEAM	B BRN CHL
	PPH	GPM	PPH	BRINE PPH
.0	21.43	70.63	0	278.77
1.0	5.90	54.23	0	118.86
2.0	5.90	83.39	0	12.22
3.0	8.25	23.56	0	234.04
4.0	8.57	12.37	0	12.22
5.0	5.80	40.13	0	358.90
6.0	58.87	94.65	1259.97	69.84
7.0	3048.18	96.28	0	12.24
8.0	1016.05	45.45	2512.97	12.24
9.0	3.83	94.62	2650.25	126.31
10.0	1021.08	98.18	2922.50	303.82
11.0	1015.90	37.89	912.42	180.42
11.0	1175.07	81.77	249.20	301.51
12.0	2033.20	77.13	0	355.72
13.0	2034.20	78.29	0	244.08
14.0	1018.62	93.11	0	302.16
15.0	5.80	62.23	0	359.62
16.0	4.93	50.12	1878.16	298.48

PLT27

12

(2269)

FRANK BRINE TUNNEL

TIME	FLOW	TEMP OUT	TEMP IN
0-24 HR	GPM	F.	F.
.00	59.11	15.40	17.40
1.00	59.30	16.13	19.20
2.00	39.65	38.60	69.47
3.00	40.47	69.03	69.93
4.00	41.97	61.27	62.77
5.00	.10	46.67	54.47
6.00	61.79	24.27	33.03
7.00	61.90	18.93	21.83
8.00	61.05	19.43	21.97
9.00	60.82	20.00	22.70
10.00	60.65	19.63	21.87
11.00	60.30	19.37	20.83
12.00	60.75	19.17	20.57
13.00	60.61	19.53	21.20
14.00	61.31	20.07	22.37
15.00	61.24	20.43	54.63
16.00	60.93	20.13	57.30
17.00	60.47	20.47	63.17
18.00	59.79	20.50	59.03
19.00	60.17	20.87	61.67
20.00	60.34	20.93	59.93
21.00	59.95	20.67	58.10
22.00	60.33	21.10	59.93
23.00	59.48	21.53	56.90

#EOR

PLT28

(2269)

INED COOK HAIR HYD BLD DRY

TIME	STEAM	STEAM	STEAM
0-24HR	PPH	PPH	PPH
.00	196.90	0	0
1.00	179.47	0	0
2.00	105.40	0	.17
3.00	170.77	20.08	.47
4.00	129.90	0	83.97
5.00	127.77	254.67	193.87
6.00	80.57	0	371.73
7.00	77.37	0	528.73
8.00	249.43	0	14.10
9.00	453.00	553.97	.33
10.00	240.10	1202.30	7.07
11.00	129.90	880.30	0
12.00	142.87	861.73	76.87
13.00	117.57	1070.03	1246.30
14.00	143.10	750.57	3974.67
15.00	172.87	911.37	3081.00
16.00	125.83	693.07	5923.33
17.00	69.07	0	5127.67
18.00	651.23	0	3103.67
19.00	1267.20	0	0
20.00	1545.60	0	0
21.00	1534.17	0	0
22.00	1132.70	0	0
23.00	907.53	0	0

#EOR

PLT29

13

(2269)

TIME 0-24HR	SINGER	DEHAIRER	SCALD TANK	
	GAS SCFH	WATER GPM	TEMP BLD F.	TEMP DEH F.
.00	.27	15.81	77.23	77.10
1.00	.40	15.37	76.93	76.47
2.00	.40	15.73	76.90	76.13
3.00	.40	14.34	85.10	76.70
4.00	.73	14.80	115.17	108.00
5.00	.40	47.73	137.03	137.30
6.00	.40	14.75	137.10	137.63
7.00	6473.67	14.58	133.37	137.70
8.00	6592.33	14.32	134.67	137.53
9.00	2139.00	14.26	135.20	137.33
10.00	4303.00	14.17	135.17	137.73
11.00	6428.33	14.16	137.33	137.50
12.00	0	14.12	133.97	137.20
13.00	6471.67	56.08	138.33	136.97
14.00	6450.33	12.82	137.63	137.60
15.00	4323.33	14.07	130.70	137.27
16.00	6487.00	13.90	113.53	137.13
17.00	0	14.51	134.37	136.80
18.00	0	13.83	37.77	128.97
19.00	0	12.22	77.47	80.30
20.00	0	14.06	25.43	76.90
21.00	.27	14.93	71.33	74.70
22.00	.27	13.98	72.83	72.47
23.00	.40	12.47	73.13	75.40

#EOR

PLT30

(2269)

TIME 0-24HR	S SMOKE		S LINK COOL	
	TEMP OUT F.	TEMP IN F.	TEMP IN F.	TEMP OUT F.
.00	116.42	150.57	37.17	36.37
1.00	129.03	85.33	37.50	36.53
2.00	111.87	83.27	37.13	35.90
3.00	106.33	134.83	36.17	34.97
4.00	119.83	149.10	37.53	36.57
5.00	123.93	87.43	42.33	42.23
6.00	90.07	97.47	37.97	37.13
7.00	92.70	94.77	37.83	36.93
8.00	95.33	78.27	37.70	35.60
9.00	95.43	92.63	35.57	33.87
10.00	107.40	161.77	34.90	34.13
11.00	121.87	94.40	35.73	35.60
12.00	109.63	81.80	35.10	34.60
13.00	103.47	139.30	34.13	33.07
14.00	129.70	129.13	35.60	34.27
15.00	107.03	137.73	37.27	36.33
16.00	122.37	157.33	40.20	41.93
17.00	137.30	89.83	42.40	42.43
18.00	111.27	109.47	39.47	37.43
19.00	109.03	164.57	38.10	36.57
20.00	137.43	94.07	38.80	37.20
21.00	109.87	112.20	37.63	36.27
22.00	105.50	171.20	38.50	37.80
23.00	134.83	101.67	40.07	39.33

#EOR

FLT31

14

(2269)

TIME 0-24HR	GAS SCFH	BACCON SMOKE		B BLST CHL TEMP F.
		TEMP OUT F.	TEMP IN F.	
.00	265.13	123.30	79.50	24.27
1.00	186.20	123.77	78.53	23.53
2.00	71.03	122.83	72.10	21.80
3.00	0	123.97	83.37	20.23
4.00	160.17	127.67	84.57	19.97
5.00	173.87	136.87	79.33	18.37
6.00	0	127.97	81.40	18.07
7.00	0	112.40	91.33	17.83
8.00	0	86.37	85.20	17.87
9.00	183.00	92.60	85.57	17.80
10.00	291.73	114.67	91.27	17.47
11.00	443.00	117.40	88.60	17.67
12.00	255.33	124.40	93.30	17.27
13.00	179.17	123.20	87.57	18.27
14.00	0	122.73	79.87	18.00
15.00	0	122.63	83.60	18.00
16.00	271.57	131.50	85.73	18.77
17.00	217.40	137.00	80.47	21.93
18.00	0	126.97	80.80	20.10
19.00	0	124.10	90.43	21.77
20.00	218.73	107.37	98.10	22.33
21.00	236.77	114.43	89.07	21.50
22.00	240.43	117.07	84.80	21.83
23.00	342.63	123.33	90.43	21.90

4EOR

FLT32

(2269)

TIME 0-24HR	WATER GPM	CLEAN UP KILL FLOOR	
		TEMP F.	
.00	5.45	138.04	
1.00	5.50	135.33	
2.00	5.69	124.87	
3.00	5.57	108.40	
4.00	5.42	149.00	
5.00	5.53	181.03	
6.00	5.58	209.37	
7.00	5.52	209.77	
8.00	5.36	210.10	
9.00	5.43	210.07	
10.00	5.78	196.47	
11.00	7.47	114.73	
12.00	9.04	166.33	
13.00	8.94	109.30	
14.00	8.68	88.07	
15.00	9.17	86.00	
16.00	8.84	85.40	
17.00	10.35	90.53	
18.00	9.11	134.40	
19.00	9.09	147.87	
20.00	11.27	142.60	
21.00	10.06	128.50	
22.00	9.46	118.27	
23.00	11.08	119.63	

1EOR

FLT33

15

(2279)

FRANK BRINE TUNNEL

TIME	FLOW	TEMP IN	TEMP OUT
0-24HR	GPM	F.	F.
.00	58.83	57.97	21.30
1.00	59.15	58.07	21.57
2.00	19.10	109.13	27.90
3.00	38.66	133.27	105.33
4.00	39.97	104.67	72.60
5.00	.11	84.03	47.10
6.00	40.86	73.03	30.03
7.00	61.57	63.17	21.90
8.00	60.31	61.67	21.27
9.00	60.12	60.37	21.30
10.00	59.61	61.47	20.87
11.00	59.84	61.03	20.63
12.00	20.10	71.97	24.77
13.00	41.83	70.50	29.40
14.00	62.33	55.47	17.50
15.00	62.63	56.37	17.50
16.00	62.94	61.93	17.57
17.00	62.50	51.13	18.43
18.00	62.43	51.43	18.80
19.00	61.60	52.33	19.00
20.00	61.84	52.13	19.27
21.00	60.05	54.53	19.13

#EOR

FLT34

(2279)

	INED COOK	HAIR HYD	BLD DRY
TIME	STEAM	STEAM	STEAM
0-24HR	PPH	PPH	PPH
.00	943.77	0	0
1.00	841.40	0	0
2.00	620.37	0	0
3.00	541.27	0	0
4.00	526.17	0	0
5.00	266.93	0	.37
6.00	262.20	0	0
7.00	202.00	0	409.30
8.00	171.90	0	89.17
9.00	213.50	0	36.50
10.00	173.93	697.33	.33
11.00	176.70	1237.87	26.87
12.00	180.30	889.63	504.90
13.00	148.40	825.20	861.37
14.00	109.27	1236.57	873.90
15.00	95.23	585.67	991.87
16.00	77.77	0	636.57
17.00	153.73	0	265.83
18.00	763.47	0	21.97
19.00	349.43	0	0
20.00	125.67	0	0
21.00	266.47	0	0

#EOR

PLT35

16

(2279)

TIME 0-24HR	SINGER	DEHAIR	SCALD TANK	
	GAS SCFH	WATER GPM	TEMP BLD F.	TEMP DEH F.
.00	.40	14.38	74.87	77.27
1.00	.40	14.55	75.00	77.43
2.00	3.52	14.84	91.50	88.80
3.00	1.07	14.72	84.43	126.73
4.00	.73	14.47	132.43	137.37
5.00	.73	14.63	135.80	137.90
6.00	1.07	14.38	129.80	137.80
7.00	6386.00	13.97	135.90	137.47
8.00	6448.33	13.67	136.13	137.30
9.00	2127.67	14.06	134.53	137.57
10.00	6427.67	12.84	129.67	137.20
11.00	6460.33	13.95	133.27	137.13
12.00	2161.67	13.17	136.77	137.27
13.00	6397.33	13.99	132.20	99.97
14.00	6436.67	13.70	127.17	137.20
15.00	2158.67	13.46	126.10	137.20
16.00	.13	13.67	132.13	133.80
17.00	.13	13.80	78.13	83.37
18.00	.27	13.92	72.00	73.60
19.00	.27	14.14	75.37	75.80
20.00	.40	14.24	73.93	75.13
21.00	.40	14.21	74.47	74.63

#EOR

#EOF

PLT36

(2279)

TIME 0-24 HR	S SMOKE		S LINK COOL	
	TEMP IN F.	TEMP OUT F.	TEMP IN F.	TEMP OUT F.
.00	119.43	86.13	38.20	36.77
1.00	103.93	135.23	38.73	37.50
2.00	109.70	164.33	38.20	36.63
3.00	127.53	81.63	37.47	36.23
4.00	114.63	80.73	38.67	38.33
5.00	101.20	82.90	40.47	39.30
6.00	87.90	91.27	38.13	36.10
7.00	89.97	94.10	38.03	36.17
8.00	93.87	60.80	36.17	34.47
9.00	99.03	102.63	34.67	33.50
10.00	105.70	165.90	34.67	34.13
11.00	127.43	90.27	38.13	37.57
12.00	111.57	76.50	39.23	36.57
13.00	104.77	104.40	39.57	37.03
14.00	107.30	165.00	39.67	37.63
15.00	133.80	87.03	39.53	37.60
16.00	108.00	108.77	40.50	40.13
17.00	110.07	171.67	41.57	40.30
18.00	129.93	99.80	39.40	36.80
19.00	108.13	160.27	41.53	39.53
20.00	116.97	123.30	41.47	38.50
21.00	115.07	79.77	39.90	37.80

#EOR

PLT37

17

(2279)

TIME 0-24HR	GAS SCFH	BACON SMOKE	TEMP IN F.	R BLST CHL TEMP F.
		TEMP OUT F.		
.00	105.00	123.23	87.50	23.23
1.00	16.23	123.20	91.90	21.50
2.00	42.30	122.73	81.63	19.80
3.00	0	122.47	78.27	18.70
4.00	111.13	128.97	83.53	18.40
5.00	125.70	134.07	78.30	17.37
6.00	0	125.20	95.03	17.40
7.00	200.53	110.27	94.30	17.50
8.00	75.03	116.50	76.20	17.97
9.00	125.23	110.00	75.00	18.13
10.00	561.97	118.90	77.93	18.00
11.00	195.57	120.60	78.17	17.30
12.00	48.50	120.43	78.10	16.23
13.00	126.70	119.90	75.53	16.40
14.00	185.63	125.17	78.73	16.93
15.00	179.53	133.70	70.57	16.10
16.00	0	124.40	65.40	17.00
17.00	0	120.13	70.57	19.80
18.00	0	90.03	82.07	19.00
19.00	352.80	114.73	80.97	83.70
20.00	175.57	116.12	77.47	22.03
21.00	248.77	122.23	74.57	21.33

#EOR

PLT38

(2279)

TIME 0-24HR	WATER GPM	CLEAN UP KILL FLOOR
		TEMP F.
.00	8.88	136.40
1.00	9.11	144.30
2.00	6.83	120.10
3.00	9.15	135.13
4.00	9.50	127.13
5.00	10.08	187.70
6.00	10.38	171.67
7.00	10.70	115.10
8.00	10.12	81.10
9.00	9.46	77.27
10.00	10.78	77.90
11.00	11.02	79.07
12.00	8.09	130.70
13.00	6.94	93.47
14.00	7.11	82.87
15.00	8.44	92.73
16.00	9.16	166.47
17.00	9.75	185.20
18.00	8.05	155.30
19.00	6.89	123.23
20.00	6.61	115.17
21.00	6.60	172.50

#EOR

FLT39

(2229)

TIME	INED COOK STEAM PPH	HAIR HYDR STEAM PPH	BLD DRI STEAM PPH
0-24HR			
.0	1321.87	0.40	0
1.0	1317.37	0.89	0
2.0	1247.00	0.80	0
3.0	1118.50	0.80	0
4.0	1123.63	0.40	0
5.0	1166.60	0.80	0
6.0	1275.93	0.00	0
7.0	1586.70	0.63	0
8.0	1991.80	0.33	59.87
9.0	1970.20	936.47	235.70
10.0	1311.89	742.52	222.00
11.0	1393.77	1333.60	246.20
12.0	1317.00	910.93	339.00
13.0	1225.50	1550.27	133.17
14.0	1012.20	1206.60	39.70
15.0	510.83	892.20	2717.00
16.0	1010.47	0.20	5897.67
17.0	806.73	0.80	3473.33
18.0	441.70	0.80	1458.67
19.0	339.20	0.80	1234.30
20.0	536.37	0.57	2121.30
21.0	800.50	0.33	838.83
22.0	1031.97	0.57	0
23.0	778.00	0.80	0

FLT40

(2229)

TIME	SINGER GAS SCFH	DEHAIRER WATER GPM	SCALD TANK TEMP BLD F.	TEMP DEH F.
0-24HR				
.0	0	15.03	77.20	80.73
1.0	2.14	14.70	72.43	82.07
2.0	0	15.22	100.30	83.20
3.0	0	15.05	122.80	108.87
4.0	0	14.81	130.53	121.20
5.0	0	14.49	137.80	131.87
6.0	0	14.10	131.07	137.60
7.0	6472.33	13.62	137.13	136.97
8.0	6515.33	13.55	130.50	137.00
9.0	4338.33	13.53	129.03	137.17
10.0	4340.33	13.75	135.13	137.60
11.0	6509.33	13.97	135.97	137.83
12.0	0	13.82	137.60	137.27
13.0	6582.00	13.82	132.87	137.30
14.0	6524.67	14.19	131.73	136.77
15.0	1776.33	14.25	133.40	136.27
16.0	0	15.65	114.67	122.07
17.0	0	15.84	81.23	80.87
18.0	0	15.77	81.43	80.10
19.0	0	15.91	81.56	80.97
20.0	0	15.80	81.89	80.03
21.0	0	16.53	81.07	79.23
22.0	0	16.15	80.27	78.97
23.0	0	16.07	82.73	79.13

PLT41

TIME 0-24HR	S SMOKE		(2229) S LINK COOL	
	TEMP IN F.	TEMP OUT F.	TEMP IN F.	TEMP OUT F.
.0	111.40	114.80	39.93	38.17
1.0	107.47	171.30	39.73	38.03
2.0	120.43	95.20	38.27	36.57
3.0	111.23	156.97	39.07	37.67
4.0	129.73	129.70	41.17	40.80
5.0	127.40	84.13	41.27	39.17
6.0	99.97	113.77	39.97	38.07
7.0	104.80	166.40	40.10	38.20
8.0	99.00	94.30	38.03	36.10
9.0	102.00	83.30	37.17	35.33
10.0	105.80	130.37	38.23	37.53
11.0	126.93	139.50	36.93	34.97
12.0	117.93	89.60	37.93	35.47
13.0	114.17	163.93	37.23	35.80
14.0	140.47	116.63	38.53	37.77
15.0	117.70	111.40	39.10	38.13
16.0	115.83	170.40	40.87	41.00
17.0	145.83	94.23	39.17	38.33
18.0	125.03	91.50	38.87	37.40
19.0	118.17	148.43	37.90	36.43
20.0	124.57	148.63	38.00	36.27
21.0	131.20	89.30	37.40	65.83
22.0	118.10	86.47	40.27	42.50
23.0	108.43	125.77	39.03	37.70

#EOR

#EOF

PLT42

TIME 0-24HR	GAS SCFH	BACON SMOKE		(2229) B RLST CHL	
		TEMP OUT F.	TEMP IN F.	TEMP F.	
.0	38.67	114.63	89.33	17.27	
1.0	0	120.00	86.73	17.13	
2.0	0	119.97	90.33	20.83	
3.0	0	120.03	84.97	23.10	
4.0	0	119.87	85.43	21.23	
5.0	105.23	123.23	95.03	19.43	
6.0	0	133.47	104.50	18.53	
7.0	0	133.13	108.23	18.30	
8.0	0	120.83	103.10	17.00	
9.0	0	104.60	100.00	18.63	
10.0	0	94.07	96.63	19.90	
11.0	0	92.23	95.73	19.43	
12.0	119.07	106.27	102.50	20.73	
13.0	365.07	114.27	99.40	20.43	
14.0	232.30	120.50	102.50	19.57	
15.0	12.83	123.77	103.57	19.87	
16.0	0	123.40	95.20	21.20	
17.0	0	123.33	95.17	23.33	
18.0	0	123.40	95.87	23.63	
19.0	182.50	132.10	99.30	23.30	
20.0	41.93	131.03	99.37	24.30	
21.0	0	125.67	93.27	22.37	
22.0	0	117.30	100.87	22.50	
23.0	710.67	99.67	98.27	22.37	

PLT43

(2229)

TIME 0-24HR	CLEAN UP FLOW GPM	KILL FLOOR TEMP F.
.0	6.42	121.47
1.0	5.35	103.50
2.0	6.39	134.33
3.0	6.35	120.70
4.0	6.28	98.53
5.0	6.31	86.37
6.0	6.26	84.77
7.0	6.27	90.00
8.0	6.21	87.90
9.0	6.30	104.17
10.0	6.45	126.00
11.0	5.33	130.27
12.0	5.36	126.43
13.0	5.46	95.00
14.0	5.41	92.80
15.0	5.46	101.97
16.0	5.57	90.17
17.0	5.58	90.73
18.0	5.59	99.80
19.0	5.58	108.70
20.0	5.55	130.63
21.0	5.61	122.87
22.0	5.67	131.13
23.0	5.67	128.63

#EOR

APPENDIX A3 - PLANT A
PROCESS LABOR REQUIREMENTS

PLANT A

PROCESS LABOR REQUIREMENTS

I. Dehairing Process

- A. Load and stun operation - 4 men
- B. Shackling operation - 1
- C. Sticking operation - 1
- D. Unshackling operation - 1
- E. Gambrel chain loading operation - 3
- F. Singeing operation - 1
- G. Shaving operation - 6
- H. Sanitation - 2

TOTAL - 19

Average working time per day = 7.25 hours

Average man hour per head = $19(7.25 \text{ hrs})/3021 \text{ head/day}$

TOTAL 0.046 man hours/head

II. Frankfurter Manufacturing Process

A. Sausage Kitchen

	1st Shift	2nd Shift
1. Tractor operation	0.5* man	
2. Set up operation	0.5	
3. Dismantling operation		0.25
4. Product analysis operation	0.75	0.75
5. Grinding operation	0.5	0.5
6. Flaking operation	0.5	0.5
7. Blending operation	0.75	0.75
8. Added ingredients operation	0.75	0.75
9. Stuffing-linking operation	3.0	3.0
10. Tree supplying operation	1.0	1.0
11. Tree washing operation	0.25	0.5
12. Spice room operation	0.33	0.33

B. Smokehouses

- 1. First quarter day - 0.88 men
- 2. Second quarter day - 0.75
- 3. Third quarter day - 0.5
- 4. Fourth quarter day - 0.25

*Man has other product duties

C. Packaging Room

	1st Shift	2nd Shift
1. Tractor operation	0.5	0.5
2. Set up operation	0.67	
3. Servicing operation	0.33	0.33
4. Brine chill operation	0.5	1.0
5. Regular franks packaging		
a. Peeler operation	1.0	2.0
b. Packaging operation	0.5	1.0
c. Boxing operation	1.5	3.0
d. Misc. labor	0.5	1.0
6. Dinner franks packaging		
a. Peeler operation	0.5	1.0
b. Bagging operation	1.0	2.0
c. Closing operation	0.5	1.0
7. Contract frank packaging		
a. Peeler operation	0.5	1.0
b. Scaling operation	0.5	1.0
c. Boxing operation	1.5	3.0

D. Sanitation = 4.59

TOTAL both shifts = 51.96 men

Ave. man hours/lb of finished franks = $\frac{51.96 (7.5 \text{ hrs})}{47,276} =$

0.0082 man hours/lb

III. Bacon Manufacturing Process

	1st Shift	2nd Shift
A. Grading and weighing operation	2.0	
B. Curing operation		
1. Tree preparation operation	3.0	
2. Injection supplying operation	2.0	
3. Inspection machine operation	1.0	
4. Drolley operation	1.0	
5. Tree loading operation	2.0	2.0
6. Tree washing operation	2.0	
C. Smokehouse		
1. First quarter day	1.0	
2. Second quarter day	1.0	

3. Third quarter day	1.0
4. Fourth quarter day	1.0

D. Skinning and Brine Chilling

1. Skinner supplying operation	1.0
2. Skinning machine operation	1.0
3. Tree preparation operation	2.0
4. Brine cabinet operation	1.0
5. Dolley operation	1.0

E. Chilling and Tempering 1.0

F. Slicing and Packaging

1. Set up operation	2.0	1.0
2. Rack operation	1.0	1.0
3. Press operation	1.0	1.0
4. Slicing operation	3.0	3.0
5. End piece handling operation	3.0	3.0
6. Scaling operation	4.0	3.0
7. Positioning operation	5.0	4.0
8. Packaging operation	6.0	4.0
9. Boxing operation	3.0	3.0
10. Dolley operation	2.0	2.0
11. Speciality line operation	2.0	2.0

G. Sanitation - 5.17

TOTAL - 91.17 men

Ave. working time per day = 7.75 hours

$$\text{Ave. man hours/lb of finished bacon} = \frac{7.75(91.17)}{68,817} =$$

0.0103 man hours/lb

IV. Lard Rendering Process

A. Loading - Unloading operation	3.0
B. Edible Rendering tanks sanitation	1.19

TOTAL - 4.19 men

Ave. working time per day = 7.75 hours

$$\text{Ave. man hours/head slaughtered} = \frac{4.19(7.75 \text{ hours})}{3021 \text{ head}} =$$

0.0107 man hours/head

V. Inedible Rendering Process

A. Cooker loading operation	0.5
B. Expeller operation	2.5
C. Grease clarification operation	2.0
D. Sanitation	0.5

TOTAL = 5.5 men

Ave. working time per day = 7.75 hours

$$\text{Ave. man hours/head slaughtered} = \frac{5.5(7.75 \text{ hours})}{3021 \text{ head}} =$$

0.0141 man hours/head

VI. Blood Drying Process

A. Loading - Unloading & Sanitation	0.5
-------------------------------------	-----

Ave. working time per day = 7.75 hours

$$\text{Ave. man hours/head slaughtered} = \frac{7.75(0.5)}{3021} =$$

0.0013 man hours/head

VII. Hair Hydrolysis and Drying Process

A. Hydrolyzing - Drying & Sanitation	1.0
--------------------------------------	-----

Ave. working time per day = 7.75

$$\text{Ave. man hours/head slaughtered} = \frac{7.75(1.0)}{3021} =$$

0.0026 man hours/head

APPENDIX A4 - PLANT A**ECONOMIC DATA**

ECONOMIC DATA

MEAT PLANT A
(1978 Dollars)

A) Equipment Cost (by operation and process)

1. Carcass operation

a) Killing	\$ 59,100
b) Dehairing	717,500
c) Dressing	544,000
d) Chill and cut	858,600

(Costs were taken to be the same as PLANT B)

2. Fresh cuts operation

a) Packaging	\$ 43,000
b) Storage	237,000

(Same as PLANT B)

3. Sausage operation (franks, bologna, loaves)

PROCESS	EQUIP. COST (\$)
a) Grinding/Blending	
-flakers, cutters, sizers	110,600
-mixers, blenders, loaders, scalers	92,700
-holding bins & other access. inst.	90,500
	<hr/>
TOTAL	293,800
b) Emulsification	
-silent cutters, mincemasters, conveyors	101,900
-holding tank and access. inst.	40,700
	<hr/>
TOTAL	142,600
c) Stuffing	
-frank-o-matics	122,900
-stuffers filler, loopers	99,500
-other acces. inst.	55,600
	<hr/>
TOTAL	278,000
d) Smoking/Cooling	
-smokehouses (6)	525,500
-smoke generators	13,800
-smoke trees - rails	37,500
-steam house	20,300

-loaf browner	11,300
-link cooler	22,400
-Brine chill-pump	63,500
-Plate chiller	11,100

TOTAL	705,400
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e) Peeling/Packaging	
-peelers (4) and conveyors	33,000
-collators and conveyors	53,900
-carton and strapping machines	191,200
-slicer and im printers	39,900
-vacuum packager and pumps	226,700

TOTAL	544,700
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TOTAL Sausage Operation Equip. Cost:	\$1,964,500
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4. Bacon Operation

PROCESS	EQUIP. COST (\$)
a) Pickling/Curing	
-pickle injector and attach.	45,100
-vats, dumper, trees and access. inst.	80,400
TOTAL	125,500
b) Smoking	
-smokehouses	350,300
-smoke generator and access. inst.	16,500
TOTAL	366,800
c) Skinning	
-skinners	11,000
-brine cabinet and pump	170,500
TOTAL	181,500
d) Cooling (Chill and Temper)	
-blast chill equip.	16,200
-temper	44,900
TOTAL	61,100
e) Slicing/Packaging	
-presses, formers	41,900
-slicers, conveyors	53,900
-packaging and strapping machines	396,200
TOTAL	492,000

TOTAL Bacon Operation Equip. Cost: \$1,226,900

5. Ham Operation

This operation was not studied in PLANT A but equipment cost can be taken comparable to that at PLANT B plant.

6. Edible Rendering (Lard) Operation

PROCESS	EQUIP. COST (\$)
a) Grinding and Loading	
-grinder and loader	19,300
-carts and other access. inst.	16,500
TOTAL	35,800
b) Cooking	
-lard cooker	59,700
-flash tank and other access. inst.	16,900
TOTAL	76,600
c) Centrifugation	
-purifier	59,900
-holding tank	1,500
-pumps and other access. inst.	4,300
TOTAL	65,700
d) Storage	
-storage tank	5,200
-pumps, piping and access. inst.	2,000
TOTAL	7,200
TOTAL Lard Operation Equip. Cost:	\$185,300

7. Inedible Rendering Operation

I. Crax and Grease:

PROCESS	EQUIP. COST (\$)
a) Prebreak (Grind and Load)	
-prebreaker and magn. separator	23,000
-carts and conveyors	25,300
-hopper and access. inst.	12,200
TOTAL	60,500

b) Cooking	
-cookers	146,000
-ejectors and other access. inst.	39,600
	<hr/>
TOTAL	185,600
c) Percolation/Expelling	
-percolation pans	33,000
-expellers	85,600
-conveyors and access. inst.	42,900
	<hr/>
TOTAL	161,500
d) Crax Grinding	
-Hammermill	15,400
-Conveyors and access. inst.	13,400
	<hr/>
TOTAL	28,800
e) Crax Storage	
-storage bin	13,300
-conveyors and access. inst.	6,200
	<hr/>
TOTAL	19,500
f) Grease Wash	
-wash tanks	7,700
-pumps, piping and access. inst.	8,500
	<hr/>
TOTAL	16,200
g) Grease Storage	
-storage tanks	5,000
-pumps and access. inst.	4,000
	<hr/>
TOTAL	9,000
TOTAL Crax and Grease Operation Equip. Cost:	\$481,100

II. Hair Hydrolyzing:

PROCESS	EQUIP. COST (\$)
a) Loading/Cooking	
-loader screw	1,500
-belt conveyor	2,600
-magn. separator	2,000
-hydrolyzer	102,800
-supp. parts and equip. inst.	21,800
	<hr/>
TOTAL	130,700

b) Drying	
-rendering tanks	30,200
-screw conveyors and access. inst.	<u>21,400</u>
TOTAL	51,600
c) Grinding	
-hammermill	15,400
-conveyors and access. inst.	<u>7,200</u>
TOTAL	22,600
d) Storage	
-storage bin	5,000
-unloader and access. inst.	<u>4,200</u>
TOTAL	9,200
TOTAL Hair Hydrolyzing Equip. Cost:	\$214,100

III. Blood Drying:

PROCESS	EQUIP. COST (\$)
a) Loading/Drying	
-tank and pump	5,800
-blood dryers	56,200
-conveyors	7,300
-ejectors and access. inst.	<u>21,000</u>
TOTAL	90,300
b) Grinding/Storage	
-hammermill	15,400
-storage bin	5,000
-conveyors and access. inst.	<u>7,200</u>
TOTAL	27,600
TOTAL Blood Drying Equip. Cost:	\$117,900
TOTAL Inedible Rendering Operation Equip. Cost:	\$813,100

8. Refrigeration

EQUIPMENT	COST (\$)
-reciproc. compressors and motors (10, total cap. 1410 tons)	215,000
-screw compressors and motors (2, total cap. 900 tons)	400,000
-evap. condensers	

9. Steam Production

EQUIPMENT	COST (\$)
-boilers	

10. Compressed Air Production

EQUIPMENT	COST (\$)
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B) Labor Cost (yearly by selected plant operations)

	1977 (\$)	Jan.-June '78 (\$)
1. Carcass operation:	3,988,244	2,033,815
2. Sausage operation:	1,438,072	539,353
3. Bacon operation:	1,874,687	718,954
4. Inedible operation:	240,228	108,689

C) Labor Amount (by operation and process)

1. Carcass Operation

Process	Hrs/1000 lbs
a) Killing	0.025
b) Dehairing	0.087
c) Dressing	1.20
d) Chill and Cut	0.77
e) Sanitation	0.06

2. Fresh Cuts Operation

Process	Hrs/1000 lbs
a) Cut and Packaging	0.65
b) Storage	0.16

3. Sausage Operation

Process	Hrs/1000 lbs
a) Grinding/Blending/Emulsification/Stuffing	2.58
b) Smoking/Cooling	0.84
c) Peeling/Packaging/Storage	3.54
d) Sanitation	0.43

4. Bacon Operation

Process	Hrs/1000 lbs
a) Pickling/Curing	1.06
b) Smoking	0.77
c) Skinning/Cooling	0.83
d) Blast Chill & Temper	0.28
e) Slicing/Packaging/Storage	8.52
f) Sanitation	0.63

5. Ham Operation

(Same as at PLANT B)

6. Edible Rendering Operation

Process	Hrs/1000 lbs
a) Grinding and Loading	0.105
b) Cooking	0.152
c) Centrifugation/Storage	0.102
d) Sanitation	0.122

7. Inedible Rendering Operation

I. Crax and Grease:

Process	Hrs/1000 lbs
a) Prebreak (Grind and Load)	0.062
b) Cooking	0.078
c) Percolation/Expelling	1.150
d) Crax Grinding/Storage	-----
e) Grease Wash/Storage	0.479
f) Sanitation	0.250

II. Hair Hydrolyzing:

a) Loading/Cooking	1.49
b) Drying	1.71
c) Grinding/Storage	-----
d) Sanitation	1.71

III. Blood Drying:

a) Loading/Drying	1.65
b) Grinding/Storage	-----
c) Sanitation	1.44

D) Utility Amount and Cost (by plant)

1. Electricity	1975	1976	July '77-Apr. '78	
KWH:	20,484,000	18,512,182	16,574,400	
\$:	292,800	292,493	373,718	
2. Natural Gas	1975	1976	1977	Jan.-June '78
100 cu.ft.:	2,345,710	2,065,450	1,267,944	667,196
\$:	204,718	255,290	171,213	99,914
3. #6 Oil	1975	1976	1977	Jan.-Apr. '78
Gal:	84,230	495,548	418,928	430,068
\$:	27,796	168,340	145,530	150,453
4. Water and Sewage	1977	Jan.-July '78		
Gal:	266,685,000	119,844,000		
\$:	84,128	87,053		

E) Production (by plant)

Product	1977 (lbs)	Jan.-June '78 (lbs)
1. Bacon	17,204,233	6,526,798
2. Hot Dogs	11,819,136	4,579,267
3. Edible (Lard)	13,208,149	8,956,800
4. Inedible (crax, hair, blood, grease)	6,358,909	4,332,180
5. Other (fresh cuts, sausage, ham & losses)	108,524,510	65,417,780

TOTAL Killed Weight	157,114,937	89,812,825
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APPENDIX A5 - PLANT A

SAMPLE CALCULATIONS

I. Dehairing Process - Unit Operations

Unless otherwise stated, the average daily slaughter of 3021 head was used for all computations.

A. Stun and Bleed Operation

Two electrical devices - 375 Volt, 1.5A stunner
- 50 hp conveyor

1. Stunner - estimate 5 seconds per hog

$$(1.5A)(375V)(1.0 \text{ P.F.})\left(\frac{5 \text{ sec}}{3600 \text{ sec}}\right) = 0.7812 \text{ WH/hog}$$

2. Conveyor - 1.0 hp, 470V, 1.7A, 7.17 hours/day

$$(1.7A)(470V)(80\% \text{ P.F.})(\sqrt{3})(7.17 \text{ hrs})/3021 \text{ hogs} = 2.628 \text{ WH/hog}$$

One steam injected knife sterilizer

3. Knife box dimensions - 12 in. x 8.25 in. x 6.25 in.

water depth - 12 inches

Volume of water - 0.3581 ft^3

Average bulk water temperature - 177°F

Average wall temperature - 190°F

Initial temperature - 70°F

$$\text{a. Startup} - m C_p \Delta T = 0.3581 \text{ ft}^3 (62.5 \text{ lbs/ft}^3) \times$$

$$(1.0 \text{ Btu/}^\circ\text{F-lb})(177 - 70^\circ\text{F}) = 2395 \text{ Btu}$$

- b. Heat loss during day from water surface

ASSUME: air velocity - 1.0 ft/sec

ambient air - 80°F

water temperature - 180°F

running time - 10 hrs/day

2750 Btu/hr ft^2 (Strock, 1959)

$$2750 \text{ Btu/hr-ft}^2 \left(\frac{8.25}{12} \text{ ft}\right) \left(\frac{6.25}{12} \text{ ft}\right) (10 \text{ hrs}) = 9847 \text{ Btu/day}$$

- c. Heat loss from metal surface by convection and radiation (Strock, 1959)

$$\text{walls } h_c = 0.28 \left(\frac{t_1 - t_2}{x} \right)^{\frac{1}{4}} = 0.28 \left(\frac{190 - 80}{10/12 \text{ ft}} \right)^{\frac{1}{4}} = 0.949$$

$$\text{bottom } h_c = 0.2(t_1 - t_2)^{\frac{1}{4}} = 0.2(190 - 80)^{\frac{1}{4}} = 0.648$$

$$q_c = (0.648 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(0.3581 \text{ ft}^2)(190 - 80^{\circ}\text{F}) \times \\ (10 \text{ hrs})(0.949 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)[(0.5208 \text{ ft}^2)(2) + \\ (0.6875 \text{ ft}^2)(2)](190 - 80^{\circ}\text{F})(10 \text{ hrs}) = 2778 \text{ Btu/day}$$

$$q_r = 0.174 A_e(T_h^4 - T_c^4)/10^8$$

$e = 0.03$ for polished aluminum (Strock, 1959)

$$q_r = 0.174(2.7747 \text{ ft}^2)(.03)(650^4 - 540^4)(10 \text{ hrs})/10^8 = \\ 135.4 \text{ Btu/day}$$

TOTAL Steam required per day -

$$2395 \text{ Btu/day} + 9847 \text{ Btu/day} + 2778 \text{ Btu/day} + \\ 135.4 \text{ Btu/day} = 15,155.4 \text{ Btu/day or } \frac{15,155.4}{3021 \text{ hogs}} = \\ 5.017 \text{ Btu/head}$$

B. Scald Tank Operation

1. Water usage

Scald tank is L-shaped tub -

-5 ft wide by 87 ft by 25.17 ft
-water depth 2.67 ft

TOTAL water volume - 1352.22 ft^3
TOTAL gallons - $1352.22 \text{ ft}^3(7.48 \text{ gal/ft}^3) = 10,115 \text{ gal.}$

An additional 3000 gallons of water are added at noon as recorded by meter.

Another 4370 gallons water is used during cleanup.

TOTAL water added during production day is 13,115 gallons (109,248 pounds) or 4.341 gallons per head

Initial water temperature - 69°F

Operating temperature - 140°F

2. Steam usage - average kill during steam flow data collection was 3597 head per day. Average total daily usage was 26,563.8 pounds of 90 psig steam or

$26,563.8 \text{ lbs}(1188 \text{ Btu/lb}) = 31,557,827 \text{ Btu/day or}$

8773 Btu/head

For a typical day, steam flow to the scald tank was -

12,510,000 Btu's startup - 2 hours

1,258,000 Btu's maintenance period after startup before production - 1.3 hours

1,892,000 Btu's/hr - Average flow during production period

1,454,000 Btu's "Extra" flow after production which can be eliminated

3. Electrical usage

3 - 2.0 hp dunkers - 470V, 3.2A

1 - 7.5 hp recirculation pump - 470V, 6.6A

1 - 7.0 hp shackle chain drive - 470V, 6.0A

Average running time per day is 11.33 hours

$(22.2\text{A})(470\text{V})(80\% \text{ P.F.})(\sqrt{3})(11.33 \text{ hr})/3021 \text{ head}$

Assume only 50% of electrical utility input appears as heat to operation -

$163,805 \text{ WH}(.50)(3.414 \text{ Btu/WH}) = 279,618 \text{ Btu/day}$

4. Combined losses from water surface -

-ambient air - 80°F

-air velocity - 2.0 ft/sec

-average water temperature 140°F

-exposed surface - 516.7 ft²

At 2.0 fps, 140°F, 80°F - heat loss is 1060 Btu/hr-ft²
(Strock, 1959)

$$516.7 \text{ ft}^2 (11.33 \text{ hr}) (1060 \text{ Btu/hr-ft}^2) = 6,205,464 \text{ Btu/day}$$

5. Convective losses from tank metal surfaces and recirculation pipes -

a. Tank (from Strock, 1959)

$$\text{walls } h_c = 0.3(t_1 - t_2)^{\frac{1}{4}} = 0.3(140 - 80)^{\frac{1}{4}} = \\ 0.835 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$\text{bottom } h_c = 0.2(t_1 - t_2)^{\frac{1}{4}} = 0.2(140 - 80)^{\frac{1}{4}} = \\ 0.557 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$q_c = (0.835 \text{ Btu/hr-}^{\circ}\text{F-ft}^2) (670.8 \text{ ft}^2) (140 - 80^{\circ}\text{F}) \times \\ (11.33 \text{ hrs}) + (0.557 \text{ Btu/hr-}^{\circ}\text{F-ft}^2) (516.7 \text{ ft}^2) \times \\ (140 - 80^{\circ}\text{F}) (11.33 \text{ hrs}) = 576,418 \text{ Btu/day}$$

b. Pipes - 100 ft.

$$h_c = 0.42(140 - 80/6)^{\frac{1}{4}} = 0.747 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$q_c = 100 \text{ ft} \left(\frac{6}{12} \text{ ft } \pi\right) (0.747 \text{ Btu/hr-}^{\circ}\text{F-ft}^2) (140 - 80) \times \\ (11.33 \text{ hrs}) = 79,753 \text{ Btu/day}$$

6. Radiation losses from tank metal surfaces and pipes -

a. Tank - e = 0.92 dark paint (Strock, 1959)

$$q_r = 0.174(1187.5 \text{ ft}^2) (.92) (600^4 - 540^4) (11.33 \text{ hrs}) / 10^8 = \\ 959,926 \text{ Btu/day}$$

b. Pipes - e = 0.92

$$0.174 \left(\frac{6}{12} \text{ ft } \pi\right) (100 \text{ ft}) (.92) (600^4 - 540^4) (11.33 \text{ hrs}) / 10^8 = \\ 126,976 \text{ Btu/day}$$

7. Water heating - 69°F to 140°F

109,248 lbs - initial and noon water added

109,248 lbs ($1.0 \text{ Btu/lb-}^{\circ}\text{F}$) ($140 - 69^{\circ}\text{F}$) - 7,756,608 Btu/day

8. Losses to hogs - only outer skin of hog is heated to 140°F since it was found that no temperature change occurs at the 1.0 inch depth, estimate 32 pounds heated per hog.

ASSUME: C_p of skin = $0.5 \text{ Btu/lb-}^{\circ}\text{F}$, i.e., mostly fat

3597 head (32 lb/head) ($0.5 \text{ Btu/lb-}^{\circ}\text{F}$) ($140 - 101^{\circ}\text{F}$) =

2,244,528 Btu/day

9. Total accountable outputs -

a. Losses from water surface -	6,205,464 Btu/day
b. Convective losses tank and pipes -	656,171 Btu/day
c. Radiant losses -	1,086,902 Btu/day
d. Water heating -	7,756,608 Btu/day
e. Heat to hogs -	<u>2,244,528 Btu/day</u>
TOTAL	17,949,673 Btu/day

10. Balance input - output

Input - Steam -	31,557,827 Btu/day
Electricity -	<u>279,618 Btu/day</u>
TOTAL	31,837,445 Btu/day

Accountable Input - 31,837,445 Btu/day

Accountable Output - 17,949,673 Btu/day

DIFFERENCE = 13,887,772 Btu/day

11. The difference represents input steam which is lost from the tank. Part of this is lost as condensate or water overflow and the remaining must be leaving the tank as non-condensed steam, at 1 atmosphere.

$$13,887,772 \text{ Btu} = m_{\text{vap}}^{212} (1150.5 \text{ Btu/lb}) + m_{\text{cond}}^{140} (107.95 \text{ Btu/lb})$$

$$26,563.8 \text{ lbs} = m_{\text{vap}} + m_{\text{cond}}$$

Solving for m_{vap} -

$$13,887,772 \text{ Btu} [(26,563.8 \text{ lb}) (107.95 \text{ Btu/lb})] =$$

$$1150.5 - 107.95 \text{ Btu/lb}) m_{\text{vap}}$$

$$11,020,209 = 1042.55 m_{\text{vap}}$$

$$10,570.4 \text{ lbs} = m_{\text{vap}} = 12,161,288 \text{ Btu/day}$$

$$15,993.4 \text{ lbs} = m_{\text{cond}} = 1,726,483 \text{ Btu/day}$$

C. Dehairing Machine Operation

1. Water usage -

The tanks beneath each of the two dehairers measure 10.75 ft x 6.0 ft x 3.33 ft.

Water required for the initial fill of these two tanks is:

$$2(10.75 \text{ ft})(6.0 \text{ ft})(3.33 \text{ ft})(7.48 \text{ gal/ft}^3) = 3213 \text{ gallons}$$

During the dehairer operating period, a constant fresh water overflow is maintained. The length of time that this overflow was running was highly variable from day to day. As a result, the water consumption ranged from 8,928 to 20,160 gallons per day. The average was 13,320 gallons.

Total water per day averaged 16,533 gallons (137,720 pounds) or 5.47 gallons per head.

2. Steam usage - average kill during steam flow data collection was 3597 head per day.

Average total daily usage was 65,087.8 pounds of 90 psig steam or

$$65,087.8 \text{ lb/day}(1188 \text{ Btu/lb}) = 77,324,306 \text{ Btu/day or}$$

$$20,178 \text{ Btu/head}$$

As with water, steam flow to the dehairers varied in running time, with up to 22.33 hours of operating time.

For a typical day, steam flow to the dehairers was -

8,383,000 Btu's startup - 2 hours

5,043,000 Btu's maintenance period after startup before production - 1 hour

5,100,000 Btu/hr average flow during production period

17,542,000 Btu's "Extra" flow after production during cleanup which can be eliminated.

3. Electricity usage -

2 - 6.0 hp recirculation pumps - 470V, 6.6A

1 - 1.0 hp inclined conveyor - 470V, 3.5A

2 - 20.0 hp main drives - 470V, 20.0A

1 - 5.0 hp gambrel table drive - 470V, 1.7A

1 - 5.0 hp gambrel chain drive - 470V, 1.6A

Average running time per day is 12.33 hours.

$$(60.3A)(470V)(80\% \text{ P.F.})(\sqrt{3})(12.33 \text{ hours})/3021 \text{ head} =$$

$$160.3 \text{ WH/head}$$

Assume only 50% of electrical utility input appears as heat to operation.

$$484,204 \text{ WH} (.50)(3.414 \text{ Btu/WH}) = 826,537 \text{ Btu/day}$$

4. Combined losses from water surface of base tanks -

- ambient air - 80°F
- air velocity - 10.0 ft/sec
- average water temperature - 130°F
- exposed surface - 129 ft^2

At 10.0 fps , 130°F , 80°F - heat loss is 1620 Btu/hr-ft^2
(Strock, 1959)

Typical time that water remains in the tanks is 15.5 hours.

$$129 \text{ ft}^2(15.5 \text{ hrs})(1620 \text{ Btu/hr-ft}^2) = 3,239,190 \text{ Btu's/day}$$

5. Convective losses from metal surfaces of the dehairers -
(from Strock, 1959)

$$\text{walls } h_c = 0.3(130 - 80)^{1/4} = 0.798 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$\text{bottom } h_c = 0.2(130 - 80)^{1/4} = 0.532 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$\text{top } h_c = 0.38(130 - 80)^{1/4} = 1.010 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$\begin{aligned} q_c &= (0.798 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(480 \text{ ft}^2)(130 - 80^{\circ}\text{F})(15.5 \text{ hrs}) + \\ &\quad (0.532 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(129 \text{ ft}^2)(130 - 80^{\circ}\text{F})(15.5 \text{ hrs}) + \\ &\quad (1.010 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(129 \text{ ft}^2)(130 - 80^{\circ}\text{F})(15.5 \text{ hrs}) = \\ &\quad 451,017 \text{ Btu/day} \end{aligned}$$

6. Radiant losses from dehairers -

Assume - $e = 0.92$ dark paint (Strock, 1959)

$$q_r = 0.174(738 \text{ ft}^2)(.92)(590^4 - 540^4)(15.5 \text{ hrs})/10^8 =$$

$$661,835 \text{ Btu/day}$$

7. Water heating - 70°F to 130°F

$$137,720 \text{ lbs}(1.0 \text{ Btu/lb-}^{\circ}\text{F})(130 - 70^{\circ}\text{F}) = 8,263,193 \text{ Btu/day}$$

8. Losses to hogs - hogs enter dehairer from scald tank which is 10°F hotter. Assume no change in carcass temperature.

9. Total accountable outputs -

a. Losses from water surface in base tanks -	3,239,190 Btu/day
b. Convective losses from dehairers -	451,017 Btu/day
c. Radiant losses from dehairers -	661,835 Btu/day
d. Water heating -	<u>8,263,193 Btu/day</u>
TOTAL	12,615,235 Btu/day

10. Balance - Input-Output

Input - Steam -	77,324,306 Btu/day
Electricity -	<u>826,537 Btu/day</u>
TOTAL	78,150,843 Btu/day
Accountable Input -	78,150,843 Btu/day
Accountable Output -	12,615,235 Btu/day
DIFFERENCE:	65,535,608 Btu/day

11. A certain amount of steam is lost as overflow due to condensate but the remainder is lost either as non-condensed steam or by combined losses from the water sprays as air passes through the dehairers.

$$65,535,608 \text{ Btu/day} = m_{\text{vap}}^{212} + m_{\text{vap}}^{130} + m_{\text{cond}}^{130}$$

For simplicity, assume that m_{vap}^{212} and m_{vap}^{130} can be replaced by m_{vap}^* with h_v^{212} 1150.5 Btu/lb

$$65,535,608 \text{ Btu} = m_{\text{vap}}^* (1150.5 \text{ Btu/lb}) + m_{\text{cond}} (97.96 \text{ Btu/lb})$$

$$65,087.8 \text{ lb} = m_{\text{vap}}^* + m_{\text{cond}}$$

Solving for m_{vap}^*

$$65,535,608 \text{ Btu} [(65,087.8 \text{ lb}) (97.96 \text{ Btu/lb})] =$$

$$(1150.5 - 97.96 \text{ Btu/lb}) m_{vap}$$

$$59,159,607 = 1052.54 m_{vap}$$

$$56,206.5 \text{ lbs} = m_{vap} = 64,665,597 \text{ Btu/day}$$

$$8881.3 \text{ lb} = m_{cond} = 870,012 \text{ Btu/day}$$

D. Singeing Operation

1. Gas usage - average kill during gas flow data collection was 3643 head per day.

Average total daily usage was 48,451 cubic feet of natural gas at 15 psig. Assuming 1000 Btu/ft³, the total daily input is 48,451,000 Btu's or 13,300 Btu's/head.

2. Electricity usage -

1 - 2.0 hp blower motor - 470V, 1.7A

Average running time is 7.17 hours

$$1.7A(470V) (80\% \text{ P.F.}) (\sqrt{3}) (7.17 \text{ hrs}) / 3021 \text{ head} = 2.628 \text{ WH/head}$$

Assuming that only 50% of the electrical usage input appears as heat into the operation, the daily input is -

$$7938.1 \text{ WH} (.50) (3.414 \text{ Btu/WH}) = 13,500 \text{ Btu/day}$$

3. Heat to hogs - there is essentially no change in the overall temperature of a hog while it is in the singer.
4. Heat loss from cabinet and duct to room by convection and radiation.

Duct - 2 ft x 3 ft x 20 ft

-exhaust air - 900°F ($C_p = 0.259$, Heldman, 1975)

-ambient air - 80°F ($C_{p,p} = 0.24$, Heldman, 1975)

-surface of duct - 900°F
 -total area - 200 ft^2

a. Convection -

$$\text{walls } h_c = 0.3(t_1 - t_2)^{\frac{1}{4}} = 0.3(900 - 80)^{\frac{1}{4}} =$$

$$1.605 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$q_c = (1.605 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(200 \text{ ft}^2)(900 - 80^{\circ}\text{F})(7.17 \text{ hrs})$$

$$= 1,887,287 \text{ Btu/day}$$

b. Radiation - assume; $e = 0.80$ sheet steel, oxidized
 (Perry and Chilton, 1973)

$$q_r = 0.174(200 \text{ ft}^2)(0.80)(1360^4 - 540^4)(7.17 \text{ hrs})/10^8 =$$

$$6,659,062 \text{ Btu/day}$$

5. Heat loss to heating excess air -

$$48,464,550 \text{ Btu/day} - 1,887,287 \text{ Btu/day} - 6,659,062 \text{ Btu/day} =$$

$$39,918,201 \text{ Btu/day}$$

$$39,918,201 \text{ Btu} = m_{\text{air}}^{900} (0.259 \text{ Btu/lb-}^{\circ}\text{F})(900 - 60^{\circ}\text{F}) -$$

$$m_{\text{air}}^{80} (0.24 \text{ Btu/lb-}^{\circ}\text{F})(80 - 60^{\circ}\text{F})$$

$$39,918,201 \text{ Btu} = 212.76 m_{\text{air}}$$

$$187,621 \text{ lbs} = m_{\text{air}}$$

E. Polishing Operation

1. Electrical usage -

1 - 10 hp polisher 1 drive - 470V, 13A
 1 - 25 hp polisher 2 drive - 470V, 15A

Typical running time 7.25 hours

$28A(470V)(80\% \text{ P.F.})(\sqrt{3})(7.25 \text{ hrs})/3021 \text{ head}$

43.76 WH/head

2. Water usage -

Typical average water usage was 11,107 gallons per day as measured by the water totalizing meter. Values ranged from 7272 to 19,625 gallons per day.

For a typical day, the amount used per head was -

$11,107 \text{ gal}/3021 \text{ head} = 3.676 \text{ gal/head}$

F. Shaving Operation

1. Steam usage -

This operation has six knife boxes identical to the one in the sticking area. A boxes are turned on at the same time.

$6(15,155.4 \text{ Btu/day}) = 90,932.4 \text{ Btu/day}$ or 30.1 Btu/head

G. Rinse Cabinet Operation

1. Water usage -

Typical average water usage was 6792 gallons per day as measured by the totalizing meter. Values ranged from 4510 to 9700 gallons per day.

For a typical day, the amount used per head was:

$6792 \text{ gal}/3021 \text{ head} = 2.248 \text{ gal/head}$

H. Sanitation and General Utilities

1. Sanitation water -

a. Water for cleanup at scold tank averaged 4370 gallons per day - not heated.

b. Water at cleanup station next to singer used 26,835 gallons per day.

- c. Assume bleed pit hose requires the same amount.

$$\begin{aligned}\text{TOTAL water} &= 4370 + 2(26,835) = 58,040 \text{ gal/day or} \\ &19.21 \text{ gal/head}\end{aligned}$$

2. Steam usage -

Steam used only for bleed pit and singer hoses -

$$\begin{aligned}q &= 58,040 \text{ gal}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(130 - 60^{\circ}\text{F}) = \\ &33,843,124 \text{ Btu/day or } 11,203 \text{ Btu/head}\end{aligned}$$

3. Electrical usage -

- a. Electrical usage - lights - 18 hours per day -

40 - 40 watt fluorescent tubes
10 - 250 watt mercury vapor

$$40(40)(18) + 10(250)(18) = 73,800 \text{ WH/day}$$

- b. Electrical usage - ventilating fans - 24 hrs/day -

5 - 0.5 hp fans - 230V, 4.9A

$$5(4.9\text{A})(230\text{V})(80\%)(24 \text{ hrs}) = 108.192 \text{ WH/day}$$

$$\text{TOTAL electrical use} = 181,992 \text{ WH/day or } 60.24 \text{ WH/head}$$

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II. Bacon Manufacturing Process - Unit Operations

Unless otherwise stated, the average daily production of 68,817 pounds of bacon was used for all computations.

A. Curing Operation

1. Refrigeration usage -

3 units each moving 16,450 CFM measured at the exhaust -

Average RH = 95%

TIME	TEMPERATURE IN	TEMPERATURE OUT
12:20 AM	52	48
2:30	54	48
5:30	49	44
8:20	51	50
9:00	49	46
10:20	49	48
11:30	54	52
12:30 PM	52	50
1:30	49	45
2:30	53	49
3:30	50	48
9:00	48	44
11:00	51	46
Average	50.8	47.5

(From Zimmerman and Lavine, 1945)

Enthalpy of inlet air, 51°F, 95% RH, is -

$$h = 4.5639 \text{ Btu/lbDA} + 0.007427 \text{ lbwv/lbDA}(1083.5 \text{ Btu/lbwv}) = 12.51 \text{ Btu/lbDA}$$

Since 0.007427 lbwv/lbDA is greater than the water vapor in saturated air at 48°F, it is assumed that the air leaving the evaporator is saturated, with enthalpy 11.505 Btu/lbDA and specific volume of 12.838 ft³/lbDA. Excess water is condensed in the evaporators.

Total air flow per day through the three units is -

$$\frac{3(16.450 \text{ ft}^3/\text{min})(60 \text{ min/hr})(24 \text{ hr})}{12.938 \text{ ft}^3/\text{lbDA}} = 5,492,657 \text{ lbs}$$

The energy removed from the condensed water leaving the evaporators is -

$$5,492,657 \text{ lbDA} (0.007427 \text{ lbwv/lbDA} - 0.007098 \text{ lbwv/lbDA}) \times (1066.1 \text{ Btu/lbwv}) = 1,926,532 \text{ Btu/day}$$

The energy removed from the air is -

$$5,492,657 \text{ lbDA} (12.61 \text{ Btu/lbDA} - 11.505 \text{ Btu/lbDA}) = 6,069,386 \text{ Btu/day}$$

Total refrigeration load is -

$$7,995,918 \text{ Btu/day or } 116.2 \text{ Btu/lb bacon}$$

2. Electrical usage -

- a. 6 - 0.5 hp refrigeration blowers - 230V, 1.2A

$$6(1.2A)(230V)(80\% \text{ P.F.})(24 \text{ hrs/day}) = 31,795 \text{ WH/day or } 0.462 \text{ WH/lb}$$

- b. 2 - 2.0 hp injection machines - 230V, 1.2A

$$2(1.2A)(230V)(80\% \text{ P.F.})(8 \text{ hrs/day}) = 3533 \text{ WH/day or } 0.051 \text{ WH/lb}$$

B. Smoking Operation

A typical smokehouse run lasts 6 to 11 hours depending on the type of bacon. The average weight of pumped bellies put into a house was 11,874 lbs at 50°F. The exit weight averaged 10,908 pounds (8.1% loss) at 140°F.

For this specific balance, data was collected for a smoke run with 10,278 pounds bacon entering and 9368 pounds bacon removed from the house. The run lasted 8.167 hours. From Armour production data, the weight of bacon off-smoke is 1.081 times the finished, packaged weight.

1. Electrical usage - average run is 8.17 hrs

- 1 - 30.0 hp recirculation blower - 470V, 25A
- 1 - 1.0 hp damper motor - 470V, 2A
- 1 - 0.5 hp burner blower - 470V, 1A

$$28A(470V)(80\% \text{ P.F.})(\sqrt{3})(8.17 \text{ hrs}) = 148,980 \text{ WH/run}$$

Per pound finished product - the average;

$$\frac{148,980 \text{ WH}}{\frac{10,278 \text{ lb}}{1.081 \frac{\text{lb}}{\text{lb}}}} = 15.7 \text{ WH/lb}$$

The heat input to the house due to electricity was estimated as -

$$148,980 \text{ WH}(.50)(3.414 \text{ Btu/WH}) = 254,309 \text{ Btu/run}$$

2. Gas usage -

The total gas flow to the house was measured as 3177.3 ft³ at 15 psig.

At 1000 Btu/ft³, the total heat input was 3,177,300 Btu.

In terms of pounds of product, the gas use was -

$$\frac{3,177,300 \text{ Btu}}{\frac{9,368 \text{ lb}}{1.081 \frac{\text{lb}}{\text{lb}}}} = 366.6 \text{ Btu/lb}$$

Bacon Smokehouse Runs -

	Time hrs	Gas Used SCF	Hot Weight	Finished Weight	Btu/lb
1.	8	2736.7	10,651	9,853	277.8
2.	7.6	3134.4	12,870	11,548	271.4
3.	7.67	3443.4	12,870	11,906	289.2
4.	7.33	3178.1	12,488	11,552	275.1
5.	8.50	3512.7	10,750	9,944	353.2
6.	7.33	2731.5	9,380	8,677	314.8
7.	7.67	2423.3	8,330	7,706	314.5
8.	8.17	3177.3	9,368	8,666	366.6
				Ave.	307.8

3. Heating and drying bacon -

Bacon was heated from 50°F to 140°F. The water evaporated from the product amounted to -

$$10,278 \text{ lb} - 9,368 \text{ lb} = 910 \text{ lb water}$$

The composition of the bacon entering the house was 61.7% fat, 36.7% water, and 1.6% solids.

$$C_p = 0.5X_F + 0.3X_S + 1.0X_m \text{ (Charm, 1971)} =$$

$$0.5(.617) + 0.3(.016) + 1(.367) = 0.680 \text{ Btu/lb-}^\circ\text{F}$$

The composition of the bacon removed from the house was 67.6% fat, 1.8% solids and 30.6% water.

$$C_p = 0.5(.676) + 0.3(.018) + 1(.306) = 0.649 \text{ Btu/lb-}^\circ\text{F}$$

The amount of heat required to change the temperature of the bacon was -

$$9368 \text{ lb}(0.649 \text{ Btu/lb-}^\circ\text{F})(140 - 32) - [(10,278 \text{ lb}) \times (0.680 \text{ Btu/lb-}^\circ\text{F})(50 - 32^\circ\text{F})] = 530,819 \text{ Btu's}$$

4. Fat is melted during the heating process and the energy of fusion required is 81 Btu's per pound of fat -

$$10,278 \text{ lbs}(61.7\% \text{ F})(81 \text{ Btu/lb}_F) = 513,664 \text{ Btu's}$$

5. Air enters the house at a relatively constant rate over the entire smoke cycle. The average flow was 2059.3 CFM at 87°F DB, 70% RH. The pounds of air flow was (Zimmerman and Lavine, 1945) -

$$V = 13.778 \text{ ft}^3/\text{lbDA} + 0.01967 \text{ lbwv/lbDA} (22.122 \text{ ft}^3/\text{lbwv}) = 14.21 \text{ ft}^3/\text{lbDA}$$

$$\frac{2059.3 \text{ ft}^3/\text{min} (60 \text{ min/hr})}{14.21 \text{ ft}^3/\text{lbDA}} = 8695.1 \text{ lbDA/hr with 171 lb water/hr}$$

The enthalpy of the entering air was -

$$h = 13.217 \text{ Btu/lbDA} + 0.01967 \text{ lbwv/lbDA} (1099.1 \text{ Btu/lbwv}) = 34.84 \text{ Btu/lbDA}$$

Total heat in air entering house was -

$$8.167 \text{ hrs} (8655 \text{ lb/hr}) (34.84 \text{ Btu/lb}) = 2,473,959 \text{ Btu's}$$

Total water in air entering house was -

$$8.167 \text{ hrs} (171 \text{ lb/hr}) = 1396.6 \text{ lb water}$$

6. Air leaves the house at four different temperature regimes -

2 hours, 140°F DB, 94°F WB
 2.67 hours, 140°F DB, 115°F WB
 2.25 hours, 130°F DB, 113°F WB
 1.25 hours, 130°F DB, 110°F WB

The air flowing out of the house is equal to the pounds of dry air entering plus the carbon dioxide formed from combustion of the gas.

Assuming complete combustion, the amount of carbon added by the natural gas in the form of CO_2 was -

Assume gas is 83.4% CH_4 and 16.6% C_2H_6 , then for 1.0 SCF of gas (Strock, 1959) -

$$\begin{aligned} \text{CH}_4 &- 0.834 \text{ ft}^3 (0.749 \text{ lb c/lb gas}) = 0.6247 \\ \text{C}_2\text{H}_6 &- 0.166 \text{ ft}^3 (0.799 \text{ lb c/lb gas}) = \underline{0.1326} \\ &0.7573 \text{ lb c/lb gas} \end{aligned}$$

1.0 SCF gas weighs -

$$\begin{aligned} 0.834 \text{ ft}^3 (0.0423 \text{ lb/ft}^3) &= 0.035278 \text{ lb} \\ 0.166 \text{ ft}^3 (0.0801 \text{ lb/ft}^3) &= \underline{0.013297 \text{ lb}} \\ &0.048575 \text{ lb/ft}^3 \end{aligned}$$

$$3177.3 \text{ ft}^3 (0.04575 \text{ lb/ft}^3) (0.7573 \text{ lb c/lb gas}) = 116.9 \text{ lb c}$$

If the CO_2 is distributed evenly over the 8.167 hour run, the hourly addition is 14.3 pounds additional.

Total flow per hour out of house is -

$$8695.1 + 14.3 = 8709.4 \text{ lbDA/hr}$$

7. At each of the four smoking periods -

a. The air leaving the house in the first 2 hours takes with it heat and water -

At 140°F DB, 94°F WB, the air contains 0.02442 lbwv/lbDA and has an enthalpy of -

$$\begin{aligned} h &= 25.968 \text{ Btu/lbDA} + 0.02442 \text{ lbwv/lbDA}(1121.7 \text{ Btu/lbwv}) \\ &= 53.36 \text{ Btu/lbDA} \end{aligned}$$

$$\begin{aligned} \text{Water in air - 2 hours } (8709.4 \text{ lbDA/hr}) (0.02442 \text{ lbwv/lbDA}) \\ &= 425.4 \text{ lb water} \end{aligned}$$

$$\begin{aligned} \text{Energy in air - 2 hours } (8709.4 \text{ lbDA/hr}) (53.36 \text{ Btu/lbDA}) \\ &= 929,467 \text{ Btu's} \end{aligned}$$

b. During the next 2.67 hours -

At 140°F DB, 115°F WB, the air contains 0.06296 lbwv/lbDA and has an enthalpy of -

$$\begin{aligned} h &= 25.968 \text{ Btu/lbDA} + 0.06296 \text{ lbwv/lbDA}(1121.7 \text{ Btu/lbwv}) \\ &= 96.59 \text{ Btu/lbDA} \end{aligned}$$

$$\begin{aligned} \text{Water in air - 2.67 hr}(8709.4 \text{ lbDA/hr}) (0.06296 \text{ lbwv/lbDA}) \\ &= 1464.1 \text{ lb water} \end{aligned}$$

$$\begin{aligned} \text{Energy in air - 2.67 hr}(8709.4 \text{ lbDA/hr}) (96.59 \text{ Btu/lbDA}) \\ &= 2,246,113 \text{ Btu's} \end{aligned}$$

c. During the next 2.25 hours -

At 130°F DB, 113°F WB, the air contains 0.06081 lbwv/lbDA and has an enthalpy of -

$$\begin{aligned} h &= 23.560 \text{ Btu/lbDA} + 0.06081 \text{ lbwv/lbDA}(1117.6 \text{ Btu/lbwv}) \\ &= 91.52 \text{ Btu/lbDA} \end{aligned}$$

Water in air - 2.25 hr(8709.4 lbDA/hr) (0.06081 lbwv/lbDA)

= 1191.6 lb water

Energy in air - 2.25 hr (8709.4 lbDA/hr) (91.52 Btu/lbDA).

- 1,793,440 Btu's

d. During the last 1.25 hours -

At 130°F DB, 110°F WB, the air contains 0.05422 lbwv/lbDA and has an enthalpy of -

$h = 23.560 \text{ Btu/lbDA} + 0.05422 \text{ lbwv/lbDA} (117.6 \text{ Btu/lbDA})$

= 84.16 Btu/lbDA

Water in air - 1.25 hrs (8709.4 lbDA/hr) (0.05422 lbwv/lbDA)

= 590.3 lb water

Energy in air - 1.25 hrs (8709.4 lbDA/hr) (84.16 Btu/lbDA)

= 915,715 Btu's

TOTAL water in air out - 3671.4 lb water

TOTAL energy in air out - 5,884,735 Btu's

e. Water from combustion (from Strock, 1959) -

Per pound natural gas -

$\text{CH}_4 - 0.035278 \text{ lb} (2.25 \text{ lbwv/lb gas}) = 0.079376 \text{ lb}$

$\text{C}_2\text{H}_6 - 0.013297 \text{ lb} (1.80 \text{ lbwv/lb gas}) = \underline{0.023935 \text{ lb}}$

0.103311 lb
water/lb gas

$3177.3 \text{ ft}^3 (0.048575 \text{ lb/ft}^3) (0.103311 \text{ lb water/lb gas})$

= 15.9 lb water

8. Convective and radiant losses from house -

a. Convective loss -

House is 25.58 ft x 10.0 ft x 10.75 ft. Surface temperature 130°F top, 110°F sides, 90°F bottom.

$$h_{c \text{ top}} = 0.38(130 - 90)^{\frac{1}{4}} = 0.956 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$h_{c \text{ sides}} = 0.3(110 - 80)^{\frac{1}{4}} = 0.702 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$q_c = (0.956 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(25.58 \text{ ft})(10.75 \text{ ft}) \times \\ (130 - 90^{\circ}\text{F}) + (0.702 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(2)[(10.75 \text{ ft}) \\ (10.0 \text{ ft}) + (25.58 \text{ ft})(10.0 \text{ ft})(110 - 80^{\circ}\text{F})] = \\ 25,818 \text{ Btu/hr or } 210,930 \text{ Btu's in } 8.17 \text{ hours}$$

b. Radiant loss -

$$e = 0.85 \text{ for stainless steel (Heldman, 1975)}$$

$$q_r = \frac{(0.174)(0.85)}{10^8} [(590^4 - 540^4)(275 \text{ ft}^2) + \\ (570^4 - 540^4)(727 \text{ ft}^2) + (550^4 - 540^4)(275 \text{ ft}^2)] = \\ 36,774 \text{ Btu/hr or } 300,445 \text{ Btu's in } 8.17 \text{ hours}$$

c. Total convective and radiant losses for entire run -
511,375 Btu's

9. Energy balance -

Balance to obtain the steam input required for humidity control -

$$\text{Bacon}_{in} + \text{Air}_{in} + \text{Elec}_{in} + \text{Gas}_{in} + \text{Steam}_{in} = \text{Bacon}_{out} +$$

$$\text{Air}_{out} + \text{Fusion of fat} + \text{Losses}$$

$$\text{Steam}_{in} = (\text{Bacon}_{out} - \text{Bacon}_{in}) + (\text{Air}_{out} - \text{Air}_{in}) +$$

$$\text{Fusion of fat}_{in} + \text{Losses} - \text{Gas}_{in} - \text{Elec}_{in} =$$

$$530,819 \text{ Btu's} + (5,884,735 \text{ Btu's} - 2,473,959 \text{ Btu's}) +$$

$$513,664 \text{ Btu's} + 511,375 \text{ Btu's} - 3,177,300 \text{ Btu's} -$$

$$254,309 \text{ Btu's} = 1,535,025 \text{ Btu's}$$

10. Water balance -

$$\text{Air}_{\text{in}} + \text{Steam}_{\text{in}} + \text{Combustion} + \text{Bacon}_{\text{in}} = \text{Air}_{\text{out}} + \text{Bacon}_{\text{out}}$$

$$\text{Steam}_{\text{in}} = (\text{Air}_{\text{out}} - \text{Air}_{\text{in}}) + (\text{Bacon}_{\text{out}} - \text{Bacon}_{\text{in}}) -$$

$$\text{Combustion} = (3671.4 - 1396.6) + (-910) - 15.9 =$$

1348.9 lb water

Since the steam is fed to the smokehouse at 90 psig, the pounds of water equivalent to 1,535,025 Btu's is -

$$\frac{1,535,025 \text{ Btu's}}{1,188 \text{ Btu's/lb}} = 1292.1 \text{ pounds water}$$

This does not precisely equal the 1348.9 pounds of water obtained from the water balance but is relatively close.

C. Skin and Brine Chill Operation

1. Electrical usage -

a. Skinning -

1 - 2-0 hp skinner - 470V, 1.2A

$$(1.2A) (470V) (80\% \text{ P.F.}) (\sqrt{3}) (9 \text{ hrs/day}) = 7033.5 \text{ WH/day}$$

In terms of finished product, the electrical usage is -

$$\frac{7033.5 \text{ WH/day}}{68,917 \text{ lb/day}} = 0.102 \text{ WH/lb}$$

b. Brine chiller -

Average running time 14.9 hours per day including cleanup.

2 - 7.5 hp brine pumps - 470V, 10.5A

$$2(10.5A) (470V) (80\% \text{ P.F.}) (\sqrt{3}) (14.9 \text{ hrs/day}) =$$

203,776 WH/day or 2.96 WH/lb

Electrical input as energy to warm brine -

$$203,776 \text{ WH}(0.5) (3.414 \text{ Btu/WH}) = 347,845 \text{ Btu/day}$$

2. Refrigeration usage -

Average flow rate of brine for a typical 2 hr. run is 357.8 gpm. Cabinet is usually loaded with approximately 13,200 pounds of bacon. At this stage in the process, the bacon represents an average of 1.014 times the finished weight. From temperature data recorded at the plant, the average temperature of brine going into the cabinet was 25.2°F. The average exit temperature was 21.9°F, 6% brine,

$$C_p - 0.946 \text{ Btu/lb-}^{\circ}\text{F}, \quad 1 \text{ gal} = 8.1/2 \text{ lbs.}$$

$$120 \text{ min} (357.8 \text{ gal/min}) (8.72 \text{ lb/gal}) (0.946 \text{ Btu/lb-}^{\circ}\text{F}) \times \\ (21.0 - 18.5^{\circ}\text{F}) = 885,460 \text{ Btu's per run}$$

Per pound finished product -

$$\frac{885,460 \text{ Btu's}}{\frac{13,200 \text{ lb}}{1.014 \frac{\text{lb}}{\text{lb}}}} = 68.0 \text{ Btu/lb}$$

3. Actual energy removed from bacon in chilling from 51°F to 25°F internal temperature -

$$13,200 \text{ lb} (0.649 \text{ Btu/lb-}^{\circ}\text{F}) (51 - 25^{\circ}\text{F}) = 222,737 \text{ Btu/run}$$

The remaining input as heat to the brine must be from the pumps and from ambient conditions.

D. Blast Chill Operation

1. Electrical usage -

4 - 2 hp blowers - 230V, 3.4A

$$4(3.4\text{A})(230\text{V})(80\% \text{ P.F.})(24 \text{ hrs}) = 60,058 \text{ WH/day or}$$

$$0.873 \text{ WH/lb}$$

Since entire motor is within the chill room, all electrical input appears as heat load to room.

$$60,058 \text{ WH/day } (3.414 \text{ Btu/WH}) = 205,038 \text{ Btu/day}$$

2. Refrigeration usage - (80% RH)

TIME	TEMPERATURE IN	TEMPERATURE OUT
12:25 AM	23	20
2:37	22	21
5:32	20	16
8:20	20	18
9:15	20	17
10:25	19	17
11:35	20	18
12:35 PM	21	20
1:35	23	22
2:35	23	21
3:35	23	22
9:12	20	18
11:09	22	19
AVERAGE	21.2	19.2

Average flow rate for the two units is 20,250 CFM each, (from Zimmerman and Lavine, 1949). The enthalpy of the entering air -

$$h = 2.642 \text{ Btu/lbDA} + 0.002064 \text{ lbwv/lbDA } (1070.2 \text{ Btu/lbwv})$$

$$= 0.4331 \text{ Btu/lbDA}$$

Since the refrigeration units are direct contact brine units, it is assumed that the air leaving is saturated -

$$h = -0.7797 \text{ Btu/lbDA}$$

Specific volume of entering air is -

$$v = 12.110 \text{ ft}^3/\text{lbDA} + 0.002064 \text{ lbwv/lbDA } (19.485 \text{ ft}^3/\text{lbwv})$$

$$= 12.15 \text{ ft}^3/\text{lbDA}$$

Air flow rate is -

$$\frac{20,250 \text{ ft}^3/\text{min } (60 \text{ min/hr})}{12.15 \text{ ft}^3/\text{lbDA}} = 100,000 \text{ lbDA/hr}$$

$$\begin{aligned}
 q &= 2(24 \text{ hrs})(100,000 \text{ lbDA/hr})(-0.4331 - (-0.7797) \text{ Btu/lbDA}) \\
 &= 1,663,680 \text{ Btu/day or } 24.2 \text{ Btu/lb bacon}
 \end{aligned}$$

3. Actual energy removed from bacon -

Bacon is chilled from 25°F (out of brine chiller) to 18°F -

$$\begin{aligned}
 &68,817 \text{ lb/day } (1.014 \text{ lb/lb finished}) (0.649 \text{ Btu/lb-}^{\circ}\text{F}) \times \\
 &(25 - 18^{\circ}\text{F}) = 317,012 \text{ Btu/day}
 \end{aligned}$$

All the rest of the heat load is from infiltration into the room and conduction through the walls. Motor heat also plays a part.

E. Tempering Operations

1. Electrical usage -

There are four refrigeration units in tempering with a total of 10 motors.

10 - 0.5 hp fans - 230V, 1.2A

$$10(1.2\text{A})(230\text{V})(80\% \text{ P.F.})(24 \text{ hrs/day}) = 52,992 \text{ WH/day or}$$

$$0.770 \text{ WH/lb}$$

2. Refrigeration usage - (75% RH)

TIME	TEMPERATURE IN	TEMPERATURE OUT
12:28 AM	30	29
2:41	24	23
5:25	25	22
8:20	25	25
9:30	23	23
10:30	23	23
11:40	29	23
12:40 PM	26	25
1:40	24	24
2:40	30	28
3:40	26	20
9:10	24	22
11:06	25	22
AVERAGE	25.7	23.7

Two of the four units had flow rate of 13,400 CFM measured at the outlet and two of the units had flow rates of 9800 CFM measured at the outlet.

(from Zimmerman and Lavine, 1949) Enthalpy of inlet air, 26°F, 75% RH is -

$$h = -1.4411 \text{ Btu/lbDA} + 0.002263 \text{ lbwv/lbDA} (1072.5 \text{ Btu/lbwv}) \\ = 0.9860 \text{ Btu/lbDA}$$

Enthalpy of outlet air, 24°F -

$$h = -1.922 \text{ Btu/lbDA} + 0.002263 \text{ lbwv/lbDA} (1071.6 \text{ Btu/lbwv}) \\ = 0.5030 \text{ Btu/lbDA}$$

Specific volume of exhaust air -

$$v = 12.186 \text{ ft}^3/\text{lbDA} + 0.002263 \text{ lbwv/lbDA} (19.606 \text{ ft}^3/\text{lbwv}) \\ = 12.23 \text{ ft}^3/\text{lbDA}$$

Air flow for the four units per hour is -

$$\frac{2(13,400 \text{ ft}^3/\text{min})(60 \text{ min/hr}) + 2(9800 \text{ ft}^3/\text{min})(60 \text{ min/hr})}{12.23 \text{ ft}^3/\text{lbDA}} =$$

$$226,791 \text{ lbDA/hr}$$

The refrigeration load for tempering is -

$$225,791 \text{ lbDA/hr} (24 \text{ hr}) (0.9860 - 0.5030 \text{ Btu/lbDA}) =$$

$$2,617,366 \text{ Btu/day or } 38.0 \text{ Btu/lb}$$

The internal temperature of the bacon actually rises in the tempering room. For this reason, the bacon contributes nothing to the overall refrigeration load.

F. Packaging Operation

1. Room refrigeration -

a. Electrical usage -

6 - 0.5 hp fans - 230V, 1.2A

6(1.7A) (240V) (80% P.F.) (24 hrs) = 45,043 WH/day or

0.654 WH/lb bacon

b. Refrigeration usage -

Three refrigeration units, each moving 9200 CFM
measured at the exhaust. Room air averages 73% RH.

TIME	TEMPERATURE IN	TEMPERATURE OUT
12:33 AM	49	46
2:45	57	53 (cleaning)
5:22	53	47
6:30	54	49
7:30	53	49
8:30	53	50
9:30	52	48
10:30	54	49
11:30	51	46
12:30 PM	54	48
1:30	54	51
2:30	53	46
3:30	53	47
9:30	55	47
11:20	<u>55</u>	<u>50</u>
AVERAGE	53.3	48.4

Enthalpy of inlet air at 53°F, 73% RH is -

$$h = 5.0444 \text{ Btu/lbDA} + 0.006455 \text{ lbwv/lbDA} \times$$

$$(1084.4 \text{ Btu/lbwv}) = 12.04 \text{ Btu/lbDA}$$

Enthalpy of exhaust air at 48°F -

$$h = 3.8432 \text{ Btu/lbDA} + 0.006455 \text{ lbwv/lbDA} \times$$

$$(1082.2 \text{ Btu/lbwv}) = 10.83 \text{ Btu/lbDA}$$

Specific volume of outlet air was -

$$v = 12.792 \text{ ft}^3/\text{lbDA} + 0.006455 \text{ lbwv}/\text{lbDA} \times \\ (20.565 \text{ ft}^3/\text{lbwv}) = 12.92 \text{ ft}^3/\text{lbDA}$$

Total hourly flow of air through the three units was -

$$\frac{(3)9200 \text{ ft}^3/\text{min} (60 \text{ min}/\text{hr})}{12.92 \text{ ft}^3/\text{lbDA}} = 128,173 \text{ lbDA}/\text{hr}$$

Total refrigeration load per day was -

$$128,173 \text{ lbDA}/\text{hr} (24 \text{ hrs}) (12.04 \text{ Btu}/\text{lbDA} - 10.83 \text{ Btu}/\text{lbDA}) \\ = 3,722,144 \text{ Btu's}/\text{day} \text{ or } 54.1 \text{ Btu}/\text{lb}$$

2. Equipment electrical usage -

- 3 - 5.0 hp hydraulic bacon press - 470V, 4.2A
- 4 - 5.0 hp bacon slicers - 470V, 3.9A
- 3 - 1.0 hp package sealer - 470V, 0.98A
- 3 - 0.5 hp packaging drive - 470V, 0.72A
- 1 - 10.0 hp vacuum pump - 470V, 8.3A
- 1 - 15 hp vacuum pump - 470V, 12.5A

The vacuum pumps run 18 hours per day while the remaining equipment runs 15 hours per day.

Average production of bacon per day without slab bacon is 62,461 lbs.

$$(33.3\text{A}) (470\text{V}) (80\% \text{ P.F.}) (\sqrt{3}) (15 \text{ hrs}/\text{day}) = 325,300 \text{ WH}/\text{day}$$

$$(20.8\text{A}) (470\text{V}) (80\% \text{ P.F.}) (\sqrt{3}) (18 \text{ hrs}/\text{day}) = 243,828 \text{ WH}/\text{day}$$

Total electrical use by equipment is -

$$569,128 \text{ WH}/\text{day} \text{ or } 9.11 \text{ WH}/\text{lb}$$

3. Sanitation and general utilities -

a. Sanitation -

The amount of water used by the cleanup hoses was as follows:

curing area - 2 hoses - 4130 gal/day
 smokehouse area - 2 hoses - 1898 gal/day
 packaging area - 5 hoses - 10,324 gal/day
 skinning area - 3 hoses - 2850 gal/day

TOTAL water used - 19,202 gal/day or 0.28 gal/lb

The steam required to heat this water from 70°F to 140°F was -

19,202 gal/day (9.33 lb/gal) (1.0 Btu/lb-°F) (140 - 70°F) =
 11,196,686 Btu/day or 162.7 Btu/lb

b. Electrical usage for lighting and ventilation -

1. Cure room -

24 - 250 watt mercury vapor lamps
 8 - 40 watt fluorescent tubes
 3 - 0.5 hp fans, 230V, 4.9A

[24 (250 watt) + 8(40 watt)] (10 hrs/day) +
 3(4.9A) (230V) (80% P.F.) (24 hrs/day) = 128,115 WH/day

2. Smokehouse area -

23 - 350 watt incandescent bulbs
 8 - 40 watt fluorescent tubes
 2 - 0.5 hp fans - 230V, 4.9A

[23 (350 watt) + 8(40 watt)] + 2(230V) (4.9A) (80% P.F.)
 (24 hrs/day) = 244,157 WH/day

3. Chill and skin area -

36 - 250 watt mercury vapor lights
 12 - 40 watt fluorescent tubes
 2 - 0.5 hp fans - 230V, 4.9A

[36(250 watt) + 12(40 watt)] (18 hrs/day) +
 2(4.9A) (230V) (80% P.F.) (24 hrs/day) = 213,917 WH/day

4. Blast chill and tempering -

- 11 - 250 incandescent - 8 hrs/day
- 25 - 250 mercury vapor - 18 hrs/day
- 3 - 0.5 hp fans, 230V, 4.9A - 24 hrs/day

$$[11(250 \text{ watt})(8 \text{ hrs/day}) + 25(250 \text{ watt})(18 \text{ hrs/day})]$$

$$3(4.9A)(230V)(80\% \text{ P.F.})(24 \text{ hrs/day}) = 199,415 \text{ WH/day}$$

5. Packaging area -

- 30 - 250 watt mercury vapor - 20 hrs/day
- 2 - 40 watt fluorescent tubes - 20 hrs/day
- 6 - 0.5 hp fans, 230V, 4.9A - 24 hrs/day

$$[30(250 \text{ watt}) + 2(40 \text{ watt})](20 \text{ hrs/day}) +$$

$$6(4.9A)(230V)(80\% \text{ P.F.})(24 \text{ hrs/day}) = 281,430 \text{ WH/day}$$

TOTAL electrical demand per day -

1,067,035 WH/day or 15.5 WH/lb

III. Frankfurter Manufacturing Process - Unit Operations

Unless otherwise stated, the average daily production of 47,276 pounds of franks was used for all computations.

Since the refrigerated rooms in which franks are made are also used for the manufacturing of other sausage products, the energy requirement due to franks was based upon production ratios.

1977 Production

Total fresh and smoked sausage - 18,007,002

Total franks - 11,819,136

Percent franks - 65.6

A. Raw Materials Cooler Operation

1. Electrical usage -

6 - 0.5 hp fans - 230V, 1.7A

$6(230V)(1.7A)(80\% \text{ P.F.})(24 \text{ hrs/day})(0.656) = 29,548 \text{ WH/day}$

or 0.625 WH/lb

3. Refrigeration usage -

There are three refrigeration units in the raw material cooler each with an air flow of 17,300 CFM measured at inlet. Air in the raw materials cooler was saturated most of the time.

TIME	TEMPERATURE IN	TEMPERATURE OUT
5:30 AM	41	38
6:30	41	40
7:30	40	39
8:30	41	39
9:30	40	39
10:30	41	41
11:30	40	39
12:30 PM	42	41
1:30	41	39
2:30	<u>40</u>	<u>39</u>
AVERAGE	41	39

Enthalpy of inlet air, 41°F, 100% FH, 0.005420 lbwv/lbDA

$$h = 8.010 \text{ Btu/lbDA}$$

Specific volume of inlet air -

$$v = 12.725 \text{ ft}^3/\text{lbDA}$$

Total daily air flow through evaporators -

$$\frac{3(17,300 \text{ ft}^3/\text{min})(60 \text{ min/hr})(24 \text{ hrs})}{12.725 \text{ ft}^3/\text{lbDA}} = 5,873,163 \text{ lbDA}$$

Enthalpy of air out was saturated since inlet air contained more moisture than outlet air could hold (at saturation, 0.005011 lbwv/lbDA

$$h = 7.084 \text{ Btu/lbDA}$$

Total refrigeration requirement for cooling air -

$$5,873,163 \text{ lbDA} (8.010 - 7.084 \text{ Btu/lbDA}) = 5,438,549 \text{ Btu's}$$

Total refrigeration requirement for condensing water -

$$5,873,163 \text{ lbDA} (0.005420 \text{ lbwv/lbDA} - 0.005011 \text{ lbwv/lbDA}) \times (1071.2 \text{ Btu/lbwv}) = 2,573,155 \text{ Btu's}$$

Total requirement is 8,011,704 Btu's/day

For franks the requirement is -

$$8,011,704 \text{ Btu} (0.656) = 5,255,678 \text{ Btu's or } 111.2 \text{ Btu/lb}$$

B. Sausage Kitchen Operation

1. Refrigeration requirements -

a. Electrical usage -

24 - 0.5 hp fans - 230V, 1.2A

$24(1.2A)(230V)(80\% \text{ P.F.})(24 \text{ hrs/day})(0.656) =$

83,431 WH/day or 1.76 WH/lb

b. Refrigeration usage -

There are a total of 11 refrigeration units in the sausage kitchen, each with an average flow of 14,500 CFM measured in the exhaust. The average relative humidity is 87%.

TIME	TEMPERATURE IN	TEMPERATURE OUT
12:05 AM	48	46
2:15	52	48
5:00	48	44
8:50	49	46
9:45	48	40
10:45	49	47
12:00 PM	49	47
1:00	49	45
2:00	51	45
3:00	51	49
4:00	46	44
8:30	48	44
10:50	48	45
AVERAGE	48.9	45.4

Enthalpy of inlet air, 49°F , 87% RH was -

$$h = 4.0834 \text{ Btu/lbDA} + 0.006377 \text{ lbwv/lbDA} (1082.7 \text{ Btu/lbwv})$$

$$= 10.99 \text{ Btu/lbDA}$$

Since the inlet air contains more water than the outlet air can hold, condensation occurs and the outlet air is saturated (0.006329 lbwv/lbDA).

Enthalpy of outlet air, 45°F, was -

$$h = 9.963 \text{ Btu/lbDA}$$

Specific volume of outlet air was -

$$v = 12.846 \text{ ft}^3/\text{lbDA}$$

Total daily flow of air was -

$$\frac{11(14,500 \text{ ft}^3/\text{min})(60 \text{ min/hr})(24 \text{ hrs})}{12,846 \text{ ft}^3/\text{lbDA}} = 17,879,495 \text{ lbDA}$$

Refrigeration load for chilling air -

$$17,879,495 \text{ lbDA} (10.99 \text{ Btu/lbDA} - 9.96 \text{ Btu/lbDA}) =$$

$$18,415,880 \text{ Btu/day}$$

Refrigeration load for condensing water which is removed from the air -

$$17,879,495 \text{ lbDA} (0.006377 \text{ lbwv/lbDA} - 0.006329 \text{ lbwv/lbDA})$$

$$\times (1067.8 \text{ Btu/lbwv}) = 916,403 \text{ Btu/day}$$

Total refrigeration load for franks -

$$19,332,283 \text{ Btu's} (0.656) = 12,681,977 \text{ Btu's or}$$

$$268.2 \text{ Btu/lb}$$

2. Equipment requirements -

All the following electrical equipment is used strictly for franks so that no correction factor is required.

a. Electrical usage -

- 1 - 50.0 hp grinder - 470V, 28A - 2.77 hrs/day
- 1 - 10.0 hp flaker - 470V, 23A - 2.50 hrs/day
- 6 - 2.0 hp top storage motor - 470V, 3A - .3 hrs/day
- 6 - 3.0 hp bottom storage motor - 470V, 3A - 1.5 hrs/day

- 1 - 5.0 hp scale screw conveyor - 470V, 3.3A - 4.5 hrs/day
- 1 - 5.0 hp pivot screw conveyor - 470V, 3.0A - 4.5 hrs/day
- 2 - 20.0 hp blend tank 2 motors - 470V, 10A - 4.2 hrs/day
- 1 - 100 hp emulsifier - 470V, 120A - 3 hrs/day
- 1 - 125 hp emulsifier - 470V, 140A - 3 hrs/day
- 2 - 0.75 hp conveyors - 470V, 1.0A - 3 hrs/day
- 3 - 2.0 hp stuffer-linkers - 230V, 2.6A - 10 hrs/day

Total electrical use per day was 770,331 WH/day or

16.3 WH/lb

b. Steam usage -

The blend tanks use a steam heated jacket for warming the blended materials.

The heating time per batch is only 15 to 20 minutes using an average of 468.9 lb of 15 psig steam or 545,797 Btu/batch. For 12 runs per day, this represents 6,549,564 Btu's/day or 138.5 Btu/lb.

C. Smoking Operation

1. Input - average smokehouse for a regular weiners run lasts 1.64 hours and uses an average of 1113.47 SCF of gas. For dinner franks the average is 2037.5 SCF of gas in 2.58 hrs. For "patio pups" the typical use 1413 SCF in 2.47 hours.

a. Gas usage - (Regular franks)

Gas Used (ft ³)	Franks _{in} (lb)	Franks _{out} (lb)	Btu/lb _{out}
973.83	5531	5072	192.0
879.83	5412	4865	180.8
1445.00	6958	6364	227.0
1151.50	6507	5975	192.7
1134.00	6512	5972	189.9
<u>1096.67</u>	<u>6103</u>	<u>5596</u>	<u>196.0</u>
AVE. 1113.47	6170	5641	196.0

The ratio of product out of smoke to packaged weight was found from company records to be 1.132. This includes actual product loss, casing loss and losses which become rework later.

Therefore, the average gas use per pound of finished product is 221.9 Btu/lb.

b. Electrical usage - (Regular franks)

- 1 - 30.0 hp recirculation blower - 470V, 32A
- 1 - 1.0 hp damper motor 470V, 2A
- 1 - 0.5 hp burner blower - 470V, 1A

$$(35A)(470V)(80\% \text{ P.F.})(\sqrt{3})(1.64 \text{ hrs}) = 37,382 \text{ WH/run}$$

Per pound finished product, the average was -

$$\frac{37,382 \text{ WH}}{5641 \text{ lb}/1.132 \text{ lb}} = 7.502 \text{ WH/lb}$$

2. Balance - batch run of smokehouse. The balance for the smokehouse was performed on a batch run in which 1513 SCF of gas was used in 2.47 hours to process 8861 pounds of raw "patio pups" franks to off smoked weight of 8090 lbs.

a. Gas input -

1513 SCF or 1,513,000 Btu's

b. Electrical input -

$$(35A)(470V)(80\% \text{ P.F.})(\sqrt{3})(2.47 \text{ hrs})(50\%)(3.414 \text{ Btu/WH}) = 96,105 \text{ Btu's/run}$$

c. Steam input - unknown

d. Amount of heat required to change temperature of franks.

Input Analysis

61.3% moisture
23.0% fat
15.7% solids
Temp. 75°F

Output Analysis

53.4% moisture
19.2% solids
27.4% fat
Temp. before cook 155°F

$$C_{Pin} = (1)(0.613) + 0.3(0.157) + 0.5(0.23) = 0.775 \text{ Btu/lb-}^{\circ}\text{F}$$

$$C_{Pout} = (1)(0.534) + 0.3(0.192) + 0.5(0.274) = 0.729 \text{ Btu/lb-}^{\circ}\text{F}$$

$$8090 \text{ lb } (0.729 \text{ Btu/lb-}^{\circ}\text{F}) (155 - 32^{\circ}\text{F}) -$$

$$8861 \text{ lb } (0.775 \text{ Btu/lb-}^{\circ}\text{F}) (75 - 32^{\circ}\text{F}) = 430,113 \text{ Btu's}$$

e. Heat of fusion -

$$8922 \text{ lb } (23\% \text{ fat}) (81 \text{ Btu/lb-fat}) = 166,217 \text{ Btu's}$$

f. Water evaporated from product - assume change of weight all due to water -

$$8861 \text{ lb} - 8090 \text{ lb} = 771 \text{ lb}$$

g. Combustion of gas - (from Strock, 1959)

1. Assume gas is 83.4% CH_4 and 16.6% C_2H_6 by volume, then for 1.0 SCF of gas -

$$\begin{aligned} \text{CH}_4 &- 0.834 \text{ ft}^3 (0.0423 \text{ lb/ft}^3) = 0.035278 \text{ lb} \\ \text{C}_2\text{H}_6 &- 0.166 \text{ ft}^3 (0.0801 \text{ lb/ft}^3) = \underline{0.013297 \text{ lb}} \\ &0.048575 \text{ lb/ft}^3 \end{aligned}$$

2. Water provided by combustion -

$$\begin{aligned} \text{CH}_4 &- 0.035278 \text{ lb } (2.25 \text{ lbwv/lb gas}) = 0.079376 \\ \text{C}_2\text{H}_6 &- 0.013297 \text{ lb } (1.80 \text{ lbwv/lb gas}) = \underline{0.023935} \\ &0.103311 \\ &\text{water/lb gas} \end{aligned}$$

For 1513 SCF gas the water yield is =

$$\begin{aligned} 1513 \text{ ft}^3 (0.048575 \text{ lb/ft}^3) (0.103311 \text{ lbwv/lb gas}) = \\ 7.59 \text{ lbwv from the gas} \end{aligned}$$

3. CO_2 added to air exhaust -

$$\begin{aligned} \text{CH}_4 &- 0.834 \text{ ft}^3 (0.749 \text{ lbc/lb gas}) = 0.6247 \\ \text{C}_2\text{H}_6 &- 0.166 \text{ ft}^3 (0.799 \text{ lbc/lb gas}) = \underline{0.1326} \\ &0.7573 \text{ lbc/} \\ &\text{lb gas} \end{aligned}$$

Total CO₂ added -

$$1513 \text{ SCF } (0.048575 \text{ lb/ft}^3) (0.7573 \text{ lb c/lb gas}) =$$

$$55.6 \text{ lb c}$$

Assuming this is distributed over the entire 148 minute cycle - 0.38 lb c/min.

h. Heating air -

1. First cycle - inlet air averaged 100°F DB, 80°F WB -

$$0.01857 \text{ lbwv/lbDA}$$

Outlet air averaged 100°F DB, 90°F WB -

$$0.02873 \text{ lbwv/lbDA}$$

Time - 30 minutes; apparent air flow - 71754.9 ft³

At inlet conditions -

$$v = 14.107 \text{ ft}^3/\text{lbDA} + 0.01857 \text{ lbwv/lbDA} \times$$

$$(22.633 \text{ ft}^3/\text{lbwv}) = 14.528 \text{ ft}^3/\text{lbDA}$$

So lbs of DA in is -

$$4939.3 \text{ lbDA} + 11.3 \text{ lb c} = 4950.6 \text{ lbDA}$$

$$\text{lbwv} = 4950.6 \text{ DA} (0.02873 \text{ lbwv/lbDA}) -$$

$$(4939.3 \text{ lbDA}) (0.01857 \text{ lbwv/lbDA}) = 50.3 \text{ lbwv}$$

$$h_{in} = 16.341 \text{ Btu/lbDA} + 0.01857 \text{ lbwv/lbDA} \times$$

$$(1104.8 \text{ Btu/lbwv}) = 36.857 \text{ Btu/lbDA}$$

$$\text{heat}_{in} = 182,048.4$$

$$h_{out} = 16.344 \text{ Btu/lbDA} + 0.02873 \text{ lbwv/lbDA} \times$$

$$(1104.8 \text{ Btu/lbwv}) = 48.085 \text{ Btu/lbDA}$$

$$\text{heat}_{out} = 238,049.6 \text{ Btu's}$$

$$q = \text{heat}_{\text{out}} - \text{heat}_{\text{in}} = 56,001.1 \text{ Btu's}$$

2. Second cycle - inlet air averaged 105°F DB, 81°F WB with humidity of $0.01740 \text{ lbwv/lbDA}$

Outlet air averaged 140°F DB, 122°F WB with humidity of $0.08172 \text{ lbwv/lbDA}$

Time - 30 minutes; apparent air flow - $64,725 \text{ ft}^3$

At inlet conditions -

$$v = 14.233 \text{ ft}^3/\text{lbDA} + 0.01740 \text{ lbwv/lbDA} \times$$

$$(22.829 \text{ ft}^3/\text{lbwv}) = 14.630 \text{ ft}^3/\text{lbDA}$$

So pounds of DA in is - 4424.1 lbDA

$$\text{lbDA}_{\text{out}} = 4424.1 \text{ lbDA} + 11.3 \text{ lb c} = 4435.4 \text{ lbDA}$$

$$\text{lbwv} = 4435.4 \text{ lbDA} (0.08172 \text{ lbwv/lbDA}) -$$

$$(4424.1 \text{ lbDA}) (0.01740 \text{ lbwv/lbDA}) = 285.5 \text{ lbwv}$$

$$h_{\text{in}} = 17.544 \text{ Btu/lbDA} + 0.01740 \text{ lbwv/lbDA} \times$$

$$(1106.9 \text{ lbwv/lbDA}) = 36.804 \text{ Btu/lbDA}$$

$$\text{heat}_{\text{in}} = 4424.1 \text{ lbDA} (36.804 \text{ Btu/lbDA}) =$$

$$162,824.8 \text{ Btu's}$$

$$h_{\text{out}} = 25.968 \text{ Btu/lbDA} + 0.08172 \text{ lbwv/lbDA} \times$$

$$(1121.7 \text{ Btu/lbwv}) = 117.633 \text{ Btu/lbDA}$$

$$\text{heat}_{\text{out}} = 4435.4 \text{ Btu/lbDA} (117.633 \text{ Btu/lbDA}) =$$

$$521,750.8 \text{ Btu's}$$

$$q = \text{out} - \text{in} = 358,926 \text{ Btu's}$$

3. Third cycle - inlet air averaged 110°F DB, 83°F WB with humidity $0.01828 \text{ lbwv/lbDA}$

Outlet air averaged 155°F DB, 135°F WB with humidity 0.1247 lbwv/lbDA

Time - 40 minutes; apparent air flow - 75751.5 ft³

At inlet conditions -

$$v = 14.359 \text{ ft}^3/\text{lbDA} + 0.01828 \text{ lbwv}/\text{lbDA} \times \\ (23.024 \text{ ft}^3/\text{lbwv}) = 14.780 \text{ ft}^3/\text{lbDA}$$

So pounds of DA in was - 5125.3 lbDA

$$\text{lbDA}_{\text{out}} = 5125.3 + 15.0 \text{ lb c} = 5140.3 \text{ lbDA}$$

$$\text{lbwv} = 5140.3 \text{ DA}(0.1247 \text{ lbwv}/\text{lbDA}) - (5125.3 \text{ lbDA}) \times \\ (0.01828 \text{ lbwv}/\text{lbDA}) = 547.3 \text{ lbwv}$$

$$h_{\text{in}} = 18.747 \text{ Btu}/\text{lbDA} + 0.01828 \text{ lbwv}/\text{lbDA} \times \\ (1109.0 \text{ Btu}/\text{lbwv}) = 39.019 \text{ Btu}/\text{lbDA}$$

$$\text{heat}_{\text{in}} = 5125.3 \text{ lbDA} (39.019 \text{ Btu}/\text{lbDA}) = \\ 199,984.1 \text{ Btu's}$$

$$h_{\text{out}} = 29.581 \text{ Btu}/\text{lbDA} + 0.1247 \text{ lbwv}/\text{lbDA} \times \\ (1127.8 \text{ Btu}/\text{lbwv}) = 170.218 \text{ Btu}/\text{lbDA}$$

$$\text{heat}_{\text{out}} = 5140.3 \text{ lbDA} (170.218 \text{ Btu}/\text{lbDA}) = \\ 874,969.8 \text{ Btu's}$$

$$q = \text{out} - \text{in} = 674,985.7 \text{ Btu's}$$

4. Final cycle - inlet air averaged 125°F DB, 90°F WB with humidity 0.02275 lbwv/lbDA

Outlet air averaged 175°F DB, 135°F WB with humidity 0.1191 lbwv/lbDA

Time - 48 minutes; apparent air flow 94,909.5 ft³

At inlet conditions -

$$v = 14.738 \text{ ft}^3/\text{lbDA} + 0.02275 \text{ lbwv}/\text{lbDA} \times \\ 23.602 \text{ ft}^3/\text{lbwv} = 15.275 \text{ ft}^3/\text{lbDA}$$

So pounds of DA in was - 6213.4 lbDA

$$\text{Exhaust air} = 6213.4 + 18.0 \text{ lb c} = 6231.4 \text{ lbDA}$$

$$\text{lbwv} = 6231.4 \text{ lbDA} (0.1191 \text{ lbwv/lbDA}) =$$

$$(6213.4 \text{ lbDA}) (0.02275 \text{ lbwv/lbDA}) = 600.8 \text{ lbwv}$$

$$h_{\text{in}} = 22.356 \text{ Btu/lbDA} + 0.2275 \text{ lbwv/lbDA} \times$$

$$1115.4 \text{ Btu/lbwv} = 47.731 \text{ Btu/lbDA}$$

$$\text{heat}_{\text{in}} = 6213.4 \text{ lbDA} (47.731 \text{ Btu/lbDA}) = 296,571.8 \text{ Btu}$$

$$h_{\text{out}} = 34.402 \text{ Btu/lbDA} + 0.1191 \text{ lbwv/lbDA} \times$$

$$(1135.9 \text{ Btu/lbwv}) = 169.68 \text{ Btu/lbDA}$$

$$\text{heat}_{\text{out}} = 6231.4 \text{ lbDA} (169.68 \text{ Btu/lbDA}) =$$

$$1,057,343.9 \text{ Btu's}$$

$$q = \text{out} - \text{in} = 760,772.2 \text{ Btu's}$$

$$\text{Total heat to air} = 1,850,685 \text{ Btu's}$$

$$\text{Total water added to air} = 1483.9 \text{ lbwv}$$

i. Convective and radiant losses from the house -

1. Convective loss -

House is 25.58 ft x 10.0 ft x 10.75 ft. Surface temperature averages 140°F on top, 110°F on sides and 100°F near bottom. Ambient air averages 110°F near the top and 90°F on the sides of the house.

$$h_{\text{c top}} = 0.3(140 - 110)^{\frac{1}{4}} = 0.889 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$h_{\text{c sides}} = 0.3(110 - 90)^{\frac{1}{4}} = 0.634 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$\begin{aligned} q_{\text{c}} &= (0.889 \text{ Btu/hr-}^{\circ}\text{F-ft}^2) (25.58 \text{ ft}) (10.75 \text{ ft}) \times \\ &\quad (140 - 110) + (0.634 \text{ Btu/hr-}^{\circ}\text{F-ft}^2) (2) \times \\ &\quad [(10.75 \text{ ft}) (10.0 \text{ ft}) + (25.58 \text{ ft}) (10.0 \text{ ft})] \times \\ &\quad (110 - 90^{\circ}\text{F}) = 16,547.1 \text{ Btu/hr or} \end{aligned}$$

$$40,816 \text{ Btu's in 148 minutes}$$

2. Radiation loss -

$e = 0.85$ for stainless steel (Heldman, 1975)

$$q_r = (0.174)(0.85)/10^8 [(600^4 - 570^4)(275 \text{ ft}^2) + (570^4 - 550^4)(727 \text{ ft}^2) + (560^4 - 550^4)(275 \text{ ft}^2)] = 27,670.2 \text{ Btu/hr or } 68,253 \text{ Btu's in } 148 \text{ minutes}$$

Total convective and radiant loss - 109,069 Btu's

j. Water balance -

Total water added to air in house -	1483.9 lb
Water from franks -	771.0 lb
Water from combustion -	<u>7.6 lb</u>
	705.3 lb "extra"

k. Energy balance - solve for steam

Input = Output

$$\text{Steam}_{in} + \text{Gas}_{in} + \text{Elec}_{in} + \text{Air}_{in} + \text{Franks}_{in} = \text{Air}_{out} + \text{Franks}_{out}$$

$$\text{Steam}_{in} = (\text{Air}_{out} - \text{Air}_{in}) + (\text{Franks}_{out} - \text{Franks}_{in}) + \text{Fusion} + \text{Losses} - \text{Gas}_{in} - \text{Elec}_{in}$$

$$\begin{aligned} \text{Steam}_{in} &= 1,850,685 \text{ Btu's} + (430,113 \text{ Btu's}) + \\ &\quad (166,217 \text{ Btu's}) + 109,069 \text{ Btu's} - \\ &\quad 1,513,000 \text{ Btu's} - 96,105 \text{ Btu's} = \\ &\quad 946,979 \text{ Btu's} \end{aligned}$$

The amount of steam required based on the water balance was 837,896 Btu's (assuming 90 psig steam) as yielded by 705.3 lb of "extra" water in exhaust air. Based on

the uncertainty of the energy balances, the amount of heat input as steam required per pound of finished product was based on the water balance -

$$\frac{705.3 \text{ lbwv (1188 Btu/lb)}}{8090 \text{ lb off smoke}} (1.132 \text{ lb off smoke/lb finish}) = 117.2 \text{ Btu/lb}$$

3. Cooking Period -

Following the smoking period, the gas is shut down, all dampers are closed and steam is injected into the house to cook the franks to 165°F internally. Initially, the franks are at 155°F and the smokehouse air is at 175°F DB, 135°F WB. The time required is approximately 15 minutes.

a. Heat losses -

$$(16,547.1 + 27,670.2) \text{ Btu/hr} (15/60) \text{ from house} = 11,054 \text{ Btu's}$$

b. Temperature gain by franks -

$$8090 \text{ lb (0.729 Btu/lb-}^{\circ}\text{F)} (165 - 155^{\circ}\text{F}) = 58,976 \text{ Btu's}$$

c. Temperature gain by air -

Assume air temperature in house is raised to 212°F (1 atmosphere). Neglecting "trees" and assuming density of franks 45 lb/ft³ (Omeco-St. John).

$$\begin{aligned} \text{Volume of air} &= \text{Volume of house} - \text{Volume of franks} \\ &= 2750 \text{ ft}^3 - 8090 \text{ lb} / 45 \text{ lb/ft}^3 = \\ &2570 \text{ ft}^3 \end{aligned}$$

At 175°F DB, 135°F WB, air is -

$$\begin{aligned} v &= 16.001 \text{ ft}^3/\text{lbDA} + 0.1191 \text{ lbwv/lbDA} \times \\ &(25.481 \text{ ft}^3/\text{lbwv}) = 19.035 \text{ ft}^3/\text{lbDA} \end{aligned}$$

Pounds of air equals = $2570 \text{ ft}^3 / 19.035 \text{ ft}^3 / \text{lbDA} =$
 135.0 lbDA

The change in enthalpy is from that at starting conditions to saturated conditions at 212°F where the heat content of the water as steam far exceeds air -

$2570 \text{ ft}^3 / 26.8 \text{ ft}^3 / \text{lb} (1150.4 \text{ Btu/lb}) - (135.0 \text{ lbDA}) \times$
 $(169.68 \text{ Btu/lbDA}) = 87,411.4 \text{ Btu's}$

Total Btu's required as steam at 90 psig was -
 157,441 Btu's

In terms of final product, the amount of steam required was -

$157,441 \text{ Btu's} / 8090 \text{ lb off smoke} (1.132 \frac{\text{lb off smoke}}{\text{lb finished}}) =$
 22.0 Btu/lb

4. Showering of franks in house -

The average flow of water after the steam cook was 20 minutes at 46 gpm as measured by a meter. In terms of final product, the amount of water used was -

$\frac{20 \text{ min.} (46 \text{ gal/min})}{5641 \text{ lbs off smoke}} (1.132 \frac{\text{lb off smoke}}{\text{lb finished}}) =$

0.185 gallons per pound

D. Frank Cooler

After franks have been showered in the smokehouse, they may be moved to a frank or link cooler for chilling. It is also possible to send franks directly from smokehouse to the brine chiller.

1. Electrical requirements for the refrigeration fans -

4 - 0.5 hp fans - 230V, 1.2A

4(1.2A) (230V) (80% P.F.) (24 hrs/day) (0.656 lb franks/lb sausage)

= 13,905.1 WH/day or 0.294 WH/lb finished franks

2. Refrigeration usage -

There are two units in the frank cooler each with an average flow 5802 CFM measured at exhaust. The average relative humidity was 100%.

TIME	TEMPERATURE IN	TEMPERATURE OUT
12:15 AM	43	39
2:20	46	40
4:40	47	43
5:30	38	34
6:30	37	36
7:30	38	36
8:30	35	35
9:30	36	32
10:30	37	31
11:30	37	33
12:30 PM	44	43
1:30	37	32
2:30	36	33
5:45	45	42
8:50	44	39
11:00	44	41
AVERAGE	40.2	36.8

Enthalpy of inlet air 40°F, 100% RH was -

$$h = 7.544 \text{ Btu/lbDA}$$

Condensation occurs in the units since air is saturated at both inlet and exhaust. Enthalpy at outlet 37°F, 100%RH was -

$$h = 6.188 \text{ Btu/lbDA}$$

Specific volume of outlet air was -

$$v = 12.607 \text{ ft}^3/\text{lbDA}$$

Total daily air flow of air was -

$$2 \text{ units}(5802 \text{ ft}^3/\text{min})(60 \text{ min/hr})(24 \text{ hrs})/12,607 \text{ ft}^3/\text{lbDA} =$$

$$1,325,435 \text{ lbDA}$$

Refrigeration load for chilling air -

$$1,325,435 \text{ lbDA} (7.544 \text{ Btu/lbDA} - 6.188 \text{ Btu/lbDA}) =$$

$$1,797,290 \text{ Btu/day}$$

Refrigeration load for condensing water which was removed from air -

$$1,325,435 \text{ lbDA} (0.005212 \text{ lbwv/lbDA} - 0.004629 \text{ lbwv/lbDA}) \times$$

$$(1079.7 \text{ Btu/lbwv}) = 833,542 \text{ Btu's}$$

Total refrigeration load for franks -

$$2,630,832 \text{ Btu's} (0.656) = 1,725,826 \text{ Btu's or } 36.5 \text{ Btu/lb}$$

E. Brine Chiller

The brine is a short tunnel which has a chain drive to move the franks through. The average residence time of franks in the tunnel is 10 minutes in which time the temperature is dropped from 42 to 28°F. A 6% brine solution is recirculated through the tunnel by two 7.5 hp pumps. The tunnel runs approximately 18.3 hours per day while the refrigeration unit is in operation and 21 hours overall including cleaning. Only franks pass through chiller.

1. Electricity use -

$$2 - 7.5 \text{ hp pumps} - 470\text{V}, 10.5\text{A}$$

$$2(10.5\text{A})(470\text{V})(80\% \text{ P.F.})(\sqrt{3})(21 \text{ hrs/day}) = 287,202 \text{ WH/day}$$

$$\text{or } 6.075 \text{ WH/lb}$$

TIME	TEMPERATURE IN	TEMPERATURE OUT
12:17 AM	55	41
2:26	56	50 (cleaning)
5:15	51	45
8:30	54	52
9:30	56	49
10:45	53	49
11:45	53	49
12:45 PM	57	47
1:45	54	49
2:45	53	53
3:45	56	48
5:40	53	46
9:00	56	47
11:00	56	49
AVERAGE	54.5	48.1

Humidity of inlet air at 54°F, 86% RH was (from Zimmerman and Lavine, 1945) -

0.007794 lbwv/lbDA

Since this is more than the saturation humidity of air at 48°F, 0.007098 lbwv/lbDA, some water is rejected as condensate.

Enthalpy of inlet air - 54°F, 86% RH -

$$h = 5.2846 \text{ Btu/lbDA} + 0.007794 \text{ lbwv/lbDA} (1084.9 \text{ Btu/lbwv})$$

$$= 13.740 \text{ Btu/lbDA}$$

The specific volume of the exhaust air was 12.938 ft³/lbDA

Enthalpy of exhaust air was - 11.505 Btu/lbDA

Air flow for the three units was -

$$\frac{3(4700 \text{ ft}^3/\text{min})(60 \text{ min/hr})(24 \text{ hrs})}{12.938 \text{ ft}^3/\text{lbDA}} = 1,569,331 \text{ lbDA/day}$$

Refrigeration load for chilling air was -

$$1,569,331 \text{ lbDA} (13.740 \text{ Btu/lbDA} - 11.505 \text{ Btu/lbDA}) =$$

$$3,507,454 \text{ Btu's per day absorbed}$$

2. Refrigeration use -

Average flow of brine is 50.1 gpm with a change of temperature of 2.2 degrees.

$$65.1 \text{ gal/min} (60 \text{ min/hr}) (18.3 \text{ hr}) (8.72 \text{ ft/gal}) (0.946 \text{ Btu/lb-}^{\circ}\text{F}) \\ \times (20.4 - 18.2^{\circ}\text{F}) = 1,299,346 \text{ Btu/day or } 27.5 \text{ Btu/lb}$$

Franks pass through the chiller at an average rate of 5640 lb/hr.

The actual heat removed from the franks was -

$$5640 \text{ lb/hr} (0.729 \text{ Btu/lb-}^{\circ}\text{F}) (42 - 28^{\circ}\text{F}) = 57,562 \text{ Btu/hr}$$

The average refrigeration used per hour in the chiller is 70,886 Btu's/hr. The difference represents heat gained from room and pumps.

F. Prepack and Packaging

1. Room refrigeration -

There are three refrigeration evaporators in the packaging area which maintain room temperature at approximately 50 F. with a relative humidity of 86%.

a. Electrical use -

6 - 0.5 hp fans - 230V, 1.2A

$$6(1.2\text{A})(230\text{V})(80\% \text{ P.F.})(24 \text{ hrs/day})(0.656) =$$

20,858 WH/day or 0.44 WH/lb

b. Refrigeration use -

Each of the three air handling units has an average air flow of 4700 CFM measured in the exhaust.

Refrigeration load for condensing water was -

2,569,331 lbDA (0.007794 - 0.007098 lbwv/lbDA) x

(1082.2 Btu/lbwv) = 1,182,037 Btu's

Total refrigeration requirement was - 4,689,491 Btu's

4,689,491 Btu/day (0.656 $\frac{\text{lb franks}}{\text{lb sausage}}$) = 3,076,306 Btu's

or 65.1 Btu's/lb

2. Packaging equipment -

a. Peelers -

Use both electricity and steam. There are five peelers, three are used for 15 hours and two for 7 hours.

1. Electricity use -

5 - 3.5 hp peelers - 230V, 2.5A

(2.5A) (230V) (80% P.F.) [(2) (7 hrs) + (3) (25 hrs)] =

27,140 WH/day

2. Steam -

Estimate of steam flow from Strock, 1959. For 5 psig steam through 1/8 inch orifice, the steam flow is 7 pounds per hour.

[(2) (7 hrs) + (3) (15 hrs)] (7 lbs/hr) (1156 Btu/lb) =

477,428 Btu/day or 10.1 Btu/lb

b. Packaging machine - (machine runs 15 hours per day)

Main heater - 20A

Final sealer heater - 17A

1 - 3 hp collator-loader - 5.4A

2 - 10 hp vacuum pumps - 11A

1 - 35 hp main drive - 30A

$$[(30A) + (2)(11A) + (5.4A)(470V)(80\% \text{ P.F.})(\sqrt{3}) + (20A + 17A)(470V)(\sqrt{3})(100\% \text{ P.F.})](15 \text{ hrs}) = 1,012,533 \text{ WH/day}$$

Total electrical requirement for peelers and packager was -

1,039,672 WH/day or 22.0 WH/lb

G. Sanitation and General Utilities

1. Electrical -

a. Sausage kitchen - 24 hrs/day

58 - 250 watt mercury vapor lamps
2 - 0.5 hp fans - 1.2A (230V)

$$[(2)(1.2A)(230V)(80\% \text{ P.F.}) + 58(250 \text{ watt})](24 \text{ hrs}) = 358,598 \text{ WH/day}$$

b. Smokehouse area - 24 hrs/day

32 - 350 watt incandescent lamps
4 - 0.5 hp fans - 1.2A (230V)

$$[(4)(1.2A)(230V)(80\% \text{ P.F.}) + 32(350 \text{ watts})(24 \text{ hrs})] = 289,997 \text{ WH/day}$$

c. Frank cooler - 24 hrs/day

20 - 40 watt fluorescent tubes

$$20(40 \text{ watts})(24 \text{ hrs}) = 19,200 \text{ WH/day}$$

d. Packaging

34 - 250 watt mercury vapor lamps
8 - 40 watt fluorescent tubes
2 - 0.5 hp fans - 1.2A (230V)

$$[2(1.2A)(230V)(80\% \text{ P.F.}) + (8)(40) + 34(250)](24 \text{ hrs}) = 222,278 \text{ WH/day}$$

Total electrical use for franks -

$$890,073 \text{ WH} (0.656 \frac{\text{lb franks}}{\text{lb sausage}}) = 583,888 \text{ WH or } 12.4 \text{ WH/lb}$$

2. Water and Steam

a. Sausage kitchen - 6 hoses

38,430 gallons per day of water is used and is heated an average of 70°F, requires 22,408,533 Btu's/day steam.

b. Smokehouse - 3 hoses

3300 gallons of water per day is used with an average heating of 70°F yields 1,924,230 Btu's steam required.

c. Packaging - 6 hoses

17,700 gallons of water per day is used with an average heating of 70°F yields 10,320,870 Btu's of steam required.

Total water use -

$$59,430 \text{ gallons} (0.656) = 38,986 \text{ gal/day or } 0.825$$

Total steam use -

$$34,653,633 \text{ Btu's} (0.656) = 22,732,783 \text{ Btu/day or}$$

$$480.8 \text{ Btu/lb}$$

IV. Edible Lard Rendering

The average daily production of lard at Armour was 40,929 pounds. The yield was 13.55 per head slaughtered. An average slaughter was 3021 head.

A. Grinding and Loading

All edible trim is brought from the kill and cut rooms into the rendering area in wheeled carts. A 50 hp grinder loader on tracks is used to fill each of the 8 rendering vats. The loader runs on the average, 8.25 hours per day.

1 - 50 hp grinder loader - 470V, 38A

$(38A)(470V)(80\% \text{ P.F.})(\sqrt{3})(8.25 \text{ hrs}) = 204,167 \text{ WH/day or}$

$4.99 \text{ WH/lb finished lard or } 67.58 \text{ WH/head}$

B. Cooking

Any number of cookers can be used depending on kill. One cooker was monitored for steam flow.

Material was weighed prior to loading. Total weight was 13,309 pounds.

The composition of the input material was found by analysis to be -

16% water, 8.5% solids, 75.5% fat

Temperature at filling was 70°F. The heat capacity was determined from Charm (1971) -

$$C_p = 1.0(0.16) + 0.5(0.755) + 0.3(0.085) = 0.563 \text{ Btu/lb-}^{\circ}\text{F}$$

With no losses, the fat yield should be -

$$0.755(13,309 \text{ lbs}) = 10,048 \text{ lbs for one cooker}$$

This is clearly in excess of the daily production from 8 cookers. Since normally only 5 cookers are used the total daily yield would be 50,240 lbs as opposed to the actual daily production of 40,929. Clearly, there is a loss. The percent loss during cooking and separation appears to be 15 to 20%. Assuming a 15% loss, a factor of 1.23 was used for conversion to final product.

1. Steam input -

The steam input for this particular batch was 8194 pounds of steam at 40' psig in 6 hours but the average use was 6920 lbs. Typical steam use was estimated to be -

$$\frac{6920 \text{ lbs steam } (1175.9 \text{ Btu/lb})}{10,048 \text{ lbs}} \times 1.23 = 996.1 \text{ Btu/lb or}$$

$$13,497 \text{ Btu's/head}$$

Total steam input for tested batch -

$$8194 \text{ lb}(1175.9 \text{ Btu/lb}) = 9,635,325 \text{ Btu's}$$

2. Heat in edible trim placed into cooker at 70°F (32°F base) -

$$13,309 \text{ lbs}(0.563 \text{ Btu/lb-}^{\circ}\text{F}) (70^{\circ} - 32^{\circ}\text{F}) = 284,732 \text{ Btu's}$$

3. Heat in lard and solids removed from cooker at 285°F -

$$13,309(0.755)(0.5 \text{ Btu/lb-}^{\circ}\text{F}) (285^{\circ} - 32^{\circ}\text{F}) +$$

$$13,309(0.085)(0.3 \text{ Btu/lb-}^{\circ}\text{F}) (285^{\circ} - 32^{\circ}\text{F}) = 1,356,972.3 \text{ Btu's}$$

4. Heat required for fusion of fat -

$$13,309 \text{ lbs}(0.755)(81 \text{ Btu/lb}) = 813,911.9 \text{ Btu's}$$

Total heat required for change of product status -

$$4,389,797.8 \text{ Btu's}$$

5. Loss from uninsulated cooker by convection -

After an initial heat up (20 minutes - aver. temp. 190°F), the temperature of the cooker surface raised to 270°F and remained there throughout the cook. This is due to the injection of the steam at the bottom which forces its way up the sides of the cooker rather than mixing immediately with the product. Ambient air temperature averaged 110°F during the cook. (from Strock, 1959 for vertical plate).

$$\text{initial } h_{c_{\text{wall}}} = 0.3(190-110)^{1/4} = 0.897 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}$$

$$\text{remaining } h_{c_{\text{wall}}} = 0.3(190-110)^{1/4} = 1.067 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}$$

$$\text{initial } h_{c_{\text{top}}} = 0.38(270-110)^{1/4} = 1.136 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}$$

$$\text{remaining } h_{c_{\text{top}}} = 0.38(270-110)^{1/4} = 1.351 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}$$

Surface area of vat 6.5 ft diameter, 15 ft. high -

$$A = 6.5/4 \text{ ft}^2 \pi + 10 \text{ ft} \pi 6.5 \text{ ft} + \pi 6.5/2 \text{ ft} \sqrt{6.5/4 \text{ ft}^2 + 5 \text{ ft}^2} = 298.3 \text{ ft}^2 \text{ (33.2 ft}^2 \text{ top + 265.1 ft}^2 \text{ rest)}$$

$$\begin{aligned} q_c = & 1.136 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}(33.2 \text{ ft}^2)(190-110)(20/60 \text{ hrs}) + \\ & 1.351 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}(33.2 \text{ ft}^2)(270-110)(5.67 \text{ hrs}) + \\ & 0.897 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}(265.1 \text{ ft}^2)(190-110)(20/60 \text{ hrs}) + \\ & 1.067 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr}(265.1 \text{ ft}^2)(270-110)(5.67 \text{ hrs}) = \\ & 304,649.9 \text{ Btu's} \end{aligned}$$

6. Losses by radiation -

From Heldman (1975), the ϵ of rough steel plate is 0.94 at 100°F and 0.97 at 500°F.

Assuming ϵ to be 0.95 -

$$\begin{aligned} q_r = & (0.95)(0.174)/108[(650^4 - 570^4)(33.2 \text{ ft}^2)(20/60) + \\ & (730^4 - 570^4)(33.2 \text{ ft}^2)(5.67) + (650^4 - 570^4) \times \\ & (265.1 \text{ ft}^2)(20/60) + (730^4 - 570^4)(265.1 \text{ ft}^2)(5.67)] = \\ & 510,826.6 \text{ Btu's} \end{aligned}$$

7. Balance -

- a. Energy balance - as product cooks under pressure both vapor and liquid water exist -

$$\text{Steam}_{\text{in}} + \text{product}_{\text{in}} = \text{fat}_{\text{out}} + \text{fusion} + \text{solids}_{\text{out}} +$$

$$\text{conv.}_{\text{loss}} + \text{rad.}_{\text{loss}} + \text{water vented} + \text{water condensate}$$

$$\text{Steam}_{\text{in}} + \text{product}_{\text{in}} - \text{fat}_{\text{out}} = \text{water vented} +$$

$$\text{water condensate} - \text{solids}_{\text{out}} - \text{fusion} - \text{conv.}_{\text{loss}} -$$

$$\text{rad.}_{\text{loss}}$$

$$9,635,325 \text{ Btu's} + 284,732 \text{ Btu's} = -1,356,972 \text{ Btu's} -$$

$$813,911.9 \text{ Btu's} - 304,649.9 \text{ Btu's} - 510,826.6 \text{ Btu's}$$

$$6,933,696.6 \text{ Btu's} =$$

Since total water available was 8194 pounds from steam and $13,309(0.16) = 2129.4$ pounds from product, the total water available was 10,323.4 pounds. The cookers are vented at the end of the cook to atmospheric or near atmospheric conditions. Therefore, the amount vented was -

$$6,933,696.6 \text{ Btu's} = \text{ms}_{\text{vap}} (1150.5 \text{ Btu/lb}) + (10,323.4 \text{ lb} -$$

$$\text{ms}_{\text{vap}}) (180.17 \text{ Btu/lb})$$

$$5,073,729.6 \text{ Btu's} = 970.3 \text{ ms}_{\text{vap}}$$

$$5229.0 = \text{ms}_{\text{vap}}$$

The mass of water remaining as condensate was 5094.4 lbs

C. Centrifuge

The centrifuge operates for 8.25 hours per day typically -

1 - 25 hp separator - 470V, 19A

$$19\text{A}(470\text{V})(80\% \text{ P.F.})(\sqrt{3})(8.25 \text{ hrs}) = 102,083.6 \text{ WH/day or}$$

2.494 WH/lb or 33.79 WH/head slaughtered

After separation the fat is settled then moved to storage. Only rarely are the storage steam coils used.

D. Sanitation and General Utilities

In the two rooms used for edible rendering there are -

35 - 250 watt mercury vapor lamps

4 - 0.5 hp fans - 1.2A, 230V

1. Electricity -

Operation is commonly 24 hours per day -

$4(1.2A)(230V)(80\% \text{ P.F.})(24 \text{ hrs}) + (35)(250 \text{ watts})$

$\times (24 \text{ hrs}) = 231,196.8 \text{ WH/day or } 5.649 \text{ WH/lb pr}$

76.54 WH/head

2. Water and Steam -

For a typical day, 7630 gallons were used by the upstairs room cleanup hose and 3080 gallons by the hose downstairs or 0.262 gal/lb or 3.545 gal/head

Total average water use was 10,710 gal/day or

the steam required to heat the water an average of 70°F was -

$10,710 \text{ gal}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(70^{\circ}\text{F}) =$

6,245,001 Btu's/day or 152 Btu's/lb or

2067 Btu/head

V. Inedible Rendering

The average daily production of grease at Armour was 16,616 lbs. The yield was 5.50 pounds per head slaughtered (3021 head/day).

A. Grinding and Loading

All inedible is moved to the tank house by means of chutes and conveyors. The material is then ground and conveyed to the cookers. All utility requirements are electrical. Typical running time is 12.5 hrs/day.

8 - 2.0 hp conveyor motors - 470V, 1.0A
 3 - 3.0 hp conveyor motors - 470V, 1.5A
 1 - 1.5 hp skinner - 470V, 1.0A
 1 - 75.0 hp prebreaker - 470V, 25.7A

$$12.5 \text{ hrs} [8(1.0A) + 3(1.5A) + 1.0A + (25.7A)] (470V) (80\% \text{ P.F.}) \times (\sqrt{3}) = 319,113 \text{ WH/day or } 19.20 \text{ WH/ lb grease or } 105.63 \text{ WH/head}$$

B. Cooking or Melting

1. Material input -

There are six cookers which are ordinarily used for rendering inedible scrap. The average cook time per batch is 3.11 hours. Generally, 13 cooks are done per day. The incoming inedible trim has a composition as found by analysis of -

59% water; 21% fat; 20% solids (from Charm, 1971).

$$C_p = (1)(0.59) + (0.5)(0.21) + (0.3)(0.20) = 0.755 \text{ Btu/lb-}^{\circ}\text{F}$$

Inedible trim arrives at the tankhouse at a temperature of 70°F. Also added to the cooker is a certain amount of stickwater from edible rendering. Analysis of the stickwater indicates that it is 90% water and 10% solids.

$$C_p = (1)(0.90) + 0.3(0.10) = 0.930 \text{ Btu/lb-}^{\circ}\text{F}$$

Each cooker has a rated capacity of 180 ft³ and is usually filled to within 8 inches of the top with inedible material the remaining volume is then filled with stickwater.

Volume of stickwater added -

Cooker is 11.75 ft long x 4.48 ft diameter inside. The volume can be represented as the area of a circle segment (radius 4.48 ft) times the length.

$$v = \frac{1}{2} r^2 (\theta - \sin \theta) \times l = 11.75 \text{ ft } (4.48/2)^2 \times$$

$$\left[2 \cos^{-1} \left(\frac{4.48/2 - 8/12}{4.48/2} \right) - 1 \right] = 17.23 \text{ ft}^3 \text{ of stickwater or}$$

about 1050 lbs (density 61 lbs/ft³)

The inedible material occupies the remaining space or 180 - 17 = 163 ft³

The density of inedible trim (Oneco-St. John) is 50 lb/ft³

The load is thus; 163 ft³ (50 lb/ft³) = 8150 lbs

Total input as solids, water and fat was -

$$\begin{aligned} \text{Solids } (0.20) (8150) + (0.10) (1050) &= 1735 \text{ lbs} \\ \text{Fat } (0.21) (8150) &= 1711.5 \text{ lbs} \\ \text{Moisture } (0.59) (8150) + (.90) (1050) &= \underline{5753.5 \text{ lbs}} \\ &9200 \text{ lbs} \end{aligned}$$

2. Material output -

Output analysis of cracklings from cooker was -

2.8% water; 37.7% fat; 59.5% solids

$$C_p = 1(0.028) + 0.3(0.595) + 0.5(0.377) = 0.395 \text{ Btu/lb-}^{\circ}\text{F}$$

Output analysis of grease from cooker was -

99.9% fat with only trace moisture and solids

$$C_p = 0.5$$

3. Material balance -

- a. Since nearly all solids appear at output as cracklings, the amount of cracklings out was -

1735 lbs solids/59.5% solids = 2916 lbs

- b. Since output grease is vertically pure grease, the output in pounds was -

1711.5 lbs - (37.7% fat) (2916 lbs cracklings) =

612 pounds of "free" grease

- c. All remaining output was assumed to be water -

5672 lbs

4. Energy input -

- a. Steam -

Average steam input for a 3.11 hour run was 8695 lbs of 60 psig steam.

Total input was -

8695 lbs (1181.8 Btu/lb - 277.4 Btu/lb) =

10,275,751 Btu's

For 13 cooks per day the use was 1.3358×10^8 Btu's or

8039 Btu's/lb finished or 44,217 Btu's/head

Steam is used in a jacket and is returned as condensate. Total use of steam energy was therefore,

8695 lbs (1181.8 Btu/lb - 277.4 Btu/lb) =

7,857,672 Btu's/batch

- b. Electricity -

1 - 30 hp agitator - 470V, 18.5A

1 - 2 hp percolation pan - 470V, 1.0A

2 - 7.5 hp recirculation pumps - 470V, 10.5A

$3.11 \text{ hrs}(18.5\text{A})(470\text{V})(80\% \text{ P.F.})(\sqrt{3}) + 0.5 \text{ hrs}(1.0\text{A}) \times$

$(470\text{V})(80\% \text{ P.F.})(\sqrt{3}) + 1/13(12.5 \text{ hrs})(2)(10.5\text{A})(470\text{V}) \times$

$(80\% \text{ P.F.})(3) = 50,945.6 \text{ WH/batch}$

Assuming 50% efficiency of heat transfer to product for agitator, the input was -

$$37,469.7 \text{ WH} (0.50) (3.414 \text{ Btu/WH}) = 63,961 \text{ Btu's/batch}$$

For 13 batches/day the daily electrical use was estimated to be 662,293 WH/day or 39.86 WH/lb grease or 219.2 WH/head.

5. Energy Balance -

a. Energy in entering material - (base 32°F)

$$8150 \text{ lbs} (0.755 \text{ Btu/lb-}^{\circ}\text{F}) (70 - 32^{\circ}\text{F}) +$$

$$1050 \text{ lbs} (0.930 \text{ Btu/lb-}^{\circ}\text{F}) (70 - 32^{\circ}\text{F}) =$$

$$270,930.5 \text{ Btu's}$$

b. Energy in fat and cracklings leaving cooker -

Assuming no fat losses to ejectors, material leaves cookers at 290°F (base 32°F) -

$$612 \text{ lbs "free" fat} (0.5 \text{ Btu/lb-}^{\circ}\text{F}) (290 - 32^{\circ}\text{F}) =$$

$$376,117.6 \text{ Btu's}$$

c. Energy required to evaporate water (base 32°F) -

$$5753.5 \text{ lbs} - 2.8\% (2916 \text{ lbs}) = 5672 \text{ lbs evap.}$$

$$5672 \text{ lbs} (1150.5 \text{ Btu/lb}) = 6,525,636 \text{ Btu's}$$

d. Energy to melt fat (fusion) -

$$1711.5 \text{ lbs fat} (81 \text{ Btu/lb}) = 138,631.5 \text{ Btu's}$$

e. Total change in product energy status -

$$376,117.6 \text{ Btu's} + 6,525,636 \text{ Btu's} + 138,631.5 \text{ Btu's} -$$

$$270,930.5 \text{ Btu's} = 6,769,455 \text{ Btu's}$$

f. Heat loss due to convection during cook -

The cookers are insulated except on the ends. Ambient air conditions are 100°F. Surface temperature of

cooker on insulated parts averaged 200°F. On the ends, the average temperature was 280°F during most of the cook (from Strock, 1959) -

$$h_{\text{sides}} = 0.3(200 - 90^{\circ}\text{F})^{\frac{1}{4}} = 0.972 \text{ Btu/ft}^2\text{-}^{\circ}\text{F-hr}$$

$$h_{\text{ends}} = 0.3(280 - 90^{\circ}\text{F})^{\frac{1}{4}} = 1.114 \text{ Btu/ft}^2\text{-}^{\circ}\text{F-hr}$$

$$\begin{aligned} q_c &= (2)(1.114 \text{ Btu/ft}^2\text{-}^{\circ}\text{F-hr}) \left(\frac{63}{12}/2\right)^2 \pi (280 - 90^{\circ}\text{F}) \times \\ &\quad (3.11 \text{ hrs}) + 0.972 \text{ Btu/ft}^2\text{-}^{\circ}\text{F-hr} \left(\frac{63}{12} \frac{\text{in}}{\text{in}} \text{ ft } \pi\right) \times \\ &\quad (12 \text{ ft})(200 - 90^{\circ}\text{F})(3.11 \text{ hrs}) = 94,309 \text{ Btu's} \end{aligned}$$

g. Heat loss due to radiation -

Assume $e = 0.95$ rough steel (Heldman, 1975) -

$$\begin{aligned} q_r &= 0.174(0.95)/10^8 [(740^4 - 550^4)(43.3 \text{ ft}^2) + \\ &\quad (660^4 - 550^4)(197.9 \text{ ft}^2)](3.11 \text{ hrs}) = \\ &\quad 146,328 \text{ Btu's} \end{aligned}$$

h. Balance -

Input = Output

$$\text{Steam}_{\text{in}} + \text{Elec}_{\text{in}} + \text{Trim}_{\text{in}} = \text{Crax}_{\text{out}} + \text{Grease}_{\text{out}} +$$

$$\text{Water evaporated} + \text{fusion} + \text{conv}_{\text{loss}} + \text{rad}_{\text{loss}} +$$

Condensate

$$\text{Steam} - \text{condensate} + \text{elec} = \text{product change} + \text{losses}$$

$$7,857,672 \text{ Btu's} + 63,960.8 \text{ Btu's} = 6,769,455 \text{ Btu's} +$$

$$250,637 \text{ Btu's}$$

$$7,921,632 \neq 7,010,092$$

It is apparent that additional losses are occurring perhaps as loss through steam trap.

C. Expeller Operation

The input to the twin expellers is the cracklings from the cookers. Following expelling the cracklings have 12.9% grease remaining and are 81.3% solids.

The amount of grease removed per cooker batch by the expellers amounts to -

$$\text{Solids} - 2916 \text{ lbs (59.5\% solids)} = m_c (83.5\% \text{ solids})$$

$$2078 \text{ lbs crax}_{\text{out}} = m_c$$

$$\text{Fat} - 2916 - 2078 = 838 \text{ lbs grease}$$

The total grease per cooker batch is thus, 838 lbs "expeller" grease plus 612 lbs "free grease" or 1450 lbs per batch.

Electrical input for expellers and conveyors -

2 - 40 hp expellers - 470V, 26.8A

2 - 2.0 hp conveyors - 470V, 1.0A

1 - 3.0 hp conveyors - 470V, 1.5A

$$[(2)(26.8A) + (2)(1.0A) + (1.5A)](470V)(80\% \text{ P.F.})(\sqrt{3})(12.25 \text{ hrs}) =$$

$$455,533.9 \text{ WH/day or } 27.4 \text{ WH/lb grease or } 150.8 \text{ WH/head}$$

D. Hammermill Operation

Following expelling the cracklings are ground and moved to storage. Energy input is as electricity. This equipment is shared with hair and blood processing. The time allotted to cracklings for this equipment was 71% of total day.

8 - 2.0 hp conveyors - 470V, 1.0A

1 - 40 hp hammermill - 470V, 13.4A

$$71\%(12.25 \text{ hrs})(470V)(80\% \text{ P.F.})(\sqrt{3})[(8)(1.0) + (3.4)] =$$

$$121,215 \text{ WH/day or } 7.295 \text{ WH/lb grease or } 40.12 \text{ WH/head}$$

E. Grease Wash Tank

All grease is pumped to wash tanks for further refining. Of the total input to the tanks, plant personnel estimate that 1000 lbs are lost per day.

Input to tanks - 16,616 lbs + 1000 lbs = 17,616 lb

If the total grease from expellers and percolation pans per day was 17,616 lbs and from each cooker there was (calculated) 612 lb "free" grease plus 838 lbs "expeller" grease (1450 lbs total) based on the cracklings then -

1450 lbs (13 batches) = 18,850 lbs

The difference between this figure and the 16,616 pound average yield represents losses occurring from the cooker on. The ratios used in computing energy use per pound of finished product was -

18,850 lbs/16,616 lbs = 1.134 for cooker output

17,616/16,616 = 1.060 for wash tank on

1. Water use for washing -

a. Initial wash -

4000 pounds of water and steam (90 psig) is used together with 17,616 lbs of grease. Temperature is raised from 100° to 180°F.

$$m_{\text{steam}} + m_{\text{water}} = 4,000 \text{ lbs}$$

$$m_{\text{water}} = 4000 - m_{\text{steam}}$$

$$m_{\text{steam}} (1188 \text{ Btu/lb}) = (4000 - m_{\text{steam}}) (1.0 \text{ Btu/lb}) \times (180 - 65^\circ\text{F}) + 17,616 \text{ lbs } (0.5 \text{ Btu/lb}) (180 - 100^\circ\text{F})$$

$$m_{\text{steam}} (1188 = 11.5 \text{ Btu/lb}) = 460,000 + 704,640$$

$$m_{\text{steam}} = 1085 \text{ lbs steam or } 1,289,461 \text{ Btu/day}$$

2. Final wash -

Another wash is performed using 2000 pounds of water and heating to 200°F from 140°F. Product at this stage is 500 lbs less since some was lost in first wash.

$$m_{\text{steam}} (1188) = 2000 - m_{\text{steam}} (1.0 \text{ Btu/lb-}^\circ\text{F}) (200 - 65^\circ\text{F}) +$$

$$17,116 \text{ lb } (0.5 \text{ Btu/lb-}^\circ\text{F}) (200 - 140^\circ\text{F})$$

$$m_{\text{steam}} (1188 - 135) = 270,000 + 513,480$$

$$m_{\text{steam}} = 744 \text{ lbs or } 883,926 \text{ Btu's/day}$$

Total water used was 6000 pounds or 720 gallons or 0.04 gal per pound of grease or 0.23 gal per head.

Total steam used was 2,173,387 Btu/day or 130 Btu's per pound of grease or 719 Btu's/head.

3. Electrical use by pump -

1 - 5.0 hp pump - 470V, 3.2A

$$1.2 \text{ hrs/day } (3.2\text{A}) (470\text{V}) (80\% \text{ P.F.}) (\sqrt{3}) = 2500.8 \text{ WH/day or}$$

$$0.15 \text{ WH/lb or } 0.83 \text{ WH/head}$$

F. Sanitation and General Utilities

1. Lights and fans run 24 hrs/day -

There are 2 areas designated for inedible rendering. The downstairs area has -

16 - 350 watt incandescent lamps

3 - 0.5 hp fans - 230V, 1.2A

The section of the main floor dedicated to inedible rendering has -

17 - 250 watt mercury vapor lamps

7 - 350 watt incandescent lamps

2 - 0.5 hp fans - 230V, 1.2A

$$5(1.2\text{A}) (230\text{V}) (80\% \text{ P.F.}) (24 \text{ hrs}) + [23(350 \text{ watt}) +$$

$$17(250 \text{ watt})](24 \text{ hrs}) = 321,696 \text{ WH/day or } 19.4 \text{ WH/lb of}$$

grease or 106 WH/head

2. Water use -

2 hoses total use - 19,600 gallons/day or 1.18 gal/lb grease or 6.68 gal/head

Steam required to heat water 70°F was -

19,600 gal (8.33 lb/gal) (1.0 Btu/lb-°F) (70°F) =

11,428,760 Btu/day pr 687.8 Btu/lb grease or 3783 Btu/head

VI. Blood Drying

A. Loading

Blood is usually moved to the tank house by gravity from the kill floor and thus the blood tank agitator and pump are not used. Input temperature of the blood averages 90°F. Analysis of dried blood indicates 5% moisture while fresh blood was 85% water. Thus, for a typical day with 4,132 pounds of blood produced, the input to the two driers was -

$$\text{Solids} - m_{\text{blood}}(0.15) = 4132(0.95)$$

$$m_{\text{blood}} = 26,169 \text{ lbs input (this is approximate equal to the } 7 \text{ lb/head reported by Oneco-St. John)}$$

$$\text{Blood}_{\text{in}} C_p = (1)(0.85) + 0.3(0.15) = 0.895 \text{ Btu/lb-}^{\circ}\text{F}$$

Since the daily load far exceeds the combined capacity of the cookers, raw blood is continuously added to each drier during the day. Assuming the input is divided equally, 13,085 lbs of blood is loaded into each drier.

B. Drier

Blood enters the drier at 90°F. At the end of the run, the dried material leaves the drier at a temperature of 280°F.

1. Energy input -

a. Steam use -

The average steam use by a blood drier was 19,472 lbs of steam at 60 psig during a 12 hour run.

Total input is thus -

$$19,472 \text{ lbs steam } (1181.8 \text{ Btu/lb}) = 23,012,089 \text{ Btu's or}$$

$$11,138 \text{ Btu/lb or } 15,259.6 \text{ Btu/head}$$

Since condensate is returned, the actual energy released from the steam was -

$$19,472 \text{ lb}(1181.8 \text{ Btu/lb} - 277.4 \text{ Btu/lb}) =$$

$$17,610,476 \text{ Btu's/cooker/day}$$

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$$19,472 \text{ lb}(1181.8 \text{ Btu/lb} - 277.4 \text{ Btu/lb}) =$$

$$17,610,476 \text{ Btu/cooker/day}$$

b. Electrical use -

$$1 \sim 50 \text{ hp agitator} - 470\text{V}, 24.8\text{A}$$

12 hrs (24.8A) (470V) (80% P.F.) ($\sqrt{3}$) = 193,812 WH/cooker/day
 or 93.8 WH/lb blood or 128.5 WH/head

Electrical input as heat to one cooker -

193,812 WH (0.50) (3.414 Btu/WH) = 330,837 Btu's

2. Product input energy (base 32°F) -

13,085 lbs (0.895 Btu/lb-°F) (90 - 32°F) = 679,242 Btu's

3. Energy in product leaving -

$$C_p = (1)(0.05) + 0.3(0.95) = 0.335 \text{ Btu/lb-}^\circ\text{F}$$

Product out - 2066 lbs

2066 lbs (0.335 Btu/lb-°F) (280 - 32) = 171,643 Btu's

4. Energy in evaporated water - evaporated at 212°F -

13,085 lbs - 2066 lbs = 11,019 lbs water

11,019 lbs (1150.5 Btu/lb) = 12,677,359

5. Energy lost by convection -

Cooker is 16 ft long with a diameter of 5.25 ft. The average outside surface temperature of the shell was 200°F on the insulated portions and 280°F on the uninsulated ends. Ambient air temperature in the area was 100°F (from Strock, 1959) -

$$h_{\text{side}} = 0.3(200 - 100^\circ\text{F})^{\frac{1}{4}} = 0.949 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$h_{\text{ends}} = 0.3(280 - 100^\circ\text{F})^{\frac{1}{4}} = 1.099 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$q_c = (2) (1.099 \text{ Btu/hr-}^{\circ}\text{F-ft}^2) (5.25/2 \text{ ft})^2 \pi (280 - 100^{\circ}\text{F}) \times$$

$$(12 \text{ hrs})$$

$$0.949 \text{ Btu/hr-}^{\circ}\text{F-ft}^2 (5.25 \text{ ft}) \pi (16 \text{ ft}) (200 - 100^{\circ}\text{F}) \times$$

$$(12 \text{ hrs}) = 403,298 \text{ Btu/drier/day}$$

6. Energy loss by radiation - (assume $e = 0.95$)

$$q_r = 0.174(0.95)/10^8 [(740^4 - 560^4) (43.3 \text{ ft}^2) (12 \text{ hrs}) +$$

$$(660^4 - 560^4) (263.9 \text{ ft}^2) (12 \text{ hrs})] = 651,552 \text{ Btu's}$$

7. Balance -

$$\text{Steam}_{in} - \text{Cond}_{out} + \text{Elec}_{in} + \text{Product}_{in} = \text{blood}_{out} +$$

$$\text{water evap} + \text{conv loss} + \text{rad loss}$$

$$17,610,476 \text{ Btu's} + 330,837 \text{ Btu's} + 679,242 \text{ Btu's} =$$

$$171,643 \text{ Btu's} + 12,677,359 \text{ Btu's} + 403,298 \text{ Btu's} + 651,552 \text{ Btu's}$$

$$18,620,555 \text{ Btu's} \neq 13,903,852 \text{ Btu's}$$

The input far exceeds the output which estimated using standard procedures. The difference must be due either to large steam losses or to a higher energy requirement to remove water as the product nears 5% moisture.

C. Output Conveyors and Hammermill -

All electrical use -

9 - 2.0 hp conveyors - 470V, 1.0A

1 - 40 hp hammermill - 470V, 13.4A

Average use by blood for 12.25 hrs daily usage was 11%.

$$0.11(9A + 13.4) (470V) (80\% \text{ P.F.}) (\sqrt{3}) (12.25 \text{ hrs}) =$$

$$19,657 \text{ WH/day or } 4.757 \text{ WH/lb blood or } 6.52 \text{ WH/head}$$

D. Sanitation and General Utilities

1. Electrical use -

The section of the tankhouse designated for blood contains -

7 - 250 watt mercury vapor lamps

3 - 350 watt incandescent lamps

1 - 0.5 hp fan - 240V, 1.2A

All equipment runs 24 hours per day.

$24 \text{ hrs}[(1.2\text{A})(240\text{V})(80\% \text{ P.F.}) + 3(350 \text{ watt}) + 7(250 \text{ watt})] =$

$72,499.2 \text{ WH/day or } 17.5 \text{ WH/lb blood or } 24.0 \text{ WH/head}$

2. Water and steam use -

The single clean up hose near the blood driers used an average of -

2352 gallons per day or 0.569 gal/lb or 0.780 gal/head

The steam needed to heat the water to 70°F was -

$2352 \text{ gal}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(70^{\circ}\text{F}) = 1,371,451 \text{ Btu/day}$

or 332 Btu/lb or 455 Btu/head

VII. Hair Hydrolysis and Drying

Since hair is mixed with cracklings it is difficult to determine daily production. Estimates by plant personnel ranged from 0.70 to 1.5 lb per head. The Wilson plant produces hair at a slightly higher moisture content at 0.89 lbs/head and this is the amount which is used here. Wet hair in was estimated to be 2.0 to 2.5 lbs per head.

A. Loading

Hair is removed from the dehairers and transferred to the tank house by means of conveyors, 2 - 2.0 hp and 2 - 3.0 hp. The total operating time of the conveyors averaged 8.5 hours per day.

2 - 3.0 hp conveyors - 470V, 1.7A

2 - 2.0 hp conveyors - 470V, 1.0A

$$8.5 \text{ hours } [(2(1.7) + 2(1.0))(470V) (80\% \text{ P.F.}) (\sqrt{3}) =$$

29,892 WH/day or 9.89 WH/head or 11.11 WH/lb dried hair

B. Continuous Hydrolyzer

Hair enters the hydrolyzer at a temperature 90°F. Analysis of hair into and out of hydrolyzer indicates that only a small amount of water is removed.

60.8% water in input hair; 56.8% water in output hair

1. Steam use -

The hydrolyzer operates on the average only 5.84 hours/day. Total steam use (90 psig) for a single day was -

$$6000.9 \text{ lb}(1188 \text{ Btu/lb}) = 7,129,069 \text{ Btu's or } 2359.8 \text{ Btu's/head}$$

$$\text{or } 2651 \text{ Btu/lb}$$

Part of the total is injected and part is used in the jacket.

2. Electrical use -

1 - 20 hp agitator - 470V, 10A

$$5.84 \text{ hrs}(10A) (470V) (80\% \text{ P.F.}) (\sqrt{3}) = 38,033 \text{ WH/day or } 12.59$$

WH/head or 14.1 WH/lb hair

Of the total electrical use, it is assumed that only 50% is input to the product as heat -

$$38,033 \text{ WH}(0.50) (3.414 \text{ Btu/WH}) = 64,922 \text{ Btu's/day}$$

3. Energy input due to hair -

It is assumed that 2.5 lb of wet hair per head are input to system. The difference between 2.5 and 95.1% (0.89 lbs/39.2% = 2.16 lbs will be assumed to cover product losses.

Analysis of wet hair indicated 60.6% moisture at 90°F -

$$C_p = (1) (0.606) + 0.3(0.394) = 0.724 \text{ Btu/lb-}^{\circ}\text{F}$$

$$m_{\text{hair}_{\text{in}}} = 3021 \text{ head}(2.5 \text{ lbs/head}) = 7552 \text{ lbs}$$

$$7552 \text{ lbs}(0.724 \text{ Btu/lb-}^{\circ}\text{F}) (90 - 32^{\circ}\text{F}) =$$

$$317,144 \text{ Btu/day}$$

4. Energy output in hair -

Analysis indicates 56.8% water in hydrolyzed hair. Temperature of hair leaving the hydrolyzer was 230°F.

$$C_p = (1) (0.568) + 0.3(0.432) = 0.698 \text{ Btu/lb-}^{\circ}\text{F}$$

$$\text{Solids } m_{\text{hair}_{\text{out}}} (0.432) = 3021 \text{ head}(2.5 \text{ lbs/head}) (0.394)$$

$$m_{\text{hair}_{\text{out}}} = 6888 \text{ lbs}$$

$$6888 \text{ lbs}(0.698 \text{ Btu/lb-}^{\circ}\text{F}) (230 - 32^{\circ}\text{F}) = 951,949 \text{ Btu's}$$

5. Energy required to evaporate the small amount of water lost at atmospheric -

$$7552 - 6888 \text{ lbs}(1050.5 \text{ Btu/lb}) = 697,532 \text{ Btu's}$$

6. Energy loss due to convection -

Hydrolyzer is essentially a 4 ft diameter by 10 ft long horizontal cylinder. There is insulation on the surface but surface temperatures were 200°F.

$$h_c \text{ sides and ends} = 0.3(200 - 100^\circ\text{F}) = 0.949 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$q_c = 2(2 \text{ ft})^2 (0.949 \text{ Btu/hr-}^\circ\text{F-ft}^2) (200 - 100^\circ\text{F}) (5.84 \text{ hrs}) + \\ (4 \text{ ft } \pi) (10 \text{ ft}) (0.949 \text{ Btu/hr-}^\circ\text{F-ft}^2) (200 - 100^\circ\text{F}) \times \\ (5.84 \text{ hrs}) = 83,573.8 \text{ Btu's}$$

7. Energy loss due to radiation -

Painted surface $e = 0.94$ (from Heldman, 1975)

$$q_r = \frac{0.174(0.94)}{10^8} (660^4 - 560^4) (25.1 \text{ ft}^2 + 125.2 \text{ ft}^2) (5.84 \text{ hrs}) = \\ 131,655 \text{ Btu's}$$

8. Balance -

$$\text{Steam}_{in} + \text{Elec}_{in} + \text{Product}_{in} = \text{Cond} + \text{Venting} + \text{Product}_{out} +$$

Water evap + Losses

$$7,129,069 \text{ Btu's} + 64,922 + 317,144 = 951,949 - 697,532 -$$

$$83,574 = 131,655 = \text{Cond} + \text{Venting}$$

$$5,646,425 \text{ Btu's} = m_{\text{cond}} + m_{\text{vap}}$$

Since total weight of vapor and condensate was 6000.8 lbs, the m_{cond} is equal to 6000.8 lbs = m_{vap}

$$5,646,425 \text{ Btu's} = m_{\text{vap}} (1188 \text{ Btu/lb}) + (6000.8 \text{ lb} - m_{\text{vap}}) \times \\ (302.2 \text{ Btu/lb})$$

$$3,833,283.2 = 1188 m_{\text{vap}} - 302.2 m_{\text{vap}}$$

$$4327.5 \text{ lbs} = m_{\text{vap}} = 5,141,048 \text{ Btu's}$$

$$1673.3 \text{ lbs} = m_{\text{cond}} =$$

C. Drier

A drier run usually lasts 8.5 hours

1. Electrical input -

2 - 3.0 hp conveyors - 470V, 1.7A

1 - 30 hp agitator - 470V, 18.5A

$$8.5 \text{ hrs}(3.4\text{A} + 18.5\text{A})(470\text{V})(80\% \text{ P.F.})(\sqrt{3}) = 121,230 \text{ WH/day or}$$

40.13 WH/head

Energy input of agitator as heat -

$$102,409 \text{ WH}(0.50)(3.414 \text{ Btu/WH}) = 174,812 \text{ Btu's/day}$$

2. Steam input -

Steam input to hair drier was not measured but is of the same design as the blood drier. The efficiency was assumed the same -

$$\text{Blood drier} \quad \frac{23,012,089 \text{ Btu's} + 330,837 \text{ Btu's}}{11,019 \text{ lb water evap}} = 2118.4 \text{ Btu per}$$

pound water evap

Hair into drier was 56.8% water; out of drier was 4.9% water

$$\text{Solids} \quad 6888 \text{ lbs hair} (43.2\%) = m_{\text{out}} (95.1\%)$$

$$3129 \text{ lbs} = m_{\text{out}}$$

$$6888 - 3129 \text{ lbs} = 3759 \text{ lbs water}$$

Therefore, the amount of steam used was -

$$3759 \text{ lbs water}(2118.4 \text{ Btu/lb water}) = 7,963,160 \text{ Btu's/day}$$

of which 64,922 comes from agitator

The steam requirement was -

$$7,898,238 \text{ Btu/day or } 2614.4 \text{ Btu/head or } 2938 \text{ Btu/lb}$$

D. Hammermill

The dried hair is handled in the same way and using the same equipment as the cracklings and blood. All input is electrical. It is estimated that hair is processed in the equipment 18% of the 12.25 hrs time.

- 9 - 2.0 hp conveyors - 470V, 1.2A
- 1 - 40 hp hammermill - 470V, 13.4A

$$0.18(12.25 \text{ hrs})[(9)(1.2) + 13.4A](470V)(80\% \text{ P.F.})(\sqrt{3}) =$$

$$34,751 \text{ WH/day or } 11.50 \text{ WH/head or } 12.9 \text{ WH/lb}$$

E. Sanitation and General Utilities -

1. Electrical input -

The electrical input for lights and fans in the hydrolyzer-drier areas of the tank house include -

- 10 - 250 watt mercury vapor
- 4 - 350 watt incandescents
- 1 - 0.5 hp fan - 230V, 1.2A

All equipment runs 24 hours per day.

$$24 \text{ hrs}[(1.2A)(230V)(80\% \text{ P.F.}) + (10)(250 \text{ watt}) + (4)(350 \text{ watt})]$$

$$= 97,699 \text{ WH/day or } 32.3 \text{ WH/head or } 36.3 \text{ WH/lb}$$

2. Water and steam use -

The hair handling area is very similar to the blood area. For this reason the water and steam requirements were assumed to be the same -

$$0.780 \text{ gal/head and } 455 \text{ Btu/head}$$

APPENDIX B1 - PLANT B
PRODUCTION DATA

PLANT B

TYPICAL YEAR HOG SLAUGHTER

Month	Number of Hogs Killed	Weight of Hogs Killed (lbs)
January	76,176	18,724,227
February	83,163	20,784,222
March	125,676	31,226,660
April	115,606	28,009,765
May	92,294	23,215,738
June	109,626	27,952,044
July	79,834	19,550,958
August	81,177	19,770,657
September	128,010	30,926,505
October	102,244	25,330,371
November	103,657	26,648,014
December	108,316	27,720,125
TOTAL	1,205,779	299,859,280

Average Slaughter

Per Day (250 days/year) - 4823 Head

Average Liveweight

Per Head Slaughtered - 248.7 Pounds

PLANT B

TYPICAL YEAR BY-PRODUCT PRODUCTION

Month	Lard (pounds)	Inedible Tallow (pounds)	Meat and Bone Meal (pounds)	Dried Hair (pounds)	Dried Blood (pounds)
January	925,975	483,136	641,856	86,165	85,260
February	943,098	530,600	791,680	101,785	108,750
March	1,617,655	721,398	1,165,600	135,030	153,080
April	1,545,557	630,394	968,510	104,895	164,460
May	1,275,474	518,065	894,210	80,390	128,300
June	1,485,420	686,356	1,028,945	73,260	130,880
July	1,147,578	526,416	733,535	27,925	88,300
August	1,041,024	442,394	708,550	53,345	107,640
September	1,481,366	962,337	1,100,975	96,925	179,320
October	1,250,632	658,292	1,017,805	103,508	137,660
November	1,498,735	838,301	1,002,480	96,300	90,380
December	1,426,575	879,519	1,132,610	95,130	142,820
TOTAL	15,637,089	7,877,208	11,186,856	1,054,658	1,516,850

Average Production Per Day (250 days/year)	62,548	31,509	44,747	4,219	6,067
Average Production Per Head Killed	12.97	6.53	9.28	0.87	1.26

PLANT B
TYPICAL YEAR
FRANKFURTERS AND HAM PRODUCTION

Month	Pounds of Franks	Pounds of All Ham Type Products*
January	1,608,196	808,729
February	905,772	824,326
March	1,538,670	2,216,814
April	1,374,741	1,208,316
May	2,358,205	877,931
June	2,726,618	668,066
July	1,681,996	466,416
August	1,090,701	784,769
September	1,301,724	915,074
October	962,967	1,381,430
November	720,179	1,979,997
December	766,424	1,941,078
YEARLY TOTAL	17,836,193	14,072,946

Average Daily Production (250 days/year)	71,345	56,292
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*Includes bone-in, boneless, and semi-boneless hams,
as well as picnics, butts and ham rolls.

PLANT B

TYPICAL YEAR
CUT FLOOR PRODUCTION

Product	Pounds Produced Per Year	Pounds Produced Per Day*
Hams	52,201,543	208,806
Butts	14,596,225	58,385
Bellies	37,360,963	149,444
Jowls	4,355,474	17,422
Loins	43,425,262	173,701
Spareribs	8,244,770	32,979
Trim	10,232,480	680,930
TOTAL	170,232,480	680,930

Average Product Per Head Killed - 141.2 pounds

*Assume 250 production days per year..

APPENDIX B2 - PLANT B

UTILITY FLOW DATA

PLANT B

TYPICAL YEAR UTILITY USAGE

Month	Water Million Gal.	Electricity Million Kwh	Refrigeration Billion BTU's*	Gas and Oil Billion BTU's
January	24.278	1.1899	4.6797	33,163
February	25.972	1.3060	4.7019	29,467
March	34.609	1.6900	7.4209	44,677
April	29.548	1.3441	6.5059	32,718
May	30.925	1.4349	7.3305	33,337
June	35.805	1.7090	9.8067	37,137
July	29.261	1.3869	9.0844	27,892
August	30.877	1.4209	9.2485	29,392
September	40.844	1.7570	11.2870	39,954
October	30.431	1.4449	7.2164	33,630
November	32.472	1.5020	7.7573	37,371
December	39.376	1.9540	8.9654	55,438

*Ton Refrigeration = 288,000 BTU's

PLANT B

BASELINE ENERGY REQUIREMENTS
AVERAGE WEEKEND USAGE 1979

Month	Water (Gal./Day)	Electricity (Kwh/Day)	Gas (Million BTU's/Day)
January			
February		26400	232
March		30400	317
April		38400	248
May			
June	404,600	28800	308
July	551,600	32400	282
August			
September			
October			
November	211,200	39100	218
December	200,000	43200	173

PLANT B

TYPICAL DAILY UTILITY USAGE (7-17 to 7-27-78)

Day	Water Million Gal.	Electricity KwH	Natural Gas Million BTU's
Monday	1.7007	43200	567.9
Tuesday	1.8073	81600	891.0
Wednesday	1.4862	62600	638.4
Thursday	1.4050	67200	602.0
Friday	1.3035	64800	663.8
Saturday	0.5560	34800	264.9
Sunday	0.4362	34800	264.9
Monday	1.3287	57600	559.4
Tuesday	1.4588	67200	702.4
Wednesday	1.3410	67200	638.6
Thursday	1.6328	72000	710.9

PLANT B

AVERAGE HOURLY UTILITY FLOWS
7-11-78

Water		Electricity		Gas	
Time*	Gal/Hr.	Time	Kw/Hr.	Time	Million BTU/Hr.
12 MIDNT	57,800	12 MIDNT	1800	12 MIDNT	-----
1:00	51,900	3:00	1800	12:30	19.2
2:00	35,400	5:00	1800	1:30	19.3
3:00	31,400	7:00	2400	3:30	19.1
4:00	31,400	9:00	2400	6:30	21.3
5:00	59,900	11:00	1200	7:30	36.0
6:00	25,400	12 Noon	-----	8:30	45.4
7:00	37,500	1:00	1200	9:30	43.4
8:00	76,100	3:00	2400	10:30	45.0
9:00	76,100	5:00	1200	11:30	40.7
10:00	79,100	7:00	1200	12 Noon	-----
11:00	80,100	9:00	1200	12:30	41.9
12 Noon	85,200	11:00	1200	1:30	42.0
1:00	77,200	12 MIDNT	1200	2:30	40.0
2:00	81,300			4:00	43.1
3:00	98,200			5:30	38.8
4:00	75,600			6:30	35.8
5:00	71,900			7:30	27.1
6:00	77,200			8:30	24.2
7:00	65,900			9:30	25.2
8:00	62,900			10:30	19.1
9:00	63,900			11:30	19.4
10:00	60,900			12 MIDNT	-----
11:00	54,700				
12 MIDNT	40,600				

*Time indicates midpoint between two successive readings.

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PLANT B

Monitor Labs #1 (downstairs)

MDE = 11111

TEMPERATURE DEVICES

Monitor Labs - range 3V
scale factors m=1000 b=0

<u>Channel</u>	<u>Wire Code</u>	<u>Stations</u>
0	10	Product inlet Equacooker
1	8	Product outlet Equacooker
2	7	Hot air blood drier
3	4	Raw blood inlet blood coagulator
4	6	Product outlet blood coagulator
5	5	Dried blood in cyclone
6	20	Product in hair hopper
7	21	Hair hydrolyzer
8		
9		
10	13	Edible rendering - holding tank outlet after steam
11	1	Edible rendering - holding tank outlet injection
12	11	Product at first centrifuge (upstairs).
13	2	Product at second centrifuge
14	3	Product out of wash tank
15	12	Product to storage tanks
16		
17		
18		
19		
20	72	Dehairer #1 (near scald tank)
21	76	Dehairer #2 (near gambling table)
22	24	Hot water for kill floor 6" main
23	25	Cold water for kill floor 6" main
24	73	Mix for 6" mains
25		
26		
27	74	Entrail pan cleaner after mix
28		
29	75	Scald tank (near bleed pit)
30	71	Scald tank (near singer)

<u>Channel</u>	<u>Wire Code</u>	<u>Stations</u>
31		
32		
33		
34		
35		
36		
37	37	Waste water from rest of plant
38	36	Waste water from kill floor
39		Test

FLOW METERS
Monitor Labs - range 3V

Readings In	Channel	Wire Code Signal/Power	Station	Scale Factors	
				m	b
PPH	40	30/29	Scald tank (bleed)-EM steam 2"	2,375	-475
PPH	41	35/34	Scald tank (singer)-EM steam 2"	2,375	-475
PPH	42	78/	Dehairer #1-EM steam 1.5"	1,500	-300
	43	77/	Dehairer #2		
SCFH	44	28/27	Singer-NE gas 2"	10,912	-2,182
GPM	45	80-79	Polisher-Mead water 2.5"	312.5	-62.5
GPM	46	66/	Rinse after shave-Mead water 1.5"	125	-25
GPM	47	70/	Cold 6" main-Mead water 6"	1,250	-250
GPM	48	68/	Hot 6" main-Mead water 6"	1,250	-250
GPM	49	64/	Final rinse-Mead water 1.5"	125	-25
SCFH	50	23/22	Blood drier-NE gas 2"	10,912	-2,182
PPH	51	31/32	Equacooker-EM steam 6"	30,000	-6,000
PPH	52	35/34	Hair hydrolyzer-NE steam 3"	6,381	-1,276
PPH	53	39/38	Blood coagulator-NE steam 2"	1,925	-385
PPH	54	19/18	Edible holding tank-NE steam 2"	1,925	-385
	55	15/14	Edible wash tank-		
	56	17/16	Edible square tank-		
	57				
PPH	58	41/40	Boiler-EM steam 6"	*3.000	*-0.600
SCFH	59	43/42	Boiler-NE steam 3"	*3.488	*-0.698

*For these meters, the numbers obtained as data must be multiplied by 10,000 to get actual flow rate.

PPH = Pounds of steam per hour

SCFH = Standard Cubic feet per hour of gas

GPM = gallons per minute

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PLANT B
Monitor Labs #2 (upstairs)

MDE = 22222

TEMPERATURE DEVICES
Monitor Labs - range 3V
scale factors m=1000 b=0

<u>Channel</u>	<u>Wire Code</u>	<u>Stations</u>
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20	59	Cut floor refrigeration inlet
21	60	Cure room refrigeration outlet
22	61	Cure room refrigeration inlet
23	4	Ham shower after smoke
24	12	Ham blast refrigeration inlet #2
25	11	Ham tempering refrigeration inlet
26	10	Ham tempering refrigeration outlet
27	3	Ham blast refrigeration inlet #1
28	2	Ham blast refrigeration outlet #2
29	1	Ham blast refrigeration outlet #1
30	62	Carcass cooler refrigeration

<u>Channel</u>	<u>Wire Code</u>	<u>Stations</u>
31	24	Carcass cooler refrigeration
32	25	Carcass cooler refrigeration
33	23	Carcass cooler refrigeration
34	83	Frank water shower in
35	22	Frank water shower out
36	63	Cut floor refrigeration outlet
37	14	Brine tunnel out
38	13	Brine tunnel in
39	16	Sausage kitchen clean up

FLOW METERS
Monitor Labs - range 3V

<u>Findings</u> <u>In</u>	<u>Channel</u>	<u>Wire Code</u> <u>Signal/Power</u>	<u>Stations</u>	<u>Scale Factors</u>	
				<u>m</u>	<u>b</u>
GPM	40	9/	Ham shower-Mead water 1/25"	93.75	-18.75
SCFH	41	6/5	Ham smokehouse #5-NE gas 2"	10,912	-2,182
SCFH	42	8/7	Bologna smokehouse-NE gas 1.5"	5,000	-1,000
SCFH	43	17/18	Frank smokehouse-NE gas 2"	10.912	-2,182
PPH	44	21/20	Frank smoke-shower end-NE steam 2"	1,925	-385
	45		Frank-smoke-peeler end-		
GPM	46	15/	Frank brine - Mead water 3" ss	437.5	-87.5
GPM	47	19/	Frank shower - Mead water 2"	210.75	-43.75
	48				
PPH	49	45/44	Gambrel chain cleaner-NE steam 3"	6,381	-1,276

PPH = Pounds of steam per hour

SCFH = Standard Cubic feet per hour of gas

GPM = gallons per minute

REFRIGERATION

TIME	CUT IN	CUT OUT	CURE OUT	CURE IN
0-24 HR	F.	F.	F.	F.
.0	54.03	37.57	31.20	37.60
1.0	56.63	40.23	35.50	39.17
2.0	60.13	43.70	55.47	55.63
3.0	57.83	39.93	50.10	54.13
4.0	57.97	40.13	36.37	43.00
5.0	56.40	38.07	35.17	41.63
6.0	61.20	42.77	34.97	40.90
7.0	63.53	44.77	34.57	40.27
8.0	64.03	46.00	35.07	40.17
9.0	60.47	42.37	36.80	39.80
10.0	62.17	43.53	47.93	48.20
11.0	62.03	42.57	39.97	43.93
12.0	66.13	49.80	38.47	42.53
13.0	67.53	49.10	39.33	43.60
14.0	63.87	48.00	37.33	42.13
15.0	54.53	54.50	49.17	49.80
16.0	48.50	58.93	39.83	50.50
17.0	50.67	59.17	38.83	43.37
18.0	53.07	59.93	38.67	42.87
19.0	67.43	69.63	40.50	45.40
20.0	74.00	74.80	50.97	54.80
21.0	80.20	73.80	44.90	49.93
22.0	77.67	72.77	43.67	49.10
23.0	76.40	75.70	39.93	46.47

CARCASS CHILL REFRIGERATION

TIME	KILL FLOOR	END	CUT FLOOR	END
0-24 HR	INLET	OUTLET	INLET	OUTLET
	F.	F.	F.	F.
.0	43.87	37.33	43.00	38.47
1.0	43.83	37.03	47.07	39.93
2.0	43.37	36.73	45.43	39.30
3.0	43.50	36.93	44.67	39.00
4.0	43.60	36.80	44.00	39.17
5.0	43.20	36.30	42.97	40.30
6.0	43.80	36.70	43.67	42.40
7.0	44.43	37.10	44.40	43.83
8.0	42.27	37.30	47.97	46.77
9.0	42.13	37.01	42.90	43.73
10.0	44.23	39.63	44.33	44.17
11.0	44.63	40.07	47.60	44.53
12.0	43.77	38.10	54.20	49.27
13.0	42.90	37.73	48.60	45.57
14.0	48.50	44.43	50.20	47.53
15.0	38.77	35.10	45.30	44.87
16.0	33.13	32.20	48.00	58.37
17.0	35.57	34.40	46.87	46.87
18.0	40.53	43.07	44.73	44.50
19.0	32.50	31.33	42.60	42.07
20.0	30.57	29.33	42.90	42.23
21.0	29.90	29.70	39.93	50.07
22.0	32.70	37.57	38.20	37.40
23.0	30.17	28.93	36.40	35.20

Pit 5

(2049)

TIME 0-24 HR	REFRIGERATION			
	H TEM OUT F.	H TEM IN F.	H BLS IN F.	H BLS OUT F.
.0	28.50	29.20	42.50	39.77
1.0	26.73	30.43	40.37	37.27
2.0	26.63	26.70	38.27	35.77
3.0	25.70	26.10	36.97	34.20
4.0	27.53	28.23	35.40	32.30
5.0	27.53	31.17	33.07	30.30
6.0	36.47	33.30	34.27	33.87
7.0	26.37	26.33	37.13	37.97
8.0	27.00	29.37	37.67	38.27
9.0	25.73	28.67	35.63	35.01
10.0	33.60	35.43	34.47	34.00
11.0	28.67	31.03	35.77	34.77
12.0	29.47	31.37	37.90	36.01
13.0	30.77	32.13	37.47	35.67
14.0	41.60	42.23	36.13	34.57
15.0	34.47	36.93	37.33	35.33
16.0	38.13	39.73	37.23	35.43
17.0	36.47	38.03	36.50	34.50
18.0	31.43	32.73	35.90	34.30
19.0	29.33	31.27	35.87	34.60
20.0	29.93	32.00	35.80	32.90
21.0	28.07	29.87	34.37	32.17
22.0	40.33	39.43	33.20	30.43
23.0	28.83	30.00	32.43	29.77

Pit 6

(2049)

TIME 0-24 HR	FRANK BRINE CHILL TUNNEL		
	FLOW GPM	OUTLET F.	INLET F.
.0	0	34.20	26.27
1.0	0	33.77	41.13
2.0	0	33.33	28.63
3.0	0	33.53	30.03
4.0	0	33.90	30.03
5.0	0	34.37	31.70
6.0	0	34.40	29.40
7.0	0	34.17	27.83
8.0	0	34.03	27.80
9.0	146.84	9.00	11.37
10.0	150.90	13.40	17.70
11.0	161.87	12.80	17.43
12.0	188.24	10.00	12.83
13.0	191.26	9.83	12.43
14.0	127.75	9.10	10.30
15.0	191.74	12.53	14.13
16.0	192.51	14.23	15.63
17.0	0	14.13	15.97
18.0	185.81	15.33	16.80
19.0	187.85	14.07	15.67
20.0	186.76	10.70	12.03
21.0	189.54	14.30	16.53
22.0	191.40	16.20	18.40
23.0	104.33	15.00	17.33

Pit7

133

(2049)

FRANK FRESH WATER SHOWER

TIME	FLOW	INLET	OUTLET
0-24 HR	GPM	F.	F.
.0	0	88.33	86.00
1.0	0	88.03	85.43
2.0	0	87.70	84.73
3.0	0	87.43	84.10
4.0	0	87.20	83.50
5.0	0	87.07	83.10
6.0	0	86.77	82.70
7.0	0	86.73	83.40
8.0	29.91	77.03	78.13
9.0	89.64	56.37	69.10
10.0	89.57	55.80	72.70
11.0	89.22	54.60	71.60
12.0	88.84	54.60	72.90
13.0	88.83	54.57	69.37
14.0	88.93	54.50	62.67
15.0	88.99	54.50	69.20
16.0	89.45	54.50	69.80
17.0	90.12	54.50	58.77
18.0	90.11	54.50	70.17
19.0	90.40	54.50	69.70
20.0	90.70	54.47	66.10
21.0	91.42	54.50	70.37
22.0	91.08	54.50	67.60
23.0	91.66	54.47	60.63

Pit8

(186U)

TIME	H SMOKE	S SMOKE	GAM CHN CLNR
0-24 HR	GAS SCFH	GAS SCFH	STEAM PPH
.0	0	110.00	0
1.0	1004.17	0	0
2.0	1764.33	0	0
3.0	1485.17	0	0
4.0	1667.33	0	3.75
5.0	1303.33	0	1.93
6.0	970.00	0	1075.48
7.0	2011.00	0	812.12
8.0	838.68	0	806.17
9.0	856.25	0	782.25
10.0	689.93	0	794.15
11.0	698.85	0	735.35
12.0	0	0	787.45
13.0	0	0	737.27
14.0	0	0	603.15
15.0	1347.00	342.75	476.82
16.0	2911.33	246.92	0
17.0	1042.33	220.50	0
18.0	0	236.08	0
19.0	622.83	188.92	0
20.0	2422.67	176.75	0
21.0	1533.33	162.92	0
22.0	1387.00	141.42	0
23.0	1162.27	27.75	0

Plt9

(186U)

TIME 0-24 HR	FRANKFURTER LINE			
	F SMOKE	F SMOKE	WATER SHWR	BRINE SHWR
	GAS SCFH	STEAM PPH	WATER GPM	BRINE GPM
.0	3901.17	802.65	115.48	90.07
1.0	3150.50	769.62	175.04	89.88
2.0	239.83	169.57	75.07	89.98
3.0	0	33.25	0	45.26
4.0	0	27.05	0	0
5.0	0	19.88	0	0
6.0	0	41.72	0	0
7.0	3897.50	654.27	0	48.70
8.0	3860.17	956.35	114.63	50.79
9.0	3527.00	1066.02	162.81	88.71
10.0	2942.83	1207.35	168.12	88.66
11.0	4164.50	1180.02	136.76	87.69
12.0	3919.33	1439.73	173.72	88.24
13.0	2540.67	1518.63	158.93	88.03
14.0	3935.67	1430.10	134.98	87.66
15.0	3829.50	1234.22	173.45	88.12
16.0	3948.50	1258.72	170.05	88.01
17.0	3458.83	1220.35	170.18	87.62
18.0	2913.67	1427.82	84.53	88.62
19.0	4268.83	1194.18	155.31	89.84
20.0	3861.50	1093.47	170.95	90.10
21.0	3585.83	1188.15	168.45	89.87
22.0	3038.83	1254.07	141.38	90.66
23.0	2554.50	1290.50	166.98	90.67

Plt10

(2049)

TIME 0-24 HR	GAM CHN CLNR		H SHWR	
	STEAM	WATER	TEMP	
	PPH	GPM	F.	
.0	0	.09	107.40	
1.0	0	.09	102.70	
2.0	0	.10	101.50	
3.0	0	.09	100.47	
4.0	0	.10	100.90	
5.0	0	13.71	124.93	
6.0	1430.33	6.38	89.47	
7.0	775.27	.09	100.77	
8.0	778.60	.09	108.10	
9.0	746.10	.09	117.40	
10.0	722.90	.09	114.67	
11.0	659.30	.10	116.57	
12.0	681.63	.10	116.87	
13.0	665.27	.10	115.30	
14.0	642.10	.10	114.07	
15.0	416.77	.10	115.80	
16.0	0	.06	116.10	
17.0	0	.09	115.27	
18.0	0	.09	113.53	
19.0	0	.10	108.90	
20.0	0	.07	108.47	
21.0	0	.10	109.30	
22.0	0	.10	108.93	
23.0	0	.10	109.40	

Plt11

TIME 0-24 HR	H SMOKE	S SMOKE	F SMOKE	(2049) F SMOKE
	GAS	GAS	GAS	STEAM
	SCFH	SCFH	SCFH	PPH
.0	563.43	0	0	0
1.0	875.87	0	0	0
2.0	898.83	0	0	0
3.0	311.23	0	0	0
4.0	.27	0	0	0
5.0	.28	0	0	0
6.0	.40	0	0	0
7.0	.40	0	1513.00	0
8.0	.40	0	2532.33	463.53
9.0	.40	0	4963.33	1279.80
10.0	.40	0	4374.00	1232.90
11.0	4165.00	0	3267.00	1326.77
12.0	1710.67	0	3699.00	1209.07
13.0	.27	0	2808.67	1230.30
14.0	.40	0	1991.33	1337.63
15.0	1575.47	0	4140.67	1206.40
16.0	1734.67	206.67	2334.00	1284.40
17.0	1521.33	319.00	3113.67	1317.63
18.0	1613.67	275.50	5057.33	1192.37
19.0	1592.00	189.00	3679.33	1264.17
20.0	1315.03	162.00	3726.33	1218.03
21.0	910.80	142.83	4232.67	1233.17
22.0	867.53	218.67	2650.33	1288.53
23.0	937.57	53.50	4584.67	1275.50

Plt12

TIME 0-24 HR	REFRIGERATION			
	CUT IN	CUT OUT	CURE IN	CURE OUT
	F.	F.	F.	F.
.0	76.87	75.57	41.87	38.50
1.0	76.17	74.37	41.73	47.83
2.0	64.73	60.00	56.03	58.30
3.0	48.47	41.47	68.23	67.90
4.0	43.87	36.97	60.17	62.47
5.0	42.83	37.30	39.20	46.13
6.0	49.90	43.77	37.10	44.20
7.0	54.43	47.37	37.00	43.83
8.0	54.53	48.13	40.40	19.50
9.0	56.40	49.27	39.23	22.17
10.0	56.50	49.33	45.33	22.60
11.0	56.57	49.33	40.47	21.50
12.0	56.97	50.17	39.80	20.57
13.0	58.23	51.07	38.37	19.37
14.0	57.47	50.53	39.07	18.60
15.0	57.23	54.40	43.97	17.63
16.0	49.47	62.80	40.63	17.77
17.0	63.23	63.70	41.33	17.83
18.0	60.33	65.80	40.67	17.53
19.0	76.60	79.83	42.80	18.50
20.0	81.83	76.83	46.60	18.20
21.0	80.80	76.43	42.53	19.97
22.0	81.33	76.70	44.60	20.27
23.0	78.13	74.53	45.97	22.97

(2059)

TIME 0-24 HR	CARCASS CHILL REFRIGERATION			
	KILL FLOOR END		CUT FLOOR END	
	INLET F.	OUTLET F.	INLET F.	OUTLET F.
.0	26.40	28.20	35.43	34.17
1.0	26.07	28.50	36.50	46.53
2.0	27.27	28.53	34.40	34.27
3.0	27.20	28.63	34.40	33.67
4.0	27.87	28.47	34.17	33.67
5.0	31.57	21.73	34.07	23.60
6.0	36.37	27.80	33.93	33.27
7.0	35.97	29.00	35.07	35.47
8.0	35.57	29.33	38.07	53.33
9.0	35.23	30.90	36.40	36.53
10.0	26.43	33.60	36.83	36.83
11.0	37.10	32.80	39.97	39.93
12.0	35.77	30.00	41.13	51.47
13.0	39.33	31.73	43.13	23.53
14.0	44.67	37.93	48.00	40.27
15.0	48.13	40.00	45.87	46.00
16.0	49.80	40.93	49.57	59.60
17.0	40.20	43.33	49.33	48.80
18.0	56.73	50.33	47.03	46.23
19.0	54.33	40.13	44.93	44.17
20.0	51.03	37.57	45.50	44.70
21.0	48.93	36.33	42.00	51.03
22.0	47.33	42.37	41.57	40.73
23.0	45.60	40.37	40.93	39.50

(2059)

TIME 0-24 HR	REFRIGERATION			
	H TEM OUT	H TEM IN	H BLS IN	H BLS OUT
	F.	F.	F.	F.
.0	27.40	29.27	32.47	20.53
1.0	34.50	36.77	36.47	32.70
2.0	30.27	33.20	37.27	32.60
3.0	29.20	31.50	37.23	32.67
4.0	27.67	30.50	35.57	31.03
5.0	30.60	34.77	46.33	43.20
6.0	44.00	46.10	46.40	43.37
7.0	30.43	32.87	45.40	43.03
8.0	31.97	34.33	42.33	40.87
9.0	30.53	33.93	38.73	35.87
10.0	32.00	36.80	37.53	34.37
11.0	32.10	35.40	39.50	37.10
12.0	31.67	35.03	40.13	37.40
13.0	30.87	33.60	42.73	42.77
14.0	43.03	41.67	58.87	44.47
15.0	34.23	36.13	43.20	41.73
16.0	32.83	34.53	43.70	41.80
17.0	32.00	34.27	43.93	41.90
18.0	31.60	34.33	41.33	39.53
19.0	30.53	33.40	41.60	41.00
20.0	31.03	33.97	46.00	46.17
21.0	29.37	31.30	41.30	40.27
22.0	46.00	45.37	39.50	38.30
23.0	31.33	32.87	39.13	37.47

Plt15

(2059)

FRANK BRINE TUNNEL			
TIME	FLOW	INLET	OUTLET
0-24 HR	GPM	F.	F.
.0	193.46	15.83	16.17
1.0	193.09	15.00	14.73
2.0	125.37	12.13	10.60
3.0	0	18.37	28.10
4.0	0	23.77	33.20
5.0	0	28.20	32.33
6.0	0	31.87	30.13
7.0	0	33.10	29.70
8.0	123.62	23.33	19.10
9.0	176.51	5.97	4.90
10.0	186.27	11.90	10.37
11.0	187.97	11.00	15.87
12.0	192.66	14.03	13.07
13.0	193.79	13.37	11.63
14.0	190.58	12.60	9.97
15.0	186.58	10.20	9.00
16.0	173.11	12.13	11.30
17.0	190.41	12.87	11.43
18.0	129.06	13.60	13.53
19.0	62.40	13.93	15.03
20.0	178.00	11.80	9.40
21.0	177.04	13.67	11.33
22.0	122.39	16.63	16.13
23.0	167.85	15.67	14.97

Plt16

(2059)

FRANK FRESH WATER SHOWER			
TIME	FLOW	INLET	OUTLET
0-24 HR	GPM	F.	F.
.0	92.60	54.50	69.73
1.0	89.48	54.77	68.10
2.0	92.45	54.80	61.50
3.0	62.06	56.07	57.57
4.0	0	65.90	78.03
5.0	0	71.23	84.00
6.0	0	73.37	86.00
7.0	0	75.67	86.23
8.0	16.62	70.03	80.73
9.0	76.27	54.60	68.13
10.0	90.18	54.57	68.60
11.0	90.29	54.53	66.17
12.0	90.06	54.53	70.07
13.0	90.15	54.53	67.60
14.0	90.14	54.50	61.70
15.0	89.25	54.50	68.70
16.0	89.60	54.50	68.50
17.0	90.11	54.50	64.30
18.0	90.38	54.50	62.07
19.0	90.27	54.50	60.90
20.0	90.87	54.50	66.20
21.0	90.56	54.50	59.40
22.0	90.19	54.50	63.80
23.0	90.23	54.50	69.10

Plt17

(2059)

TIME	GAM CHN CLNR STEAM PPH	H SHWR WATER GPM	H SHWR WATER F.
0-24 HR			
.0	0	4.44	119.37
1.0	0	.10	130.73
2.0	0	.13	110.87
3.0	0	.09	117.30
4.0	0	.10	109.93
5.0	0	.10	109.23
6.0	1188.87	6.41	112.73
7.0	681.00	6.35	111.03
8.0	615.70	.09	110.20
9.0	661.63	.09	112.47
10.0	663.77	20.06	111.80
11.0	616.37	.10	113.27
12.0	620.67	.09	113.63
13.0	688.03	5.53	113.63
14.0	651.87	.09	113.37
15.0	455.27	16.11	113.30
16.0	0	8.09	112.23
17.0	0	.10	114.03
18.0	0	9.51	120.03
19.0	0	.10	119.13
20.0	0	.10	113.90
21.0	0	9.87	129.00
22.0	0	5.02	130.33
23.0	0	.10	115.77

Plt18

(2059)

TIME	H SMOKE GAS SCFH	S SMOKE GAS SCFH	F SMOKE GAS SCFH	F SMOKE STEAM PPH
0-24 HR				
.0	883.50	46.50	4161.33	1209.70
1.0	888.97	55.33	3062.67	1308.73
2.0	453.10	79.83	613.67	397.50
3.0	0	109.33	0	0
4.0	1521.80	104.00	0	0
5.0	1257.33	129.17	0	0
6.0	409.80	36.17	0	0
7.0	0	49.50	3431.00	0
8.0	1647.80	0	2266.33	439.00
9.0	1586.67	0	4393.00	1011.60
10.0	1277.67	0	3821.67	1131.73
11.0	1659.00	0	3780.33	1224.83
12.0	1353.33	0	3846.33	1188.43
13.0	1067.30	285.00	3091.37	806.37
14.0	990.77	237.00	2597.67	1269.40
15.0	.27	270.83	4380.00	1161.23
16.0	.13	146.33	3450.67	1179.30
17.0	.13	264.00	3311.33	1213.67
18.0	0	111.67	1555.00	1294.87
19.0	1080.67	109.67	3485.00	1243.90
20.0	1797.00	0	3723.67	1217.70
21.0	823.13	0	5840.33	1671.70
22.0	.40	382.33	4209.67	1187.87
23.0	281.40	0	2489.00	1149.03

(202U)

TIME 0-24 HR	REFRIGERATION			
	CUT IN F.	CUT OUT F.	CURE OUT F.	CURE IN F.
.0	83.50	74.03	38.70	45.47
1.0	57.77	73.37	39.43	43.73
2.0	80.20	75.33	60.13	75.23
3.0	67.67	54.67	63.87	63.47
4.0	53.27	37.17	53.83	50.90
5.0	51.73	35.83	37.53	44.40
6.0	50.33	35.73	35.23	41.80
7.0	51.93	37.47	36.77	43.23
8.0	51.97	37.57	37.20	42.87
9.0	52.17	37.70	37.80	42.03
10.0	53.07	38.27	43.13	43.50
11.0	54.17	38.40	36.90	43.07
12.0	55.57	38.27	35.30	41.10
13.0	55.57	37.67	36.17	41.43
14.0	56.87	40.13	37.20	41.17
15.0	57.40	42.20	41.80	42.90
16.0	58.97	44.13	35.17	41.23
17.0	60.40	45.13	35.20	41.33
18.0	60.57	46.23	36.27	42.67
19.0	60.97	46.93	36.90	42.80
20.0	61.40	47.87	41.57	43.50
21.0	61.43	48.13	37.03	43.63
22.0	53.63	53.43	36.13	43.07
23.0	53.23	57.07	34.33	40.70

(202U)

TIME 0-24 HR	CARCASS CHILL REFRIGERATION			
	KILL FLOOR INLET F.	END OUTLET F.	CUT FLOOR INLET F.	END OUTLET F.
.0	36.30	26.03	36.70	35.83
1.0	34.43	26.03	41.80	38.33
2.0	36.40	26.10	35.47	34.43
3.0	36.30	27.20	35.33	34.37
4.0	35.93	30.17	37.20	35.93
5.0	38.77	32.77	39.07	37.63
6.0	39.33	33.27	39.53	38.47
7.0	40.03	33.60	39.90	39.00
8.0	40.40	33.93	40.13	39.30
9.0	40.67	34.07	40.27	39.43
10.0	40.83	34.20	40.47	39.57
11.0	41.00	34.17	40.43	39.60
12.0	40.97	34.27	40.40	39.67
13.0	41.07	34.40	40.50	39.73
14.0	41.17	34.60	40.70	39.80
15.0	41.23	34.63	40.87	39.83
16.0	41.33	34.80	41.03	39.97
17.0	41.47	34.93	41.27	40.10
18.0	41.63	35.03	41.23	39.37
19.0	41.67	35.17	40.77	37.03
20.0	41.70	35.30	40.63	37.07
21.0	41.83	35.33	40.67	37.33
22.0	41.87	35.30	40.77	37.23
23.0	41.93	35.40	40.90	37.80

PLT21

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(2020)

REFRIGERATION

TIME	H TEM OUT	H TEM IN	H BLS IN	H BLS OUT
0-24 HR	F.	F.	F.	F.
.0	29.00	31.30	51.47	43.20
1.0	27.73	30.30	50.33	44.30
2.0	27.80	29.50	43.83	39.27
3.0	27.13	33.20	44.67	39.20
4.0	26.07	33.93	41.97	38.07
5.0	22.27	25.30	44.07	39.43
6.0	37.80	38.23	43.10	38.70
7.0	31.00	31.67	44.97	41.93
8.0	31.63	33.00	45.27	42.80
9.0	29.60	30.80	41.93	39.20
10.0	29.00	29.90	39.20	36.13
11.0	29.17	30.97	38.73	35.10
12.0	28.33	33.23	38.57	34.97
13.0	27.43	34.27	38.20	34.33
14.0	30.93	37.03	37.63	33.37
15.0	28.67	28.13	37.07	32.87
16.0	27.93	27.97	35.43	31.70
17.0	27.93	20.70	35.27	32.80
18.0	27.87	28.53	34.03	31.10
19.0	27.33	27.30	34.33	31.03
20.0	27.93	28.10	33.73	30.73
21.0	27.93	30.57	35.63	31.40
22.0	37.00	36.87	36.87	32.27
23.0	27.20	27.00	37.77	33.00

PLT22

(143)

TIME	H SMOKE	S SMOKE	F SMOKE
0-24 HR	GAS	GAS	GAS
	SCFH	SCFH	SCFH
.0	5328.17	148.58	3776.83
1.0	5328.00	95.58	2972.67
2.0	5129.00	0	756.57
3.0	5111.50	0	0
4.0	4362.00	0	0
5.0	6280.33	0	0
6.0	5657.83	0	0
7.0	4873.17	232.08	2081.50
8.0	4362.00	94.58	4203.67
9.0	4749.67	9.42	4597.00
10.0	6775.67	289.08	2989.00
11.0	5466.83	108.33	5848.00
12.0	5397.33	22.83	4360.83
13.0	5634.33	81.92	3834.17
14.0	5096.00	30.58	5108.83
15.0	5343.83	0	3214.83
16.0	4360.67	0	3860.17
17.0	4361.33	28.25	2821.67
18.0	4355.33	0	3320.83
19.0	4363.00	0	5036.83
20.0	4866.67	0	3968.83
21.0	6343.00	0	4514.17
22.0	5357.33	0	5303.33
23.0	4363.00	238.33	2975.17

PLT23

141

(143)

TIME 0-24 HR	FRANK BRINE TUNNEL		
	FLOW GPM	INLET F.	OUTLET F.
.0	187.09	9.21	14.30
1.0	174.81	13.44	17.87
2.0	155.89	11.50	16.80
3.0	82.12	13.17	15.08
4.0	0	22.23	34.83
5.0	0	25.89	33.28
6.0	0	27.30	32.97
7.0	0	23.28	27.66
8.0	123.92	13.73	14.30
9.0	251.20	7.30	2.86
10.0	250.30	7.64	12.90
11.0	124.58	9.37	15.78
12.0	249.43	12.67	16.97
13.0	124.58	9.01	15.41
14.0	249.57	7.99	12.16
15.0	249.03	7.14	10.74
16.0	161.28	6.56	9.56
17.0	246.75	9.73	13.29
18.0	111.18	1.10	2.73
19.0	244.30	5.25	9.70
20.0	248.57	10.31	13.47
21.0	244.67	7.75	11.61
22.0	248.17	11.85	15.40
23.0	239.33	11.76	15.88

PLT24

(143)

TIME 0-24 HR	FRANK FRESH WATER SHOWER		
	FLOW GPM	INLET F.	OUTLET F.
.0	93.94	46.26	54.34
1.0	94.27	46.49	56.83
2.0	93.76	46.46	53.24
3.0	62.75	47.03	49.71
4.0	7.90	52.98	62.72
5.0	0	52.75	65.99
6.0	0	47.97	67.52
7.0	0	61.25	59.82
8.0	77.37	46.53	53.51
9.0	90.45	46.56	30.76
10.0	89.99	46.65	45.89
11.0	90.28	46.58	56.17
12.0	90.77	46.74	58.85
13.0	91.08	46.40	53.28
14.0	90.78	46.55	58.87
15.0	90.36	46.56	49.26
16.0	90.87	45.94	54.28
17.0	92.30	45.20	53.88
18.0	92.26	30.61	16.13
19.0	91.80	38.48	46.06
20.0	92.41	38.68	49.26
21.0	92.49	46.46	55.80
22.0	93.44	46.34	58.84
23.0	93.82	45.87	49.11

PLT25

TIME 0-24 HR	SCLD	TNK	SNG	POLSHR	BLD DRIER	(181) BOILER
	STEAM			WATER	GAS	GAS
	PPH			GPM	SCFH	SCFH X 10000
.0			0	0	.33	3.23
1.0			0	0	.67	3.24
2.0			0	0	.00	3.23
3.0			0	0	.33	3.23
4.0	243.73			0	0	3.23
5.0	762.50			0	.27	3.23
6.0	1095.87			0	.27	3.23
7.0	2394.80			34.08	.13	3.22
8.0	1996.10			39.00	2521.00	3.22
9.0	2223.17			76.13	2325.00	3.23
10.0	3277.67			29.33	2397.00	3.23
11.0	1370.60			12.78	2278.33	3.23
12.0	2196.33			15.29	2258.33	3.23
13.0	2213.03			0	1957.00	3.23
14.0	3301.67			0	2321.00	3.23
15.0	1086.67			0	2252.00	3.23
16.0	0			71.47	2091.33	3.23
17.0	0			102.38	2450.67	3.24
18.0	0			46.19	0	3.23
19.0	0			19.33	0	3.23
20.0	0			52.88	0	3.23
21.0	0			111.59	0	3.23
22.0	0			109.77	0	3.23
23.0	0			115.76	0	3.23

PLT26

TIME 0 24 HR	SHV RNS	COLD MN	HOT MN	(181) FINAL RNS
	WATER	WATER	WATER	WATER
	GPM	GPM	GPM	GPM
.0	.15	.70	99.00	0
1.0	.14	.66	106.80	0
2.0	.14	.70	105.50	0
3.0	.14	.62	81.50	0
4.0	.14	.62	116.53	0
5.0	.15	.62	103.53	0
6.0	.15	.62	98.80	0
7.0	51.99	.62	95.07	16.16
8.0	49.28	.62	92.73	16.06
9.0	47.43	.62	85.90	14.89
10.0	46.98	.62	79.40	22.77
11.0	45.68	.62	73.58	22.24
12.0	15.45	.62	68.83	15.62
13.0	44.99	.54	66.29	14.48
14.0	44.62	.62	64.54	21.57
15.0	14.66	.58	63.45	15.31
16.0	.14	.58	62.37	0
17.0	.15	.58	60.33	0
18.0	.14	.58	59.33	0
19.0	22.49	.66	58.96	0
20.0	12.86	.75	58.58	0
21.0	8.30	.71	58.41	0
22.0	.15	.75	58.29	0
23.0	.15	.65	58.25	0

APPENDIX B3 - PLANT B
PROCESS LABOR REQUIREMENTS

PLANT B

PROCESS LABOR REQUIREMENTS

I. Dehairing and Evisceration

A. Main Carcass Line

1. Loading and stunning operation	3 men
2. Shackling operation	1
3. Scalding operation	1
4. Gambrel chain loading operation	3
5. Singeing operation	2
6. Shaving line operation	10
7. Head dropping operation	3
8. Head and feet trimming operation	2
9. Head inspection operation	2
10. Neck wound removal and trim operation	2
11. Split brisket operation	1
12. Open carcass operation	2
13. Bung dropping operation	1
14. Carcass spreading operation	1
15. Viscera removal and inspection	5
16. Enucleate kidneys operation	1
17. Split carcass back operation	2
18. Condemned hock removal operation	1
19. Ham trimming operation	2
20. Line inspection operation	1
21. Head removal operation	2
22. Kidney removal operation	1
23. Leaf lard removal operation	5
24. Scaling operation	2

B. Viscera Lines

1. General

a. Organ inspection operation	3
b. Organ separation operation	10

2. Chitterling and casing lines

a. Gut separation operation	9
b. Black gut removal operation	7
c. Chitterling cleaning operation	12
d. Casing crushing operation	1
e. Casing finishing and packing oper.	3

3. Heat and liver lines

a. Liver trimming operation	2
b. Heart slash and scald operation	0.5

4. Stomach line

a. Stomach cleaning & inspection oper.	3
b. Skinning operation	1
c. Scalding operation	0.5

5. Head table line

a. Tongue removal operation	1
b. Tongue trimming operation	2
c. Ear and forehead trim operation	2
d. Ear removal & forehead skinning operation	1
e. Ear cleaning operation	2
f. Jaw meat removal operation	3
g. Snout stripping and jaw pulling operation	1
h. Snout meat removal operation	2
i. Cheek meat removal operation	2
j. Cheek meat trimming operation	3
k. Head meat trimming operation	4
l. Skull splitting operation	1
m. Brain removal operation	1

C. Sanitation

1. Sticking area sanitation	1
2. Dehairer area sanitation	1
3. Evisceration area sanitation	3

TOTAL = 138 men

Ave. working time per day = 8.2 hours

Ave. man hours/head slaughtered = $\frac{138(8.2 \text{ hours})}{4823} =$

0.235 man hours/head

II. Cut Floor Process

A. Main Conveyor

1. Set up men	3
2. Carcass alignment operation	2
3. Ham cut off operation	1
4. Shoulder cut off operation	1
5. Loin pulling operation	2
6. Belling rolling operation	1
7. Rib pulling operation	1

B. Ham Line

1. Hind foot saw operation	1
2. Ham skinning operation	2
3. Hand trimming operation	2
4. Scaling operation	3

C. Shoulder Line

1. Neck trimming operation	4
2. Hock and butt removal operation	2
3. Butt skinning operation	2
4. Scaling and boxing butts	3
5. Picnic trimming and jowl removal oper.	5
6. Scaling and boxing picnics operation	2
7. Jowl handling operation	4

D. Belly Line

1. Rib pulling operation	3
2. Fat back removal operation	4
3. Belly trimming	6
4. Belly skinning operation	1
5. Belly scaling and packing operation	2
6. Rib scaling and boxing operation	2

E. Loin Line

1. Loin pulling and trimming operation	4
2. Loin cutting operation	3
3. Scaling operation	2
4. Boxing operation	3

F. Sanitation 3

TOTAL - 74 men

Ave. working time per day = 8.2 hours

Ave. man hours/head slaughtered = $\frac{8.2 \text{ hours}(74)}{4823} =$

0.126 man hours/head

III. Ham Manufacturing Process

A. Cure Area

1. Brine makeup operation	0.5
2. Deboning and trimming operation	21
3. Tenderizing machine operation	1
4. Injection machine operation	7
5. Converting line operation	13

B. Smokehouse Area

1. Smoking operation	2
2. Tree movement and showering operation	4

C. Tempering and Blast Chill Operation

1. Tree movement operation	1

D. Packaging Area

1. Sawing operation	1
2. Vacuum packaging operation	4
3. Scaling operation	3
4. Boxing operation	4

E. Sanitation 6

TOTAL - 67.5

Ave. working time per day = 8.2 hours

$$\text{Ave. man hours/lb of finished ham} = \frac{8.2 \text{ hours (67.5)}}{56,292} =$$

0.0098 man hours/lb

IV. Frankfurter Manufacturing Process

A. Sausage Kitchen Area

	1st Shift	2nd Shift
1. Grinding and flaking operation	1.0	1.0
2. Blending operation	2.0	2.0
3. Chopper operation	1.0	1.0
4. Stuffing-linking operation	3.5	3.5
5. Chain loading operation	0.5	0.5

B. Smokehouse Area

1.0	1.0
-----	-----

C. Peeling Area

3.0	3.0
-----	-----

D. Packaging Area

1. First packaging machine	4.0	4.0
2. Second packaging machine	5.0	5.0
3. Boxing and palletizing	1.0	1.0

E. Sanitation

1. Sausage kitchen	5
2. Smokehouses and peelers	2
3. Packaging	2

TOTAL - 53

Ave. working time per day = 7.25 hours

$$\text{Ave. man hours/lb finished franks} = \frac{7.25 \text{ hours}(53)}{71,345} =$$

0.0054 man hours/lb

V. Lard Rendering Process

A. Startup and Loading Operation	1
B. Day Production Operation	0.1
C. Shut Down and Sanitation Operation	1

TOTAL - 3

Ave. working time per day = 7.5 hours

$$\text{Ave. man hours/head slaughtered} = \frac{3(7.5)}{4823} =$$

0.0047 man hours/head

VI. Inedible Rendering Process

A. Condemned Carcass Operation	1
B. Start up and Day Production Operation	1
C. Shut Down and Sanitation Operation	1

TOTAL - 3

Ave. working time per day = 7.5 hours

$$\text{Ave. man hours/head slaughtered} = \frac{3(7.5)}{4823} =$$

0.0047 man hours/head

VII. Blood Drying Process

A. Day Production and Sanitation Oper.	0.5

Ave. working time per day = 7.5 hours

$$\text{Ave. man hours per head slaughtered} = \frac{0.5(7.5)}{4823} = 0.0008 \text{ man hrs/head}$$

VIII. Hair Hydrolysis and Drying Process

A. Day Production and Sanitation Operation 0.5

Average working time per day = 7.5 hours

$$\text{Ave. man hours/head slaughtered} = \frac{0.5(7.5)}{4823} = 0.0008 \text{ man hrs/head}$$

APPENDIX B4 - PLANT B

ECONOMIC DATA

ECONOMIC DATA

MEAT PLANT B
(1978 Dollars)

A) Equipment Cost (by operation and process).

1. Carcass operation

Process	Equip. Cost (\$)
---------	------------------

a) KILLING

-drive-in-chute and guide	8,600
-stunning apparatus	4,100
-stick and shackle equipment	14,100
-blood tank	2,300
-conveyors, expansion and installation	30,000

Total	59,100
-------	--------

b) DEHAIRING

-scalding tub and drains	129,000
-dehairer	175,600
-gambrel table, trolleys and hangers	33,200
-singeing, polishing, shave and rinse	62,500
-supplemental parts and equipment installation	317,100

Total	717,500
-------	---------

c) DRESSING

-rails, beams, hangers and trolleys	122,400
-saws and knives	14,600
-head work and inspection	43,600
-visceration work and inspection	248,000
-supplemental parts & equip. install.	115,400

Total	544,000
-------	---------

d) CHILL AND CUT

-rails, hangers, conveyors and tables	231,000
-saws and knives	65,700
-refrigeration units and chlorine system	132,700
-skinners, defatters and scales	61,700
-supplemental parts and equip. install.	377,500

Total	858,600
-------	---------

Total carcass operation equip. cost:	2,179,200
--------------------------------------	-----------

2. Fresh cuts operation

Process	Equip. Cost (\$)
a) PACKAGING	
-strapping and strapping machines	20,300
-conveyors	8,400
-supplemental parts and equip. install.	14,300
Total	43,000
b) STORAGE (for all meat products)	
-refrigeration units	63,000
-lift trucks and racks	135,000
-supplemental parts and equip. install.	39,000
Total	237,000
Total fresh cuts operation equip. cost:	280,000

3. Sausage operation (franks, bologna and leaves).

Process	Equip. Cost (\$)
a) GRINDING/BLENDING	
-flakers, cutters, sizers	188,200
-mixers, blenders, loaders, scales	219,100
-holding bins and equip. install.	136,600
Total	543,900
b) EMULSIFICATION	
-silent cutter	144,400
-mince master and conveyors	48,200
-holding tanks, suppl. parts, and equip. install.	205,600
Total	398,700
c) STUFFING	
-frank-o-matics	152,000
-stuffers, fillers, sizer-loopers	130,800
-supplemental parts and equip. install.	445,500
d) SMOKING/COOLING	
-liquid smoke equip.	6,800
-continuous smokehouse (franks)	320,000
-smokehouse (bologna)	69,500

-brine chill tunnel
-supplemental parts and equip. install.

16,000
135,200

Total

547,500

e) PEELING/PACKAGING

-peelers, collators
-slicers and labelers
-packaging machines
-conveyors, suppl. parts & equip. install.

46,600
41,600
40,900
121,400

Total

250,500

Total sausage operation equip. cost

2,186,100

4. Bacon operation

Process	Equip. Cost (\$)
a) PICKLING/CURING	
-pickle injectors and attach.	85,600
-pumps, suppl. parts & equip. install.	65,500
Total	151,100
b) SMOKING	
-smokehouses	169,500
-trees and washers	25,600
-supplemental parts & equip. install.	97,500
Total	292,600
c) SKINNING	
-skinners, defaters	58,400
-trimmers, conveyors	38,400
-supplemental parts & equip. install.	12,600
Total	109,400
d) COOLING (chill and temperature)	
-brine tunnel and attachment	15,500
-blast drill and temper	35,000
-supplemental parts & equip. install.	12,600
Total	63,100
e) SLICING/PACKAGING	
-presses, formers	91,600
-slicers, packagers, conveyors	65,100
-supplemental parts & equip. install.	65,600
Total	223,300
Total bacon operation equip. cost	838,500

5. Ham operation

Process	Equip. Cost (\$)
a) PICKLING/CURING	
-pickle injectors and attach.	94,600
-massagers and ceiring vats	75,700
-supplemental parts & equip. install.	35,100
Total	205,400
b) SMOKING	
-smokehouses	169,500
-trees and washers	25,600
-supplement parts & equip. install.	97,500
Total	292,600
c) COOLING	
-shower tunnel and attachments	13,800
-blast chill	
-supplement parts & equip. install.	32,100
Total	80,900
d) PACKAGING	
-presses, slicers	21,300
-packagers and conveyors	45,300
-supplemental parts & equip. install.	43,600
Total	110,200
Total ham operation equip. cost	\$689,100

6. Edible rendering (lard) operation

Process	Equip. Cost (\$)
a) GRINDING/DECANTING	
-disintegrator, grinders	34,800
-desludgers NX	101,400
-pumps, tanks, suppl. parts & equip. install.	119,400
Total	255,600
b) STEAMING/SEPARATION	
-purifiers (animal fat)	122,400
-feed tanks and pumps	35,300
- supplemental parts & equip. install.	78,800
Total	236,500
c) WASHING/CENTRIFUGATION	
-purifier (wash water/fat)	56,100
-wash tank, agitator-motor, pumps	25,900
-supplemental parts & equip. install.	65,000
Total	147,000
d) STORAGE	
-tanks and pumps	58,000
-piping and equip. install.	17,400
Total	75,400
Total lard operation equip. cost:	714,500

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7. Inedible rendering operation

I. Cracklings and Tallow:

Process	Energy Cost (\$)
a) PREBREAK (GRIND AND LOAD)	
-prebreaker, havor and magnets	106,200
-conveyors and tanks	25,500
-supplemental parts & equip. install.	59,700
Total	191,400
b) COOKING	
-Equacooker, control wheel	556,700
-condensor and jet system	115,700
-supplemental parts & equip. install.	182,500
Total	854,900
c) PRESSING/SEPARATION	
-pressor	146,800
-tanks, pumps and screws	13,000
-supplemental parts & equip. install.	46,700
Total	206,500
d) CRAX GRINDING	
-grinder and attachments	31,200
-screws and elevators	19,800
-supplemental parts & equip. install.	15,300
Total	66,300
e) CRAX STORAGE	
-silos and storage tanks	25,300
-conveyor screws and elevators	20,700
-supplemental parts & equip. install.	12,400
Total	58,400
f) TALLOW CENTRIFUGATION	
-centrifuge	104,700
-tanks and pumps	21,400
-supplemental parts & equip. install.	34,600
Total	160,700

g) TALLOW STORAGE

-tanks and silos

54,800

-supplemental parts & equip. install.

31,200

Total**86,000****Total cradlings & tallow equip. cost:****1,624,200**

II. Hair hydrolyzing

Process	Equip. Cost (\$)
a) LOADING/COOKING	
-hair collector	10,500
-hair cooker and hopper	104,100
-survey or system	19,900
-tower, supplemental parts & equip. install	34,200
	<hr/>
	168,700
b) STORAGE	
-storage bins	30,200
-conveyors and screws	21,200
-supplemental parts & equip. install.	13,400
	<hr/>
Total	64,800
Total hair hydrolyzing equip. cost:	233,500

III. Blood Drying

Process Equip.	Cost (\$)
a) COAGULATION	
-coagulator	21,100
-tanks and pumps	53,800
-supplemental parts & equip. install.	22,500
	<hr/>
Total	97,400
b) PRESSING	
-pressor	15,500
-supplemental parts & equip. install.	4,500
	<hr/>
Total	20,000
c) GRINDING	
-grinder and attachments	22,200
-conveyors, suppl. parts & equip. install.	21,300
	<hr/>
Total	43,500
d) DRYING	
-ring dryer & pump vacuum	42,700
-supplemental parts & equip. install.	11,300
	<hr/>

Total

54,000

e) STORAGE

-storage bins

41,800

-blowing system

12,000

-supplemental parts & equip. install.

16,200

Total

70,000

Total blood drying equip. cost

284,900

Total inedible rendering equip. cost:

2,132,100

8. Refrigeration

Equipment	Cost (\$)
-compressors & motors (15 tot. cap. about 2300 tons)	687,000
-evap. condensers	

9. Steam production

Equipment	Cost (\$)
-boilers (two 400 BHP oil-gas fired complete systems)	250,000

10. Compressed air production

B) Labor Amount and Cost (by operation and process)

1. Carcass operation

Process	Overhead hrs/year	Labor		Total Cost (\$) \$/year
		Variable hrs/1000 lbs		
a) KILLING	569	0.02		43,600
b) DEHAIRING	3,227	0.11		182,017
c) DRESSING	20,883	0.70		1,177,788
d) CHILL & CUT	13,290	0.65		769,195
Totals	37,969			2,172,600

2. Fresh Cuts operations

Process	Overhead hrs/year	Labor		Total Cost (\$)
		Variable hrs/1000s		
a) PACKAGING	2,214	0.04		51,554
b) STORAGE	11,074	0.16		257,804
Totals	13,288			309,358

3. Sausage operation

Process	Overhead hrs/year	Labor		Total Cost (\$)
		Variable hrs/1000 lbs		
a) GRINDING/BLENDING	2,531	1.98		207,646
b) EMULSIFICATION	3,164	2.03		254,559
c) STUFFING	3,797	2.06		311,472
d) SMOKING/COOLING	2,531	1.35		207,646
e) PEELING	3,164	1.80		259,559
f) PACKAGING	7,594	4.45		622,944
Totals	22,781			1,868,826

4. Bacon operation

Process	Overhead hrs/year	Labor		Total Cost (\$)
		Variable hrs/1000 lbs/		
a) CURING	4,339	3.39		327,904
b) SMOKING	2,712	1.84		204,942
c) SKINNING	3,255	2.43		245,930
d) COOLING	2,168	1.73		163,943
e) SLICING/PACKAGING	6,509	5.29		491,854
Totals	18,983			1,434,573

5. Ham operation

Process	Overhead hrs/year	Labor		Total Cost (\$)
		Variable hrs/1000 lbs		
a) CURING	6,134	3.79		507,329
b) SMOKING	4,381	3.16		362,376
c) COOLING	3,505	2.30		289,900
d) PACKAGING	8,762	5.74		724,752
Totals	22,782			1,884,357

6. Edible rendering (Lard) operation

Process	Overhead hrs/year	Labor		Total Cost (\$)
		Variable hrs/1000 lbs		
a) GRINDING	1,266	0.38		47,766
b) DECANTING	844	0.24		31,844
c) SEPARATION	422	0.17		15,922
d) WASHING	633	0.25		23,883
e) CENTRIFUGATION	422	0.14		15,922
f) STORAGE	211	0.08		7,961
Totals	3,798			143,298

7. Inedible rendering operation

I. Cracklings and Tallow

Process	Overhead hrs/year	Labor		Total Cost (\$)
		Variable hrs/1000 lbs		
a) PREBREAKING	282	0.34		54,403
b) COOKING	310	0.03		6,805
c) PRESSING/SEPARATION	311	0.26		16,696
d) CRAX GRINDING	311	0.26		16,696
e) CRAX STORAGE	207	0.17		11,127
f) TALLOW CENTRIFUGATION	414	0.49		22,259
g) TALLOW STORAGE	517	0.62		27,817
Totals	2,898			155,803

II. Hair hydrolyzing

Process	Overhead hrs/year	Labor		Total Cost (\$)
		Variable hrs/1000 lbs		
a) LOADING/COOKING	621	2.48		28,986
b) STORAGE	517	3.92		24,157
Totals	1,138			52,143

III. Blood drying

Labor

Process	Overhead hrs/year	Variable hrs/1000 lbs	Total Cost (\$)
a) COAGULATION	621	0.34	21,026
b) PRESSING	104	0.06	3,504
c) GRINDING	207	0.35	7,007
d) DRYING	414	0.71	14,014
e) STORAGE	311	1.09	10,516
Totals	<u>1,657</u>		<u>56,067</u>

Total yearly plant labor cost:

C) Utilities Amount and Cost (by plant)

	1976	1977	1978
1) Electricity			
KWH:	17,585,000	18,140,000	-----
\$:	285,584	364,513	
2) Natural Gas			
100 cu. ft.:	4,038,160	4,229,380	
\$:	461,618	607,214	
3) Propane			
gal.:	-	5,877	
\$: -	2,274		
4) #6 Oil			
gal:	-	73,732	
\$:	-	27,528	
5) Water			
gal.:	353,028,000	384,398,000	
\$:	24,307	31,205	

D) Production (by plant)

1977

Product	lbs
1. Fresh cuts	180,320,982
2. Sausage (Franks, bologna, loaf, cotto)	25,207,901
3. Bacon	17,111,085
4. Ham (all cured and smoked meats)	23,400,866
5. Lard	15,801,152
6. Dry blood	1,586,152
7. Hydrolyzed hair	1,075,480
8. Carcklings	11,326,451
9. Tallow and Grease	8,037,200
Total	283,868,047

APPENDIX B5 - PLANT B
PRELIMINARY COST COMPUTATIONS

Introduction

This report contains preliminary cost data for processes involved in the Meat Plant B. The costs are presented for each product. The approach to cost calculations is as follows:

1. Data on the capital investment, life of equipment, quantities of inputs, prices of inputs, capacity of equipment, and mass balances are gathered.
2. Capital investment procedures using discounted after-tax cash flows are applied to each unit of operation (process) to determine the present value of costs per unit of meat into the individual process.
3. The present value of the costs is converted into an equivalent annual after-tax cost, which is then converted into an equivalent before-tax cost to provide a better point of reference.
4. The costs are then totaled for all processes involved with a particular product, weighting the individual units of operation by the ratio of the quantity of meat into that process per unit of final product.

The approach incorporates the time value of money explicitly through the use of discounting and annualization factors. Inflation assumptions including the general rate of inflation, energy prices, and wage rates are explicitly handled in the cost analysis.

A number of data and assumptions are held constant across all cost calculations. These are presented in Tables 0.1 and 0.2. Data pertinent to particular processes are given in the appropriate sections.

TABLE 0.1

Input Prices (Costs) and Inflation Rates Used In Process Cost Calculations

Item (units)	Base Price (Cost) (\$/unit)	Inflation Rate (percentage)
General Inflation Rate	----	.06
Electricity (KWH)	.04	.08
Natural Gas (1000 cu. ft.)	2.18	.08
Oil (gallon)	.45	.08
Labor (hour)	6.00	.06
Miscellaneous Expenses (dollars)	----	.06
Steam (million BTU)	4.52	.08
Cooling (million BTU)	4.23	.08

TABLE 0.2

Assumptions Pertinent to Process Cost Calculations

Marginal Income Tax Rate = .48

Sum-of-the-year's digits depreciation method

Cost of capital = 15%

Investment Tax Credit = 10%, except insulation, heat pumps, and refrigeration heat recovery (20%)

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Product Processing Costs

The product processing costs have been calculated and are presented in Tables 2 through 10. Table 1 contains the costs of processing the carcass. This cost is then allocated to fresh cuts, hams, bacon, and franks according to the weight of the pork going into each of these products.

Table 1
Carcass Processing Costs
(equivalent before-tax \$ per 1000 pounds of chilled and cut meat)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Killing	.27	.02	.03	-0-	-0-	-0-	.18	.04
Dehairing	3.55	.42	.94	-0-	.41	.19	.98	.61
Dressing	6.73	.15	.08	-0-	.12	-0-	6.16	.22
Chill and Cut	44.77	.11	39.14	.47	.43	-0-	4.35	.27
TOTAL	55.32	.70	40.19	.47	.96	.19	11.67	1.14

^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.

^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.

^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 2
Fresh Cuts Processing Costs
(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Carcass Processing	55.32	.71	40.18	.47	.96	.19	11.67	1.14
Packing	.59	.04	-0-	-0-	.22	-0-	.31	.03
Storage	2.41	.07	-0-	.50	.05	-0-	1.15	.64
TOTAL	58.32	.82	40.18	.97	1.23	.19	13.13	1.81

- ^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.
- ^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.
- ^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 3

Ham Processing Costs

(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Carcass Processing	47.36	.61	34.40	.40	.82	.16	9.91	.97
Curing	22.48	.61	.02	.19	.26	-0-	20.64	.77
Smoking	37.63	3.77	1.32	-0-	1.53	2.21	23.01	5.80
Cooling	17.07	.22	-0-	1.65	.37	-0-	14.50	.32
Packaging	37.37	.31	-0-	.11	.03	-0-	36.54	.37
TOTAL	161.91	5.52	35.74	2.35	3.01	2.37	104.60	8.23

^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.

^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.

^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 4

Bacon Processing Costs

(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Carcass processing	54.00	.69	39.22	.46	.94	.19	11.39	1.11
Curing	22.48	.23	.08	.68	.08	-0-	21.14	.28
Smoking	23.26	3.75	.04	-0-	.50	.50	12.93	5.54
Skinning	16.24	.15	.04	-0-	.01	-0-	15.84	.21
Cooling	12.30	.20	.03	.35	.19	-0-	11.12	.33
Slicing and Packaging	37.35	1.35	.11	.17	.31	-0-	33.52	1.90
TOTAL	165.63	6.37	39.52	1.66	2.03	.69	105.94	9.37

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^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.

^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.

^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 5

Franks Processing Costs

(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Carcass Processing	39.74	.51	28.87	.34	.63	.14	8.38	.82
Grind and Blend	13.50	1.40	.17	.48	.27	-0-	10.31	.87
Emulse	17.33	3.62	.14	.39	.59	-0-	10.49	2.10
Stuffing	18.59	2.23	.16	.44	.16	-0-	14.11	1.44
Smoking	13.46	1.71	.62	-0-	.20	.29	9.31	1.33
Cooling	.27	-0-	-0-	.22	.05	-0-	-0-	-0-
Peeling	12.20	.31	.01	-0-	.06	-0-	11.52	.28
Packaging	33.69	.50	.45	.94	.19	-0-	31.28	.33
TOTAL	148.78	10.35	30.42	2.81	2.21	.43	95.40	7.17

^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant-overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.

^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.

^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 6

Crax Processing Costs

(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Prebreak	12.52	4.90	-0-	-0-	.67	-0-	5.56	1.40
Cooking	20.43	8.25	8.99	-0-	.38	-0-	.61	2.20
Separation	2.38	.91	-0-	-0-	.09	-0-	1.11	.27
Pressing	5.00	2.91	-0-	-0-	.59	-0-	.59	.92
Grinding	2.87	.50	-0-	-0-	.53	-0-	1.70	.15
Storage	3.11	1.51	-0-	-0-	.01	-0-	1.11	.47
TOTAL	46.31	18.98	8.99	-0-	2.27	-0-	10.68	5.41

^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.

^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.

^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 7
Tallow Processing Costs
(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Prebreak	12.52	4.90	-0-	-0-	.67	-0-	5.56	1.40
Cooking	20.43	8.25	8.99	-0-	.38	-0-	.61	2.20
Centrifuge	6.24	1.91	-0-	-0-	.35	-0-	3.15	.82
Storage	6.03	1.31	.03	-0-	.18	-0-	4.03	.47
TOTAL	45.22	16.37	9.02	-0-	1.58	-0-	13.35	4.89

- ^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.
- ^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.
- ^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 8

Hair Processing Costs

(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Loading	24.16	4.66	-0-	-0-	2.52	-0-	15.21	1.77
Cooking	140.81	27.20	76.19	-0-	13.38	-0-	15.45	8.59
Storage	30.95	3.51	-0-	-0-	.30	-0-	24.76	2.37
TOTAL	195.92	35.37	76.19	-0-	16.20	-0-	55.42	12.73

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- ^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.
- ^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.
- ^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 9

Blood Processing Costs

(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Coagulation	29.72	8.12	3.19	-0-	1.01	-0-	15.32	2.07
Dressing	11.44	6.31	-0-	-0-	.22	-0-	2.68	2.24
Grinding	15.50	7.65	-0-	-0-	.51	-0-	4.93	2.41
Drying	30.20	10.92	-0-	-0-	1.06	4.78	9.98	3.45
Storage	14.74	5.21	-0-	-0-	.15	-0-	7.47	1.90
422 TOTAL	101.60	38.21	3.19	-0-	2.95	4.78	40.38	12.07 180

^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.

^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.

^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

Table 10

Lard Processing Costs

(equivalent before-tax \$ per 1000 pounds of final product)^{a/}

Process	Total	Equipment ^{b/}	Steam	Cooling	Electricity	Natural Gas	Labor	Misc. ^{c/}
Grinding	8.39	2.59	-0-	.44	.37	-0-	2.53	1.46
Decanting	3.00	.30	.11	-0-	.08	-0-	2.35	.17
Separation	2.88	.60	.13	-0-	.21	-0-	1.60	.35
Washing	2.38	.33	.10	-0-	.04	-0-	1.70	.22
Centrifugation	5.70	2.80	-0-	-0-	.07	-0-	1.16	1.67
Storage	1.10	.31	.01	-0-	.04	-0-	.55	.19
TOTAL	23.45	6.93	.35	.44	.81	-0-	10.99	4.06

^{a/} The costs included are those associated directly with the process(es) and therefore do not include the pork raw materials or general plant overhead. The costs have been calculated using after-tax present values and have been converted into equivalent before-tax costs that will increase at a 6% annual rate from the amounts shown in the table.

^{b/} The equipment costs includes the annualized cost per unit of product of the capital investment, the investment tax credit, salvage values, the depreciation income-tax shield, and has taken the cost of capital (interest) into account.

^{c/} Miscellaneous expenses includes repairs and maintenance of equipment, insurance, and other expenses not accounted for in other categories but does not include pork raw materials.

APPENDIX B6 - PLANT B

SAMPLE CALCULATIONS

I. Dehairing and Evisceration Process - Unit Operations

Unless otherwise stated, the average slaughter of 4823 head was used for all computations.

A. Stun and Bleed Operation

1. Electrical use -

All motors are assumed to have 80% P.F..

a. Stunner -

375V, 1.5A device used approximately 5 seconds per hog.

$$(1.5A)(375V)(100\% \text{ P.F.}) \left(\frac{5 \text{ sec}}{3600 \text{ sec}} \right) = 0.7812 \text{ WH/hog or}$$

$$3767.7 \text{ WH/day}$$

b. Bleed conveyor and stun conveyor (7.5 hrs/day) -

1 - 5 hp conveyor - 470V, 4.2A

1 - 3 hp conveyor - 470V, 2.2A

$$7.5 \text{ hrs}(4.2A + 2.2A)(470V)(80\% \text{ P.F.}) (\sqrt{3}) =$$

$$31,260 \text{ WH/day or } 6.469 \text{ WH/head}$$

$$\text{Total electrical use/day} = 7.25 \text{ WH/head}$$

2. Steam use -

Steam is used for a knife box in the sticking area with dimensions 12 in x 8.25 in x 6.25 in -

Water depth - 12 inches

Volume of water - 0.3581 ft³

Average bulk water temperature - 177°F

Average wall temperature - 190°F

Initial temperature - 70°F

a. Startup -

$$mC_p \Delta T = 0.3581 \text{ ft}^3 (62.5 \text{ lbs/ft}^3 (1.0 \text{ Btu/lb-}^\circ\text{F}) \times$$

$$(177 - 70^\circ\text{F}) = 2395 \text{ Btu's}$$

b. Maintenance -

Equipment operates approximately 10 hours per day.

Assumptions -

Air velocity - 1.0 ft/sec

Ambient air - 80°F

Water temperature - 180°F

1. From Strock and Foxhall, 1959, the heat loss from water at 180°F into 80°F air averages 2750 Btu/hr-ft²

$$2750 \text{ Btu/hr-ft}^2 \left(\frac{8.25}{12} \text{ ft}\right) \left(\frac{6.25}{12} \text{ ft}\right) (10 \text{ hrs}) =$$

$$9847 \text{ Btu's/day}$$

2. Heat loss from metal surfaces by convection and radiation (from Strock and Foxhall, 1959) -

- calculate h_c -

$$\text{walls } h_c = 0.28 \left(\frac{t_1 - t_2}{x}\right)^{1/4} = 0.28 \left(\frac{190 - 80}{\frac{10}{12}}\right)^{1/4} =$$

$$0.949 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$\text{bottom } h_c = 0.2(t_1 - t_2)^{1/4} = 0.2(190 - 80^\circ\text{F})^{1/4} =$$

$$0.648 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$q_c = (0.648 \text{ Btu/hr-}^\circ\text{F-ft}^2) (0.358 \text{ ft}^2) (190 - 80^\circ\text{F}) \times \\ 10 \text{ hrs} + (0.949 \text{ Btu/hr-}^\circ\text{F-ft}^2) [(0.5208 \text{ ft}^2) (2) + \\ (0.6875 \text{ ft}^2) (2)] (190 - 80^\circ\text{F}) (10 \text{ hrs}) =$$

$$2778 \text{ Btu/day}$$

3. Heat loss due to radiation - (3 = 0.03 for aluminum, Strock and Foxhall, 1959) -

$$q_r = \frac{0.174(3)A(^{\circ}\text{R}_1^4 - ^{\circ}\text{R}_2^4)}{10^8} \quad (\text{time})$$

$$q_r = 0.174(2.7747 \text{ ft}^2)(0.03)(650^4 - 540^4)(10 \text{ hrs})/10^8 =$$

$$135.4 \text{ Btu/day}$$

Therefore, the total steam required per day was -

$$2395 + 9847 + 2778 + 135.4 = 15,155.4 \text{ Btu/day or}$$

$$3.142 \text{ Btu/head}$$

B. Scald Tank Operation

1. Water use -

The scald tub is an L-shaped tub 5.167 ft wide by 2.958 ft deep by roughly 136 ft long on centerline. The water depth is maintained at 2.5 feet.

Total water volume - 1983.05 ft^3

Total gallons - $(7.48 \text{ gal/ft}^3) = 14,833.26 \text{ gal}$

Heated water is added to the scald tub at temperatures which can be anywhere from 100 - 180°F. Water comes from the waste heat recovery system on the refrigeration compressor drives. The system typically heats water from the wells from 55°F to 110°F (as reported by Anonymous, 1970).

2. Electrical use -

11 motors are used in the operation.

6 - 1.0 hp "dunker" motor - 480V, 1.55A, 9.45 hrs/day

4 - 7.5 hp recirculation pumps - 480V, 8.55A, 8.68 hrs/day

1 - 10.0 hp shackle chain drive - 480V, 12.6A, 7.5 hrs/day

Total daily electrical use was -

$$6(1.55\text{A})(480\text{V})(80\% \text{ P.F.})(\sqrt{3})(9.45 \text{ hrs}) +$$

$$4(8.55\text{A})(480\text{V})(80\% \text{ P.F.})(\sqrt{3})(8.683 \text{ hrs}) +$$

$$1(12.5\text{A})(480\text{V})(80\% \text{ P.F.})(\sqrt{3})(7.5 \text{ hrs}) = 313,815 \text{ WH/day or}$$

$$66.1 \text{ WH/head}$$

Assuming 50% of the energy is input as heat -

$$313,815 \text{ WH/day } (0.50)(3.414 \text{ Btu/WH}) = 544,217 \text{ Btu's}$$

3. Steam use -

- a. Since the heat recovery system at Wilson does not usually heat the water to operating conditions, an estimate was made for raising the temperature of 110° water to 140°F water. This is performed in a separate part of the plant using an injection heater. There was wide variability in the heating load since sometimes the tank is filled with "too" hot water. Assuming that 100% efficient heaters are used the starting demand was -

$$14,833 \text{ gal/day} (8.33 \text{ lb/gal}) (1.0 \text{ Btu/lb-}^{\circ}\text{F}) (140 - 110^{\circ}\text{F}) =$$

$$3,706,767 \text{ Btu's/day as "startup" or } 768.56 \text{ Btu/head}$$

- b. During the normal operating day, 4 steam lines are used to inject water into the scald tub. Two of the lines (ends) were monitored by steam flow meters. Some of the typical flows per day were -

DATE	Total flow through 2 meters @ 135 psig (pounds)	Daily Kill (head)
348	23,874.6	5290
007	30,961.4	4807
008	30,520.6	4853
018	25,001.8	4681
111	34,325.9	6609
183	34,501.2	5345
191	32,011.6	5362
192	33,559.4	5290
193	36,817.1	5380
181	31,110.4	5310
197	<u>30,641.8</u>	<u>5401</u>
	31,211.0	5302

From recording meters, it was clear that the end of the tank nearest the bleed pit bore the brunt of heating. The average ratio of daily flows between the two ends was 2.682 to 1.0 with the end nearest the dehairers having a much lower flow rate. It was assumed that the central two steam lines performed in a manner similar to the dehairer end line. For this reason, the total steam flow to the scald tank was estimated by multiplying the total of the two meters times -

$$3 \left(\frac{\text{ave. of dehairer end}}{\text{total}} \right) + \frac{\text{ave. of bleed end}}{\text{total}} =$$

$$3(0.284) + 0.716 = 1.568$$

The average steam flow during the operating day was therefore -

$$\frac{31,211 \text{ lbs (1194.1 Btu/lb) (1.568)}}{5302 \text{ head}} = 11,021.8 \text{ Btu/head}$$

Total steam needed was 11,021.8 Btu/head + 768.6 Btu/head
or 11,790.4 Btu/head

For the day on which the balance was performed, 23,874.6 lbs of steam was used by the two ends during a 13.5 hr day (5290 hogs).

Total input 44,701,578 Btu's

4. Combined losses from scald tank surface -

Combined losses were estimated using table from Strock and Foxhall, 1959 -

Ambient air - 80°F
Air velocity - 2.0 ft/sec
Ave. water temperature - 140°F
Exposed surface - 699.25 ft²
Heat flux at conditions - 1060 Btu/hr-ft²

$$699.25 \text{ ft}^2 (1060 \text{ Btu/hr-ft}^2) = 741,205 \text{ Btu's hr}$$

Since tub was functioning on the average of 13.5 hrs the total daily loss was - 10,006,267 Btu's.

5. Loss from tank metal surface by convection - (from Strock and Foxhall, 1959) -

At this plant it was noted that the tank surfaces were hotter than the water inside. This indicates steam flow along bottom and sides of tank.

a. For tank -

$$\text{walls } h_c = 0.3(152 - 80)^{\frac{1}{2}} = 0.874 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$\text{bottom } h_c = 0.2(150 - 80)^{\frac{1}{2}} = 0.578 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

Total convective loss from tank was -

$$13.5 \text{ hrs}[(0.874 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(768.4 \text{ ft}^2)(152 - 80^{\circ}\text{F})] + \\ (0.578 \text{ Btu/hr-}^{\circ}\text{F-ft}^2)(699.25 \text{ ft}^2)(150 - 80^{\circ}\text{F}) = \\ 1,016,829 \text{ Btu's/day}$$

b. Convective losses from the recirculation pipes -

$$h_c = 0.42 (137 - 80/6)^{1/4} = 0.737 \text{ Btu/lb-}^{\circ}\text{F}$$

$$q_c = \left(\frac{6}{12} \text{ ft } \pi\right) (150 \text{ ft}) (0.737 \text{ Btu/lb-}^{\circ}\text{F}) (137 - 80^{\circ}\text{F}) \times \\ (13.5 \text{ hrs}) = 133,690.5 \text{ Btu's}$$

Total convective loss for the day was 1,150,520 Btu's

6. Losses from tank and pipes due to radiation -

($e = 0.94$ (Heldman, 1975 for paint))

a. For tank -

$$q_r = \frac{0.174(0.94)(1467.65 \text{ ft}^2)(610^4 - 540^4)(13.5 \text{ hrs})}{10^8} = \\ 1,731,412 \text{ Btu's/day}$$

b. For pipes -

$$q_r = \frac{0.174(0.94)\left(\frac{6}{12} \pi\right)(250 \text{ ft})(597^4 - 540^4)(13.5 \text{ hrs})}{10^8} = \\ 218,493 \text{ Btu's/day}$$

Total radiation loss (tank and pipes) - 1,949,905 Btu's

7. Losses to hogs -

Only the outer skin of the hogs is heated, since it was found that no appreciable temperature change occurs in the hogs at a 1.0 inch depth. An estimate of 32 pounds of skin and fat was used as the basis for heating.

Assume $C_p = 0.5 \text{ Btu/lb-}^\circ\text{F}$, mostly fat -

$$5290 \text{ hogs}(32 \text{ lb/hog}) (0.5 \text{ Btu/lb-}^\circ\text{F}) (140 - 101^\circ\text{F}) =$$

$$3,300,960 \text{ Btu's/day}$$

8. Balance -

a. Input -

Steam	-	44,701,578 Btu's
Electricity	-	<u>544,217 Btu's</u>
		45,245,795 Btu's

b. Since for this day there was no heat required of the initial water, the energy losses can be explained as

- combined losses from surface	10,006,267 Btu's
- losses by convection	1,150,520 Btu's
- losses by radiation	1,949,905 Btu's
- heat up of skin	<u>3,300,960 Btu's</u>
TOTAL	16,407,652 Btu's

Accountable Output - 45,245,795 Btu's
Accountable Input - 16,407,652 Btu's

DIFFERENCE 28,838,143 Btu's

The difference represents input steam which is lost from the tank. Part of this is lost as condensate (overflow) and the remaining must be leaving as non-condensed steam at 1 atmosphere.

$$28,838,143 \text{ Btu's} = m_{\text{vap}}^{212} (1150.5 \text{ Btu/lb}) + m_{\text{cond}}^{140} \times$$

$$(107.95 \text{ Btu/lb})$$

$$23,874.6 \text{ lb}(1.568) = m_{\text{vap}} + m_{\text{cond}}$$

$$37,435.4 \text{ lbs} = m_{\text{vap}} + m_{\text{cond}}$$

$$37,435.4 - m_{\text{vap}} = m_{\text{cond}}$$

Solving for m_{vap} -

$$28,838,143 \text{ Btu's} = (37,435.4 \text{ lbs}) (107.95 \text{ Btu/lb}) =$$

$$(1150.5 - 107.95 \text{ Btu/lb}) (m_{vap})$$

$$25,796,994 = 1042.55 m_{vap}$$

$$23,784.9 \text{ lbs} = m_{vap} = 27,364,579 \text{ Btu/day}$$

This amounts to 60% of the input. If it is assumed that both central steam lines were off during this day and the data was computed the same way, the loss would be 9657 lbs or 11,110,440 Btu's or 38%.

C. Dehairing Machine Operation

1. Electrical use -

- 1 - 2.0 hp conveyor - 480V, 2.25A, 8.4 hrs/day
- 2 - 30 hp main drives - 480V, 18.5A, 8.4 hrs/day
- 2 - 25 hp recycle pumps - 480V, 15.5A, 8.4 hrs/day
- 1 - 2 hp hair single phase conveyor - 230V, 6.4A, 8.4 hrs/day
- 1 - 5 hp gambrel table drive - 480V, 1.7A, 7.5 hrs/day
- 1 - 15 hp gambrel chain drive - 480V, 13.5A, 10.1 hrs/day

The total daily electrical requirement was -

$$8.4 \text{ hrs}(480\text{V}) (80\% \text{ P.F.}) (\sqrt{3}) [(2.25\text{A}) + (2) (18.5\text{A}) +$$

$$(2) (15.5\text{A})] + 8.4 \text{ hrs}(230\text{V}) (80\% \text{ P.F.}) (1.7\text{A}) (\sqrt{3}) + 7.5 \text{ hrs} \times$$

$$(480\text{V}) (80\% \text{ P.F.}) (1.7\text{A}) (\sqrt{3}) + 10.1 \text{ hrs}(480\text{V}) (80\% \text{ P.F.}) (13.5\text{A}) \times$$

$$(\sqrt{3}) = 501,539 \text{ WH/day or } 103.99 \text{ WH/head}$$

Assuming 50% of the main drive and pump energy was input to water -

$$109,954.7 \text{ WH}(0.50) (3.414 \text{ Btu/WH}) = 324,253 \text{ Btu's/day}$$

2. Water use -

a. Initial fill -

Preheated softened water is pumped to the dehairer base tanks prior to production. Total volume capacity of the two tanks was 428.75 ft³. The amount of water required was 3207 gallons.

c. Constant overflow -

Average daily water flow through 3 inch lines to polisher and dehairer was 91,197 gallons per day. Of this total an average of 38,750 gallons was used after production ended and cleanup began. A total of 52,447 gallons is thus used by the polisher and dehairers during production. From flow data taken when the polisher was off, it was estimated that 34.6 gpm was used by the dehairers. This compares with a normal production flow of 69.3 gpm when both dehairers and polisher were going. Since the dehairers operate on the average 9.87 hrs/day, the total daily water use was estimated to be 20,502 gallons.

Total water use was - 23,709 gallons or 4.92 gal/head.

3. Steam use -

a. Initial heat up estimate -

Assuming the need for 30°F temperature rise -

$$3207 \text{ gal} (8.33 \text{ lb/gal}) (1.0 \text{ Btu/lb-}^{\circ}\text{F}) (30^{\circ}\text{F}) =$$

$$801,429 \text{ Btu's}$$

b. Steam flow -

The steam flow for one dehairer was monitored. An average daily flow of 51,054.8 lbs (135 psig) steam was used to process 5421 hogs over 8.0 hrs. Assuming both dehairers operate similarly the total daily demand was -

$$(2) (51,054.8 \text{ lbs}) (1194.1 \text{ Btu/lb}) = 121,929,070 \text{ Btu's or}$$

$$22,492 \text{ Btu's/head}$$

4. Combined losses from water surfaces of the base tanks -

- Ambient air - 80°F
- Air velocity - 20.0 ft/sec
- Average water temperature - 140°F
- Exposed surface area - 171.5 ft²
- At these conditions the heat loss was 3600 Btu's/hr-ft²
(Strock and Foxhall, 1959)
- Steam input - 8.0 hrs

$$8.0 \text{ hrs} (171.5 \text{ ft}^2) (3600 \text{ Btu/hr-ft}^2) = 4,930,560 \text{ Btu's/day}$$

5. Convective losses from metal surface of dehairers -

$$\text{walls } h_c = 0.3(130 - 80^\circ\text{F})^{\frac{1}{4}} = 0.798 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$\text{top } h_c = 0.38(130 - 80^\circ\text{F})^{\frac{1}{4}} = 1.010 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$\text{bottom } h_c = 0.2(130 - 80^\circ\text{F})^{\frac{1}{4}} = 0.532 \text{ Btu/hr-}^\circ\text{F-ft}^2$$

$$\begin{aligned} q_c &= 0.798 \text{ Btu/hr-}^\circ\text{F-ft}^2 (1596.8 \text{ ft}^2) (130 - 80^\circ\text{F}) (8.0 \text{ hrs}) + \\ &\quad 1.010 \text{ Btu/hr-}^\circ\text{F-ft}^2 (182 \text{ ft}^2) (130 - 80^\circ\text{F}) (8.0 \text{ hrs}) + \\ &\quad 0.532 \text{ Btu/hr-}^\circ\text{F-ft}^2 (182 \text{ ft}^2) (130 - 80^\circ\text{F}) (8.0 \text{ hrs}) = \\ &\quad 621,963 \text{ Btu/day} \end{aligned}$$

6. Radiation losses from metal surfaces - (assume $e = 0.94$)

$$\begin{aligned} q_r &= 0.174 (0.94) / 10^8 (590^4 - 540^4) (8.0 \text{ hrs}) (1960.8 \text{ ft}^2) = \\ &\quad 927,310 \text{ Btu's/day} \end{aligned}$$

7. No losses to hogs since they are coming from scald tanks already at operating temperature.

8. Balance -

- a. Accountable Input -

steam	-	121,929,070 Btu's during operation
electricity	-	<u>324,253 Btu's</u>
TOTAL		122,253,320

- b. Accountable Output -

Losses from water surface	-	4,930,560 Btu's
Convective losses from metal	-	621,963 Btu's
Radiant losses from metal	-	<u>927,310 Btu's</u>

TOTAL 6,479,833

Difference - 115,773,490

Clearly there is enormous loss caused by evaporation of water or direct steam loss. A certain amount of steam is lost as overflow due to condensate but the remainder is lost either as noncondensed steam or combined losses from the water sprays as air passes through the dehairers. In either of latter two cases, the losses can more easily be explained because of the effect of latent heat. For simplicity, assume all vapor lost at temperature of 212°F.

$$115,773,490 \text{ Btu} = m_{\text{vap}}^{*212} (1150.5 \text{ Btu/lb}) + m_{\text{cond}}^{130} \times$$

$$(97.96 \text{ Btu/lb})$$

$$102,109.6 \text{ lb} = m_{\text{vap}} + m_{\text{cond}}$$

$$102,109.6 - m_{\text{vap}} = m_{\text{cond}}$$

$$115,773,490 \text{ Btu} = (102,109.6 \text{ lb}) (97.96 \text{ Btu/lb}) =$$

$$m_{\text{vap}} (1150.5 - 97.96 \text{ Btu/lb})$$

$$105,770,830 \text{ Btu's} = 1052.54 m_{\text{vap}}$$

$$100,491 \text{ lbs} = m_{\text{vap}}$$

representing 115,614,930 Btu's at 212°F

$$1618.6 \text{ lb} = m_{\text{cond}}$$

D. Singeing Operation

1. Gas usage -

Average kill during the gas flow data collection period was 5730 per day. Average total daily usage was 62,100.7 SCF per 8.0 hr day. Assuming the content of SCF was 1000 Btu's, the total daily input was 62,100,700 Btu's or 10,338 Btu per head.

2. Electrical usage -

1 - 3.0 hp blower - 480V, 1.7A

$$8.0 \text{ hrs} (1.7\text{A}) (480\text{V}) (80\% \text{ P.F.}) (\sqrt{3}) = 9045.5 \text{ WH/day or}$$

$$1.579 \text{ WH/head}$$

Assuming that 50% of the blower energy appears as heat in the air -

$$9045.5 \text{ WH}(0.5) (3.414 \text{ Btu/WH}) = 15,441 \text{ Btu's}$$

Total heat in was 62,116,140 Btu's

3. Heat to hogs was negligible
4. Heat loss from cabinet and ducts to room by convection and radiation -

Duct is 4 ft diameter x 30 ft to roof. Exhaust air 900°F ($C_p = 0.259$, Heldman 1975). Ambient air 80°F ($C_p = 0.24$, Heldman 1975). Surface of duct = 900°F . Total area of duct is 377 ft^2 .

- a. Convection -

$$\text{walls } h_c = 0.3(900 - 80)^{1/4} = 1.605 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$$

$$q_c = 1.605 \text{ Btu/hr-}^{\circ}\text{F-ft}^2 (377 \text{ ft}^2) (900 - 80^{\circ}\text{F}) (8.0 \text{ hrs}) = 3,969,357.6 \text{ Btu's}$$

- b. Radiation -

$$e = 0 \text{ dirty galvanized } 0.28 \text{ (Heldman, 1975)}$$

$$q_r = 0.174(377 \text{ ft}^2)/10^8 (0.28) (1360^4 - 540^4) (8.0 \text{ hrs}) = 4,901,887 \text{ Btu's}$$

5. Heat loss to heating excess air - base 60°F (Natural Gas Industry Base) -

$$62,116,940 \text{ Btu's} - 3,969,358 - 4,901,887 = 53,229,455 \text{ Btu's}$$

$$53,229,455 \text{ Btu's} = m_{\text{air}}^{900} (0.259 \text{ Btu/lb-}^{\circ}\text{F}) (900 - 60^{\circ}\text{F}) -$$

$$(m_{\text{air}}^{80}) (0.24 \text{ Btu/lb-}^{\circ}\text{F}) (80 - 60^{\circ}\text{F}) =$$

$$212.76 m_{\text{air}}$$

$$250,185 \text{ lbs} = m_{\text{air}}$$

Actual air need for combustion was (Strock and Foxhall, 1959)

$$0.72 \text{ lb air/ft}^3 (62,100.7 \text{ SCF}) = 44,712 \text{ lbs}$$

$$\text{Excess air} = 205,472 \text{ lbs}$$

E. Polishing Operation

1. Electrical usage -

Average running time per day is 9.87 hrs

1 - 25 hp motor - 480V, 12A

$$9.87 \text{ hrs} (12\text{A}) (480\text{V}) (80\% \text{ P.F.}) (\sqrt{3}) = 78,775.3 \text{ WH/day or}$$

$$16.33 \text{ WH/head}$$

2. Water usage -

Average water usage over data collection period was estimated from the combined water flow with dehairers as mentioned earlier -

$$69.3 \text{ gpm} - 34.6 \text{ gpm} = 34.7 \text{ gpm}$$

for 9.87 hr day this represents 20,549 gallons or 4.26 gal per head.

Over the data collection period the total flow through the 3 inch line varied 69,220.6 to 151,537.4 gallons per day. Most of the variability was due to the amount of time that the polisher was left on during cleanup. The dehairer water was usually turned off promptly.

F. Shaving Operation

Manual operation except for steam injected to knife boxes. Boxes are of same design as that in sticking area. A total of nine boxes are used.

$$9 (15,155.4 \text{ Btu's/day}) = 136,399 \text{ Btu/day or } 28.28 \text{ Btu/head}$$

G. Rinse Cabinet Operation

During the actual production day, the total flow through the cabinet averaged - 22,640 gallons. In addition, the cabinet was left running for long periods during cleanup. Average daily total use was 37,740 gallons with a range of flows from 24,270 to 52,898 gallons. Use per head averaged 7.825 gal/head.

H. Drop Head, Drop Bung and Split Brisket

1. Electrical use -

1 - 0.5 hp saw - 230V, 2.4A

Assume average time to handle hog was 6 seconds.

$$2.4A(230V)(80\% \text{ P.F.}) (\sqrt{3}) (6 \text{ sec}/3600 \text{ sec/hog}) = 0.736 \text{ WH/hog}$$

1 - 1.0 hp conveyor - 480V, 1.5A (runs 10 hrs per day)

$$1.5A(480V)(80\% \text{ P.F.}) (\sqrt{3}) (10 \text{ hrs}) = 9976.6 \text{ WH/day or } 2.068$$

WH/hog

2. Steam for sterilizing boxes -

There are 9 box sterilizers, a saw sterilizer, a steel hook sterilizer and a large general sterilizer in this operation all using steam injection.

a. 9 box sterilizer -

$$9(15,155.4 \text{ Btu's/day}) = 136,399 \text{ Btu's/day}$$

b. Saw sterilizer -

Dimensions - 24.5" wide x 25" long x 24.5" high

Water depth - 20.5 inches

Volume of water - 7.266 ft³

Average bulk temp. - 178°F

Average wall temp. - 187°F

Initial temperature - 70°F

1. Startup -

$$7.266 \text{ ft}^3 (62.5 \text{ lbs/ft}^3) (1.0 \text{ Btu/lb-}^\circ\text{F}) (178 - 70^\circ\text{F}) =$$

$$49,047.8 \text{ Btu's}$$

2. Water surface loss - operating time 10 hrs

Air velocity - 1.0 ft/sec

Surface area - 4.25 ft² (from Strock and Foxhall 1959)

$$4.25 \text{ ft}^2 (2750 \text{ Btu/ft}^2\text{-hr}) (10 \text{ hrs}) = 116,970 \text{ Btu's}$$

3. Convection losses -

$$h_c \text{ walls} = 0.949$$

$$h_c \text{ bottom} = 0.648$$

$$q_c = 0.949 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}(16.85 \text{ ft}^2)(10 \text{ hrs})(187-80^\circ\text{F}) + \\ 0.648 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}(4.25 \text{ ft}^2)(10 \text{ hrs})(187-80^\circ\text{F}) = \\ 20,059 \text{ Btu's/day}$$

4. Radiation losses - ($e = 0.03$)

$$q_r = 0.174(0.03)(21.1 \text{ ft}^2)(10 \text{ hrs})(647^4-540^4)/10^8 = \\ 993.5 \text{ Btu's}$$

$$\text{Total steam requirement per day} = 187,070 \text{ Btu's/day}$$

c. Steel hook sterilizer -

Same dimensions and conditions as brisket saws sterilizer - 187,070 Btu's/day

d. Large sterilizer -

Dimensions - 12.5" wide x 21" long x 12.5" high

Water depth - 12.5 inches

Volume - 1.899 ft³

Average water temp - 197°F

Average wall temp. - 211°F

Initial temp. - 70°F

1. Startup -

$$1.899 \text{ ft}^3(62.5 \text{ lbs/ft}^3)(1.0 \text{ Btu/lb-}^\circ\text{F})(197 - 70^\circ\text{F}) = \\ 15,072 \text{ Btu's}$$

2. Water surface loss - operating time 10 hrs -

Air velocity - 1.0 ft/sec

Surface area - 1.823 ft²

At conditions, heat loss was 5600 Btu/ft²-hr

$$1.823 \text{ ft}^2(5600 \text{ Btu/ft}^2\text{-hr})(10 \text{ hrs}) = 102,083 \text{ Btu's}$$

3. Convective losses -

$$h_c \text{ walls} = 0.28(211 - 80/1 \text{ ft})^{\frac{1}{4}} = 0.947$$

$$h_c \text{ bottom} = 0.2(211 - 80)^{\frac{1}{4}} = 0.677$$

$$q_c = 1.823 \text{ ft}^2(0.677 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr})(10 \text{ hrs})(211-80^\circ\text{F}) + \\ 7.292 \text{ ft}^2(0.947 \text{ Btu/ft}^2\text{-}^\circ\text{F-hr})(10 \text{ hrs})(211-80^\circ\text{F}) = \\ 10,663 \text{ Btu's}$$

4. Radiation losses - ($e = 0.03$)

$$q_r = 0.174(0.03)(0.115 \text{ ft}^2)(10 \text{ hrs})(671^4 - 540^4)/10^8 = \\ 560 \text{ Btu's}$$

Total steam required by this sterilizer =

128,378 Btu's/day

Total steam requirement per day all sterilizers =

638,917 Btu's/day or 132.5 Btu/head

I. Evisceration and Separation

1. Viscera Removal

Estimate 30 gpm flow to viscera pan cleaner - operates 7.67 hrs/day 13,806 gallons/day or

Steam requirement -

Water for pan cleaner is preheated by waste heat recovery to 110°F . The water is further heated at the station by steam injection to 180°F .

$$13,806 \text{ gal}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^\circ\text{F})(180 - 110^\circ\text{F}) =$$

8,050,278 Btu's/day

An addition knife box requires steam at rate 15,155.4 Btu's/day

Total steam required per day -

8,065,434 Btu's or 1672 Btu's/head

2. Viscera Separation

a. Electrical -

1 - 3 hp auger - 3.42A, 480V

$7.67 \text{ hrs}(3.42\text{A})(470\text{V})(80\% \text{ P.F.})(\sqrt{3}) = 17,446.7 \text{ WH/day or}$

3.62 WH/head

b. Water -

There are three shower spray heads each nozzle uses water at an approximate rate of 3.6 gpm.

$3(3.6 \text{ gal/min})(60 \text{ min/hr})(7.67 \text{ hrs}) = 5038 \text{ gal}$

c. Steam use -

4 knife sterilizers similar to previous.

$4(15,155 \text{ Btu's/day}) = 60,620 \text{ Btu's}$

Water for showers requires 30° rise from 110 to 140°F .

$5038 \text{ gal}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(30^{\circ}\text{F}) = 1,258,996 \text{ Btu's}$

Total steam required by evisceration and separation =

9,385,050 Btu's/day or 1945.9 Btu's/head

Total water use was -

18,844 gallons or 3.91 gal/head

Electricity used was 3.62 WH/head

J. Stomach Line

1. Electrical use -

1 - 0.75 hp stomach cleaner - 230V, 1.0A

1 - 5.0 hp scalding - 480V, 3.5A

Scalding runs 11 batches/day (50 min runs)

$7.67 \text{ hrs}(1\text{A})(230\text{V})(80\% \text{ P.F.}) + 50/60(11)(3.5\text{A})(480\text{V}) \times$

$(80\% \text{ P.F.})(\sqrt{3}) = 22,750 \text{ WH/day or } 4.717 \text{ WH/head}$

2. Water use -

Water is used by 3 spray heads (3.42 gpm) and washer (10 gpm)

Total 20.26 gpm or

$$7.67 \text{ hrs}(20.26 \text{ gal/min})(60 \text{ min/hr}) = 9323.6 \text{ gal/day}$$

An additional amount of water is used in each scalding operation. Estimate 30 gallons per batch or 330 gal/day.

Total water use - 9654 gallons/day or 2.00 gal/head

3. Steam use -

Stomach scalders use steam injection. About 160 stomachs are scalded per batch. Stomachs weigh 1.5 lbs (Oneco-St. John)

a. Startup - (assume $C_p = 0.75$ same as inedible rendering)

$$460(1.5 \text{ lb/stomach})(0.75 \text{ Btu/lb-}^{\circ}\text{F})(155 - 73^{\circ}\text{F}) +$$

$$30 \text{ gal}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(155 - 70^{\circ}\text{F}) =$$

$$63,676.5 \text{ Btu's/batch}$$

b. Convective losses -

$$h_{c \text{ ends}} = 0.3(153.5 - 87)^{\frac{1}{4}} = 0.857 \text{ Btu/lb-}^{\circ}\text{F-ft}^2$$

$$h_{c \text{ cylinder}} = 0.4(153.4 - 87/36)^{\frac{1}{4}} = 0.467 \text{ Btu/lb-}^{\circ}\text{F-ft}^2$$

$$q_c = 50/60 \text{ hrs}(0.857 \text{ Btu/lb-}^{\circ}\text{F-ft}^2)(2)(3/2 \text{ ft})^2(\pi) \times$$

$$(153 - 87^{\circ}\text{F}) 0.467 \text{ Btu/lb-}^{\circ}\text{F-ft}^2(3 \text{ ft } \pi)(3.375 \text{ ft}) \times$$

$$(153 - 87^{\circ}\text{F}) = 1483 \text{ Btu/batch}$$

c. Radiation losses - ($e = 0.85$ weathered S.S. (Heldman, 1975))

$$q_r = 0.172(0.85)(45.94 \text{ ft}^2)/10^8(613^4 - 547^4)(50/60) =$$

$$2892 \text{ Btu's/batch}$$

Total Btu's per day (11 batches) = 748,570 Btu's or

155 Btu's/head

K. Casing and Chitterling Lines

1. Chitterling lines -

a. Electrical use -

3 - 0.33 hp chitterling knife drives - 480V, 0.5A

3 - 1.0 hp chain drives - 480V, 1.5A

1 - 1.5 hp black gut conveyor - 480V, 1.6A

Machines run 12.5 hours per day including a 4.5 hour cleanup.

$$12.5 \text{ hrs}(480\text{V})(80\% \text{ P.F.})(\sqrt{3})[(3)(0.5\text{A}) + (3)(1.5\text{A}) + (1.6\text{A})] = 63,185.2 \text{ WH/day or } 13.10 \text{ WH/head}$$

b. Water use -

There are 7 shower heads each using 3.3 gpm. In addition, the 3 chittling machines use an average of 76,443 gal/day a piece during production.

Total water use was -

$$7(3.3 \text{ gal/min})(60 \text{ min/hr})(7.67 \text{ hrs}) + 3(76,443 \text{ gal/day}) = 240,077 \text{ gal/day}$$

c. Steam use -

Since water must be heated 30°F above the heat recovery potential, the steam need was -

$$240,077 \text{ gal} (9.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(30^{\circ}\text{F}) = 59,995,320 \text{ Btu's}$$

2. Casing lines -

a. Electrical use -

2 - 2.0 hp casing stripper - 480V, 2.15A

1 - 2.0 hp finishing machine - 480V, 2.15A

2 - 1.0 hp casing crushers - 480V, 2.0A

1 - 5 hp slime pump - 480V, 3.6A

Operation time including cleaning was 8.75 hrs/day
 $8.75 \text{ hrs}(480\text{V})(80\% \text{ P.F.})(\sqrt{3})[(3)(2.15) + (2)(2.0) + (3.6)] = 81,766.6 \text{ WH/day}$

b. Water use -

Water is used by stripping and crushing machines. The total water use by the entire chitterling and casing operation was 340,632 gallons of hot and cold water. Since the chitterling lines use 240,077 gal/day the rest of the operation (casing line) must use 100,555 gal/day.

c. Steam use -

Since water must be heated 30°F -

$100,555 \text{ gal/day}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(30^{\circ}\text{F}) =$

$25,128,694 \text{ Btu's/day}$

Total water use for the entire operation -

$341,632 \text{ gal/day}$ or 70.83 gal/head

Total electrise use $144,951.8 \text{ WH/day}$ or 30.05 WH/head

Total steam required -

$341,632 \text{ gal/day}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb})(30^{\circ}\text{F}) =$

$85,373,836 \text{ Btu's}$ or $17,701.4 \text{ Btu's/head}$

L. Liver and Heart

1. Electrical use -

- 1 - 1.0 hp conveyor - 480V, 1.5A
- 1 - 0.5 hp gall bladder slasher - 230V, 3.2A
- 1 - 0.5 hp heart slasher - 230V, 3.2A
- 1 - 2.0 hp heart scalding - 480V, 2.04A

Operational day including cleanup - 8.75 hrs

$$8.75 \text{ hrs } (80\% \text{ P.F.}) (480\text{V}) (\sqrt{3}) (2.04 + 1.5A) + 8.75 \text{ hrs } \times \\ (80\% \text{ P.F.}) (230\text{V}) (3.2 + 3.2) = 30,905.7 \text{ WH/day or } 6.41 \text{ WH/head}$$

2. Water and Steam use -

Use for heart scalding is assumed to be the same as for stomach scalding 330 gallons and 748,570 Btu's. In addition, there are 2 spray heads at the liver trim station each using 2.1 gpm on the average. For the entire day the water and steam use was -

$$(2) 2.1 \text{ gal/min} (60 \text{ min/hr}) (7.67 \text{ hrs}) = 1936.2 \text{ gal/day}$$

$$1936.2 \text{ gal} (8.33 \text{ lb/gal}) (1.0 \text{ Btu/lb-}^{\circ}\text{F}) (30^{\circ}\text{F}) = 483,854 \text{ Btu's/day}$$

Total water use - 2266.2 gal or 0.470 gal/head

Total steam use - 1,232,424 Btu's/day or 255 Btu/head

M. ENUCLEATE KIDNEYS, SPLIT BACK AND INSPECT

1. Electrical use -

2 - 5 hp saws - 230V, 1.7A

Estimate 12 sec/head use -

$$12 \text{ sec}/3600 (1.7A) (230V) (80\% \text{ P.F.}) = 1.043 \text{ WH/head or}$$

$$5028.8 \text{ WH/day}$$

2. Steam use -

2 - box sterilizers similar to other

2 - saw sterilizers similar to one used for brisket saw

$$(2) 15,155 \text{ Btu's} + 2(187,070 \text{ Btu's/day}) = 404,450 \text{ Btu's/day}$$

or 83.86 Btu's/head

N. Head Table

1. Electrical use -

- 1 - 1.0 hp forehead meat slicer - 230V, 1.6A
- 1 - 1.33 hp snout stripper - 230V, 2.1A
- 1 - 1.0 hp jaw puller - 230V, 1.6A
- 5 - 0.33 hp trimmer knives - 115V, 6.4A
- 1 - 15 hp skull splitter pump - 480V, 10.6A

Operational day was 7.67 hours

$$7.67 \text{ hrs}(80\% \text{ P.F.}) [(230\text{V}) (1.6 + 2.1 + 1.6) + (115\text{V}) (5) (6.41) + 480\text{V}(\sqrt{3}) (10.6\text{A})] = 84,134.8 \text{ WH/day or } 17.44 \text{ WH/head}$$

2. Water use -

Average use per day as recorded by a meter was 1650 gallons or 0.342 gal/head.

3. Steam use -

The steam requirement assuming the water required heating 30°F was -

$$1650 \text{ gal}(8.33 \text{ lb/gal}) (1.0 \text{ Btu/lb-}^{\circ}\text{F}) (30^{\circ}\text{F}) = 412,335 \text{ or } 85.5 \text{ Btu/head}$$

O. Carcass Rinsing and Leaf Lard and Kidney Removal

1. Electrical use -

- 1 - 2.0 hp oscillating wand - 480V, 1.2A
- 1 - 7.5 hp leaf lard pump - 480V, 7.75A

Total usage time was 8.75 hrs.

$$8.75 \text{ hrs}(480\text{V}) (80\% \text{ P.F.}) (\sqrt{3}) (1.2 + 7.75) = 52,086 \text{ WH/day or } 10.80 \text{ WH/head}$$

2. Water use -

a. First rinse cabinet -

water use assumed to be the same as the rinse after shave - 37,740 gal/day.

b. Second or final rinse -

This cabinet was metered and had an average flow of 9529 gallons over the production day lasting 7.67 hrs. The total average flow over 24 hours was 12,826 gal/day.

Average flow during production for all rinse cabinets was - 47,269 gals or 9.80 gal/head

P. Carcass Chill

1. Electrical use -

There are 12 units in the carcass chill room each with 3 - 1.0 hp fans for a total of 36 motors. Operation is essentially 24 hrs/day.

36 - 1.0 hp fans, 230V, 1.55A.

24 hrs (36) (230V) (1.55A) (80% P.F.) = 246,412.8 WH/day or

51.09 WH/head

2. Refrigeration -

The average velocity of air leaving the air handling refrigeration units was 24,780 CFM each measured in the exhaust. Two units were monitored continuously; a summary of one days average temperatures was -

TIME	UNIT 1		UNIT 2	
	Temp in	Temp out	Temp in	Temp out
12:00 am	39	37	43	43
2:00	40	37	46	44
4:00	39	37	44	44
6:00	42	36	43	43
8:00	43	37	44	40
10:00	44	36	43	42
12:00 pm	48	39	51	45
2:00	47	40	50	46
4:00	51	32	52	33
6:00	45	34	45	36
8:00	45	30	46	30
10:00	38	29	38	29
12:00 am	35	28	36	25
AVE.	42.8	34.8	44.7	38.5

Average R.H. = 80% (From Zimmerman and Lavine, 1945).

Enthalpy of inlet air average temp. $44^{\circ}\text{F} = 80\% \text{ R.H.}$

$$h = 2.8824 \text{ Btu/lbDA} + 0.004962 \text{ lbwv/lbDA}(1080.4 \text{ Btu/lbwv}) = 8.243 \text{ Btu/lbDA}$$

Enthalpy of outlet air average temp. 37°F . Air must be saturated since maximum can hold was $0.004629 \text{ lbwv/lbDA}$

$$h = 6.188 \text{ Btu/lbDA}$$

Specific volume of exhaust air (saturated) -

$$v = 12.607 \text{ ft}^3/\text{lbDA}$$

Air flow for the 12 units per day was -

$$24 \text{ hrs}(12) (24,780 \text{ CFM}) (60 \text{ min/hr}) / 12.607 \frac{\text{ft}^3}{\text{lbDA}} = 33,965,130 \text{ lbDA}$$

Refrigeration load for air was -

$$33,965,130 \text{ lbDA} (8.243 \text{ Btu/lbDA} - 6.188 \text{ Btu/lbDA}) = 69,798,343 \text{ Btu's}$$

In addition, some water is condensed and removed from inlet air. The refrigeration requirement for this condensation was -

$$33,965,130 \text{ lbDA} (0.004962 \text{ lbwv/lbDA} - 0.004629 \text{ lbwv/lbDA}) \times (1077.3 \text{ Btu/lbwv}) = 12,184,681 \text{ Btu's}$$

Total refrigeration requirement was -

$$81,983,024 \text{ Btu's/day absorbed or } 16,998 \text{ Btu's/head}$$

Q. Sanitation and General Utilities

1. Electrical use -

a. Main floor -

- 36 - 350 watt mercury vapor lamps
- 100 - 40 watt fluorescent tubes
- 5 - 0.5 hp fans - 230V, 1.2A

b. Carcass chill -

200 - 40 watt fluorescent tubes

Average running time - 18 hrs/day

$$18 \text{ hrs}[(5)(1.2\text{A})(230\text{V})(80\% \text{ P.F.}) + (200)(40 \text{ watt}) + (36)(350 \text{ watt}) + (100)(40 \text{ watt})] = 462,672 \text{ WH/day or } 95.93 \text{ WH/head}$$

2. Water use -

a. Bleed pit area -

1 hose estimate running 6 hrs/day at 15 gpm

$$15(60)(6) = 5400 \text{ gallons/day}$$

b. Average water use by line feeding dehairing and polishing area was 38,750 gal/day after production hours (range 4032 to 55,312 gallons) highly variable.

c. Rinse cabinet after shave used as average of 8568 gal/day after production (range 2512 to 15,900).

d. Water in six inch mains (central area). Total water flow through these mains was 65,958 gal/day average (with range 43,678 to 85,788 gallons) after production hrs.

e. Final rinse cabinet -

Average use after hours was 3297 gallons (range 2378 to 4216) after production.

3. Steam use -

Of the total water use some of the cleanup water required the 30°F boost by steam -

$$65,958 + 38,750 + 5400 \text{ gal}(8.33 \text{ lb/gal})(1.0 \text{ Btu/lb-}^{\circ}\text{F})(30^{\circ}\text{F}) = 27,515,989 \text{ Btu's}$$

4. In addition, a gambrel chain cleaner uses steam injection very much like the scald tank. The metered steam input averaged 9519 lbs/day (3647 to 12,058.9 range) at 132 psig.

a. Total daily use was -

11,364,289 Btu's/day or 1807 Btu's/head

b. Electrical use - vents steam from tank

1 - 5.0 hp blower - 230V, 14.2A at 8 hrs/day

8 hrs (14.2A) (230V) (80% P.F.) = 20,902 WH/day or

4.33 WH/head

c. Water use for spray heads on chain out average 3 gpm -

8 hrs (3 gpm) (60 min/hr) = 1440 gal/day or 0.298 gal/hog

R. Frank Continuous Smokehouse

1. Operation parameters from smokehouse charts -

	<u>DB °F</u>	<u>WB °F</u>
#1	150	132
#2	210	162

Actual exhaust temperatures at roof for these sections indicate a problem with the steam/air mixing -

	<u>DB °F</u>	<u>WB °F</u>
#1	156	136
#2	280	168

Air flow rate was taken at the exhaust vents under the actual exhaust temperatures -

	Ave. FPM	X-area (ft ²)	ACFH	Sp. Vol. (ft ³ /#DA)	#DA/hr
#1	993.2	1.48	88,196.2	18.715	4,712.6
#2	1,968.1	1.68	198,383.9	29.196	6,794.9

In addition to exhaust vent flow, a small amount of air flows out the frank chain exit opening of Section 2 into the shower cabinet. The flow rate was 50 FPM. Of the total 11.2 ft² opening, it was assumed that 80% was occupied by franks (20% for air flow).

The total air flow out was 6720 ACFH or 474.9 #DA/hr at the flow conditions 80° DB, 79° WB inside shower.

At the inlet opening for section #1, the flow was into the house, (negative).

A. Total water and energy in exhaust gases -

1. Section #1 - 156° DB, 136° WB

$$a. 4712.6 \text{ #DA/hr } (0.1289 \text{ # H}_2\text{O/#DA}) = 607 \text{ # H}_2\text{O/hr}$$

$$b. 4712.6 \text{ #DA/hr } (175.247 \text{ Btu/#DA}) = 825,869 \text{ Btu/hr}$$

$$\text{Total air}_{\text{out}}/\text{water} = 3163 \text{ # H}_2\text{O/hr}$$

$$\text{Energy} = 4,272,240 \text{ Btu/hr}$$

2. Section #2 - 280° DB, 168° WB

$$a. 6794.9\# \text{ DA/hr } (0.355\# \text{ H}_2\text{O}/\# \text{DA}) = 2412\# \text{ H}_2\text{O/hr} +$$

also assuming the opening loss is at house conditions 210° DB, 162° WB -

$$474.9\# \text{ DA/hr } (0.303\# \text{ H}_2\text{O}/\# \text{DA}) = 144\# \text{ H}_2\text{O/hr}$$

$$b. 6794.0\# \text{ DA/hr } (479.860 \text{ Btu}/\# \text{DA}) = 3,260,601 \text{ Btu/hr} +$$

also assuming the opening loss is at 210° DB, 162° WB

$$474.9\# \text{ DA/hr } (391.178 \text{ Btu}/\# \text{DA}) = 185,770 \text{ Btu/hr}$$

B. Franks

$$1. \text{ Water lost} = 10,945\#/\text{hr} - 10,204\#/\text{hr} = 741\# \text{ H}_2\text{O/hr}$$

$$2. \text{ Energy - Franks}_{\text{in}} = 10,945\#/\text{hr} (0.731 \text{ Btu}/\text{lb-}^\circ\text{F}) \times$$

$$(87 - 32) = 440,044 \text{ Btu/hr}$$

$$- \text{Franks}_{\text{out}} = 10,204\#/\text{hr} (0.725) (160 - 32) =$$

$$946,931 \text{ Btu/hr}$$

$$\text{Fusion} = 10,945\#/\text{hr} (27.4\% \text{ fat}) (81 \text{ Btu}/\text{lb}) = 242,913 \text{ Btu/hr}$$

C. Convection and Radiation Losses

1. Section #1

$$a. \text{ Convection - room air } 111^\circ \text{ ceiling, } 85^\circ \text{ sides;}$$

$$\text{top} = 456 \text{ ft}^2 \quad h_c = 0.38(135 - 111)^{1/4} =$$

$$0.84 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

$$\text{sides and end} = 328 \text{ ft}^2 \quad h_c = 0.30(110 - 85)^{1/4} = .67$$

$$456 \text{ ft}^2 (0.84 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}) (135 - 111) +$$

$$328 \text{ ft}^2 (0.67 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}) (110 - 85) =$$

$$14,699 \text{ Btu/hr}$$

b. Radiation - 0.85 e for s.s.

$$\text{top} - 0.174(456 \text{ ft}^2)(0.85)(595^4 - 571^4)/10^8 =$$

$$12,834.94 \text{ Btu/hr}$$

sides, end, bottom -

$$0.174(784 \text{ ft}^2)(0.85)(570^4 - 545^4)/10^8 = 20,101.9/$$

$$32,986.8 \text{ Btu/hr}$$

2. Section #2

a. Convection - room air 130° ceiling, 80° sides;

$$\text{top } h_c = 0.38(180 - 130)^{\frac{1}{4}} = 1.01$$

$$\text{sides } h_c = 0.3(161 - 80^{\circ})^{\frac{1}{4}} = 0.900$$

$$\text{end } h_c = 0.3(110 - 80^{\circ})^{\frac{1}{4}} = 0.702$$

$$456(1.01)(180 - 130) + 286(0.90)(161 - 80) +$$

$$42(0.702)(110 - 80) = 44,762 \text{ Btu/hr}$$

b. Radiation - e=0.85

$$\text{top} - 0.174(456 \text{ ft}^2)(0.85)(640^4 - 540^4)/10^8 =$$

$$55,802.92$$

$$\text{sides} - 0.174(286)(0.85)(621^4 - 540^4)/10^8 =$$

$$26,939.82$$

end and bottom -

$$0.174(498)(0.85)(570^4 - 540^4)/10^8 = 15,120.8/$$

$$97,863.5 \text{ Btu/hr}$$

Total convective and radiant loss from entire
house = 190,261 Btu/hr

D. Steam meter on section #2 only relatively constant flow average 1964.4#/hr.

1. 135 psig - 2,121,300 Btu/hr

Steam to first section unknown

E. Gas meter for both sections relatively constant flow of 2121.3 SCFH at 2.0 psig - 2,121,300 Btu/hr

F. Electricity - 6 motors for entire house

2 - 20 hp, 2 - .25 hp, 2 - .75 hp, assuming 70% efficiency

$0.70(42 \text{ hp})(42.4 \text{ Btu/min-hp})(60 \text{ min/hr}) = 74,793.6 \text{ Btu/hr}$

Balance - Water

$\text{Franks}_{in} + \text{Air}_{in} + \text{Steam}_{in} + \text{Combustion} = \text{Air}_{out} + \text{Franks}_{out}$

Steam input for section #2 is known = 1964.4# $\text{H}_2\text{O/hr}$

$\text{Air}_{in} + \text{Steam}_{in} \#1 = \text{Franks}_{out} - \text{Franks}_{in} + \text{Air}_{out} -$

Combustion - 1964.4# $\text{H}_2\text{O/hr}$ (from Strock)

Combustion = assume gas is 83.4% CH_4 Pennsylv. area
16.6% C_2H_6

for 1.0 SCF of gas:

$0.834 \text{ ft}^3 \text{ CH}_4 (0.0423\#/ft^3) = 0.035278\#$

$0.166 \text{ ft}^3 \text{ C}_2\text{H}_6 (0.0801\#/ft^3) = \underline{0.013297\#}$
 $0.048575\#/ft^3$

For complete combustion -

$\text{CH}_4 - 0.035278\#(2.25\# \text{ H}_2\text{O}/\# \text{ gas}) = 0.079376 \# \text{ water}$

$\text{C}_2\text{H}_6 - 0.013297\#(1.80\# \text{ H}_2\text{O}/\# \text{ gas}) = 0.023935 \# \text{ or}$

$0.10331\# \text{ water}/\# \text{ gas}$

$$2121.3 \text{ SCFH} \times 0.048575 \# \text{ gas/ft}^3 \times 0.10331 \# \text{ water/\# gas} = 10.6 \# \text{ water/hr}$$

Balance - water

$$\text{Air}_{\text{in}} + \text{Steam}_{\text{in}} \#1 = -741 \#/\text{hr} + 3163 \#/\text{hr} - 10.6 \#/\text{hr} - 1964.4 \#/\text{hr} = 447 \# \text{ H}_2\text{O/hr}$$

Energy Balance -

$$\text{Franks}_{\text{in}} + \text{Air}_{\text{in}} + \text{Steam}_{\text{in}} + \text{Gas}_{\text{in}} + \text{Elec}_{\text{in}} = \text{Franks}_{\text{out}} + \text{Fused fat} + \text{Air}_{\text{out}} + \text{Losses}$$

$$\text{Steam}_{\text{in}} \text{ for section \#2 is known} = 2,345,690 \text{ Btu/hr}$$

$$\text{Air}_{\text{in}} + \text{Steam}_{\text{in}} \#1 = (\text{Franks}_{\text{out}} - \text{Franks}_{\text{in}}) + \text{fused fat} +$$

$$\text{Air}_{\text{out}} + \text{Losses} - \text{Steam \#2} - \text{Gas} - \text{Elec} =$$

$$(946,931 - 440,044) + 242,913 + 4,272,240 + 190,261 -$$

$$2,345,690 - 2,121,300 - 74,794$$

$$\text{So energy of Air}_{\text{in}} \text{ and the steam to section \#1} =$$

$$670,517 \text{ Btu/hr}$$

$\text{Air}_{\text{in}} \neq \text{Air}_{\text{out}}$ because of added products due to combustion of 2121.3 SCFH of gas.

Assuming complete combustion, the total weight of carbon added by the natural gas to form CO_2 is -

$$0.834 \text{ ft}^3 \text{ CH}_4 (0.749 \# \text{C/\# gas}) (\text{Strock 3-5}) = 0.6247$$

$$0.166 \text{ ft}^3 \text{ C}_2\text{H}_6 (0.799 \# \text{C/\# gas}) = 0.1326/0.7573 \# \text{C/\# gas}$$

$$2121.3 \text{ SCFH} \times 0.048575 \#/\text{ft}^3 \times 0.7573 = 78.0 \# \text{C added to air per hour as CO}_2$$

O₂ is present in inlet air so only weight of carbon is added to #DA/hr exhaust.

The weight of the inlet air (#DA/hr) is thus -

$$\begin{array}{rcl}
 4712.6 \text{ #DA/hr} & + & (6794.9 + 474.9) \text{ #DA/hr} - 78\# \\
 \text{Section \#1} & & \text{Section \#2} \quad \text{C in CO}_2 \\
 \hline
 11,904.4 \text{ #DA/hr} & &
 \end{array} =$$

Inlet air condition - 90° DB, 86° WB

$$\begin{array}{l}
 \text{Water in} = 11,904.4 \text{ #DA/hr} (0.02632\# \text{ water/\# DA}) = \\
 313.3\# \text{ H}_2\text{O/hr}
 \end{array}$$

$$\text{Energy in} = 11,904.4 \text{ #DA/hr} (42.903 \text{ Btu/\#DA}) = 510,734.5 \text{ Btu/hr}$$

Balances - Water

$$\text{Steam section \#1} = 447\# \text{ H}_2\text{O/hr} - 313\# \text{ H}_2\text{O/hr} =$$

134# H₂O/hr which represents 160,009 Btu/hr
at 135 psig

Balances - Energy

$$\begin{array}{l}
 \text{Steam section \#1} = 670,517 \text{ Btu/hr} - 510,734 \text{ Btu/hr} = \\
 159,783 \text{ Btu/hr}
 \end{array}$$

160,009 ≠ 159,783 but is very close

Inedible Rendering Energy Recovery CalculationsEquacooker:

steam available off equacooker - $11,007 \frac{\text{lb}}{\text{hr}}$ (for 10.75 hrs)

$$212^{\circ}\text{F} - \frac{\text{Btu}}{\text{lb}}$$

$$1.267 \times 10^7 \frac{\text{Btu}}{\text{hr}}$$

feed: $18,105 \frac{\text{lb}}{\text{hr}}$ at 95°F

steam presently used - $16,047 \frac{\text{lb}}{\text{hr}}$

$$100 \text{ psi} - 1187 \frac{\text{Btu}}{\text{lb}}$$

$$1.905 \times 10^7 \frac{\text{Btu}}{\text{hr}}$$

heat capacity of feed is $0.76 \frac{\text{Btu}}{\text{lb}^{\circ}\text{F}}$

$$(18,105 \frac{\text{lb}}{\text{hr}}) (0.76 \frac{\text{Btu}}{\text{lb}^{\circ}\text{F}}) (175^{\circ}\text{F} - 95^{\circ}\text{F}) = 1.101 \times 10^6 \frac{\text{Btu}}{\text{hr}}$$

required for preheating

using latent heat only:

$$\text{amt. steam required: } 1.101 \times 10^6 \frac{\text{Btu}}{\text{hr}} = M_s) 1151 \frac{\text{Btu}}{\text{lb}} - 180 \frac{\text{Btu}}{\text{lb}} \quad M_s = 1134 \frac{\text{lb}}{\text{hr}} (212^{\circ}\text{F})$$

heat transfer area required:

$$Q = U A \Delta T$$

$$\text{L M T D: } \Delta T_{\text{lm}} = \frac{(212 - 175) - (212 - 95)}{1_h \frac{(212 - 175)}{(212 - 95)}} = 69.5^{\circ}\text{F}$$

$$(1.101 \times 10^6 \frac{\text{Btu}}{\text{hr}}) = (60 \frac{\text{Btu}}{\text{hr}^{\circ}\text{F ft}^2}) (A) (69.5^{\circ}\text{F})$$

$$A = 264 \text{ ft}^2$$

convective losses: assume about $12,000 \frac{\text{Btu}}{\text{hr}}$

$$12,000 \frac{\text{Btu}}{\text{hr}} = M_s (1151 \frac{\text{Btu}}{\text{lb}} - 180 \frac{\text{Btu}}{\text{lb}})$$

$$M_s = 12 \frac{\text{lb}}{\text{hr}}$$

$$\text{remaining steam} = 9861 \frac{\text{lb}}{\text{hr}} (212^\circ\text{F})$$

$$\text{Savings: } (1.101 \times 10^6 \frac{\text{Btu}}{\text{hr}}) (\frac{5}{10^6} \frac{\$}{\text{Btu}}) (10.75 \frac{\text{hr}}{\text{day}}) (260 \frac{\text{day}}{\text{yr}})$$

$$= 15,400 \frac{\$}{\text{yr}}$$

$$\text{or } \frac{(1.101 \times 10^6 \frac{\text{Btu}}{\text{hr}})}{(2930 \frac{\text{lb}}{\text{hr}} \text{ tallow})} (6.55 \frac{\text{lb}}{\text{head}}) = 2461 \frac{\text{Btu}}{\text{head}}$$

remaining steam:

$$9861 \frac{\text{lb}}{\text{hr}} (10.75 \text{ hrs})$$

$$212^\circ\text{F}$$

$$1.135 \times 10^7 \frac{\text{Btu}}{\text{hr}}$$

Blood Coagulator:

Current steam usage is $348,700 \frac{\text{Btu}}{\text{hr}}$. Use some of the steam from equacooker.

Using latent heat only -

Atmospheric steam required:

$$348,700 \frac{\text{Btu}}{\text{hr}} = M_s (1151 \frac{\text{Btu}}{\text{lb}} - 180 \frac{\text{Btu}}{\text{lb}})$$

$$M_s = 359 \frac{\text{lb}}{\text{hr}} (212^\circ\text{F})$$

heat transfer area required: $Q = U A \Delta T$

$$\text{LMTD: } \Delta T_{lm} = \frac{(212 - 95) - (212 - 200)}{\frac{(212 - 95)}{L_h} (212 - 200)} = 46^\circ\text{F}$$

$$(348,700 \frac{\text{Btu}}{\text{hr}}) = (60 \frac{\text{Btu}}{\text{hr } ^\circ\text{F ft}^2}) (A) (46^\circ\text{F})$$

$$A = 126 \text{ ft}^2$$

CONVECTIVE LOSSES - assume about $5800 \frac{\text{Btu}}{\text{hr}}$

$$5800 \frac{\text{Btu}}{\text{hr}} = M_s (1151 \frac{\text{Btu}}{\text{lb}} - 180 \frac{\text{Btu}}{\text{lb}})$$

$$M_s = 6 \frac{\text{lb}}{\text{hr}}$$

steam remaining: $9454 \frac{\text{lb}}{\text{hr}}$ (10.75 hrs)

212°F

Use remaining steam plus that from hair hydrolyzers to heat water (70°F to 130°F).

Hair Hydrolyzers:

$$\text{steam output: } (3) (1753 \frac{\text{lb}}{\text{day}}) = 5259 \frac{\text{lb}}{\text{day}}$$

$$212^\circ\text{F} - 1151 \frac{\text{Btu}}{\text{lb}}$$

$$6.05 \times 10^6 \frac{\text{Btu}}{\text{day}}$$

Remaining from Equacooker:

$$(9545 \frac{\text{lb}}{\text{hr}}) (10.75 \frac{\text{hr}}{\text{day}}) (1151 \frac{\text{Btu}}{\text{lb}}) = 1.170 \times 10^8 \frac{\text{Btu}}{\text{day}}$$

$$(101,631 \frac{\text{lb}}{\text{day}})$$

Cold water
 70°F

Condensate
 80°F

shell and
tube heat
exchanger

Hot water 130°F

Steam 212°F

$$\Delta H_{\text{steam}} = (101,631 + 5259 \frac{\text{lb}}{\text{day}}) (1151 - 48 \frac{\text{Btu}}{\text{lb}})$$

$$= 1.179 \times 10^8 \frac{\text{Btu}}{\text{day}}$$

$$\Delta H_{\text{H}_2\text{O}} = H_{\text{steam}} \text{ (neglecting losses)}$$

$$\Delta H_{\text{H}_2\text{O}} = 1.179 \times 10^8 \frac{\text{Btu}}{\text{day}} = (M) (1.0 \frac{\text{Btu}}{\text{lb } ^\circ\text{F}}) (130^\circ\text{F} - 70^\circ\text{F})$$

$$m = 1.965 \times 10^6 \frac{\text{lb}}{\text{day}} (8.34 \frac{\text{lb}}{\text{gal}})$$

or $236,000 \frac{\text{gal}}{\text{day}}$ water

heat transfer surface required: $Q = U A \Delta T$

$$\text{LMTD: } \Delta T_{lm} = \frac{(212 - 130) - (80 - 70)}{\frac{(212 - 130)}{1} - \frac{(80 - 70)}{1}} = 34.2^{\circ}\text{F}$$

Hair hydrolyzers run practically 24 $\frac{\text{hrs}}{\text{day}}$ while the equacooker runs only 10.75 hrs/day; the maximum amount of area required is when both are running.

$$Q = \left[(101.631 \frac{\text{lb}}{\text{day}}) (\frac{\text{day}}{10.75 \text{ hr}}) + (5259 \frac{\text{lb}}{\text{day}}) (\frac{\text{day}}{24 \text{ hr}}) \right] (1151 \frac{\text{Btu}}{\text{lb}})$$

$$Q = 1.113 \times 10^7 \frac{\text{Btu}}{\text{hr}}$$

$$(1.113 \times 10^7 \frac{\text{Btu}}{\text{hr}}) = (600 \frac{\text{Btu}}{\text{hr ft}^2 ^{\circ}\text{F}}) (A) (34.2^{\circ}\text{F})$$

$$A = 540 \text{ ft}^2$$

Blood Ring Dryer:

air out of ring dryer: $7404 \frac{\text{lb}}{\text{hr}}$ air } 275°F
 $574 \frac{\text{lb}}{\text{hr}}$ H_2O }

room air (into furnace): 80% relative humidity
 90°F dry bulb

from psychrometric chart - $0.025 \frac{\text{lb H}_2\text{O}}{\text{lb dry air}}$
 $\downarrow$
 $7404 \frac{\text{lb}}{\text{hr}}$ air
 $185 \frac{\text{lb}}{\text{hr}}$ H_2O

air outlet - $0.078 \frac{\text{lb H}_2\text{O}}{\text{lb dry air}}$

Assuming air flow must be at least $7404 \frac{\text{lb}}{\text{hr}}$ (dry)

recycle $3/4$ of ring dryer outlet

fresh air: $(0.25)(7404 \frac{\text{lb}}{\text{hr}}) = 1851 \frac{\text{lb}}{\text{hr}}$ dry air

water in air: $(0.025)(1851 \frac{\text{lb}}{\text{hr}}) = 46 \frac{\text{lb}}{\text{hr}}$

air purge: $1851 \frac{\text{lb}}{\text{hr}}$ dry air

water in air outlet: $H_2O \text{ out} = M_w$ (before recycle)

water evaporated from blood - $574 \frac{\text{lb}}{\text{hr}}$

water in fresh air = $46 \frac{\text{lb}}{\text{hr}}$

recycled water in air = $3/4 M_w$

$(574 \frac{\text{lb}}{\text{hr}}) + (46 \frac{\text{lb}}{\text{hr}}) + 3/4 M_w = M_w$

$M_w = 2480 \frac{\text{lb}}{\text{hr}}$

water in air leaving system = $\frac{1}{4}(2480) = 620 \frac{\text{lb}}{\text{hr}}$

Relative humidity -

saturation vapor pressure (275°F) = 45.416 psi

saturation vapor pressure (90°F) = 0.700 psi

for 80% relative humidity - 0.80 = 0.70

p_{H_2O} = partial pressure

$p_{H_2O} = 0.56 \text{ psi}$ (80% rel. hum., 90°F)

air outlet after recycle = $\frac{620}{1851} = 0.33 \frac{\text{lb } H_2O}{\text{lb dry air}}$

$$\frac{0.56 \text{ psi}}{0.025 \frac{\text{lb } H_2O}{\text{lb dry air}}} = \frac{p_r}{0.33 \frac{\text{lb } H_2O}{\text{lb dry air}}} \Rightarrow p_v = 7.39 \text{ psi } (275^\circ\text{F})$$

relative humidity = $\frac{7.39 \text{ psi}}{45.42 \text{ psi}} = 0.16 \text{ or } 16\%$

furnace:

inlet - $7404 \frac{\text{lb}}{\text{hr}}$ air

$$46 \text{ (fresh air)} + (3/4)(2480) \text{ (recycle)} = 1906 \frac{\text{lb}}{\text{hr}} \text{ H}_2\text{O in air}$$

$$90^\circ\text{F} - 1851 \frac{\text{lb}}{\text{hr}} \text{ air} + 46 \frac{\text{lb}}{\text{hr}} \text{ H}_2\text{O}$$

$$275^\circ\text{F} - 5553 \frac{\text{lb}}{\text{hr}} \text{ air} + 1860 \frac{\text{lb}}{\text{hr}} \text{ H}_2\text{O}$$

$$(1851 \frac{\text{lb}}{\text{hr}}) (90^\circ\text{F} - 32^\circ\text{F}) (1.0 \frac{\text{Btu}}{\text{lb } ^\circ\text{F}}) + (1860 \frac{\text{lb}}{\text{hr}}) (275^\circ\text{F} - 32^\circ\text{F})$$

$$(1.0 \frac{\text{Btu}}{\text{lb } ^\circ\text{F}}) = 454,648 \frac{\text{Btu}}{\text{hr}}$$

$$\text{total} = 804,265 \frac{\text{Btu}}{\text{hr}}$$

for no recycle:

$$(7404 \frac{\text{lb}}{\text{hr}}) (90 - 32^\circ\text{F}) (0.24 \frac{\text{Btu}}{\text{lb } ^\circ\text{F}}) = 103,064 \frac{\text{Btu}}{\text{hr}}$$

$$(1851 \frac{\text{lb}}{\text{hr}}) (90 - 32^\circ\text{F}) (1.0 \frac{\text{Btu}}{\text{lb } ^\circ\text{F}}) = 10,730 \frac{\text{Btu}}{\text{hr}}$$

$$113,794 \frac{\text{Btu}}{\text{hr}}$$

difference is $690,471 \frac{\text{Btu}}{\text{hr}}$ (for 12 hrs.)

Savings: @ $\frac{5}{106} \text{ \$}/\text{Btu}$

$$(690,471 \frac{\text{Btu}}{\text{hr}}) (12 \text{ hr}) (\frac{5}{106} \frac{\text{\$}}{\text{Btu}}) (260 \frac{\text{day}}{\text{yr}}) = 11,000 \frac{\text{\$}}{\text{yr}}$$

POTENTIAL ENERGY SAVINGS FOR
DEHAIRING OPERATION

The dehairing operation present potential energy savings. The hot off gases from the singer estimated at 1500°F could be utilized as an energy source.

The proposed heat recovery system utilizes a heat exchanger to recover heat from the off gases of the singer by recycling scald and dehairer tank water up to the heat exchanger and delivering a high temperature water.

The heat recovered can be used to reduce the steam consumption of the scald and dehairer tanks.

A potential savings of \$73,000/year was determined and this is enough to warrant further detailed study.

DEHAIRER ENERGY RECOVERYCALCULATIONSAir Flow Calculations

∴ Assume all heat from natural gas heats air

- (1) Heat content of natural gas

$$Q = 6700 \text{ CFH of Natural gas} \times \frac{1000 \text{ Btu}}{\text{CF}} = 6,700,000 \frac{\text{Btu}}{\text{hr}}$$

- (2) Energy Balance

$$Q_{\text{from natural gas}} = \frac{\dot{M} C_p \Delta T}{\text{air stream}}$$

where

$$\Delta T = 1500^{\circ}\text{F} - 70^{\circ}\text{F}$$

$$C_{p \text{ air}} \approx 0.26 \frac{\text{Btu}}{16^{\circ}\text{F}}$$

- (3) Air Flow Rate

$$\dot{M} = \frac{6,700,000 \frac{\text{Btu}}{\text{hr}}}{(0.26 \frac{\text{Btu}}{16^{\circ}\text{F}}) (1430^{\circ}\text{F})} = 18,020 \text{ \#/hr air}$$

Heat Content of Air.

$$(1) \text{ Heat available from air} = [(1500^{\circ}\text{F}) - (300^{\circ}\text{F})] 0.26 \frac{\text{Btu}}{16^{\circ}\text{F}}$$

$$(18,020 \frac{\#}{\text{HR}}) = \boxed{5,022,000 \frac{\text{Btu}}{\text{hr}}}$$

Heat Exchanger Area

From Perry's 5th Edition pp. 10-39, Table 10-10

$$U = 60 \frac{\text{Btu}}{\text{°F ft}^2 \text{ hr}} \quad \text{for} \quad \begin{array}{l} \text{Air in shell side} \\ \text{Water in tube side} \end{array}$$

$$\text{Area} = \frac{Q}{U AT_{lm}}$$

$$\text{where } AT_{lm} = \frac{1300 - 160}{\ln \frac{1300}{160}} = 544^{\circ}\text{F}$$

$$\text{Area} = \frac{5,622,000 \text{ Btu/hr}}{(60 \frac{\text{Btu}}{\text{°F ft}^2 \text{ hr}}) (544^{\circ}\text{F})} = \boxed{172 \text{ ft}^2}$$

H₂O Flow:

$$\frac{(5,622,000 \frac{\text{Btu}}{\text{hr}})}{(60^{\circ}\text{F}) \frac{\text{Btu}}{\text{lb}^{\circ}\text{F}}} = 93,700 \text{ \#/hr} = \boxed{187 \frac{\text{gal}}{\text{min}} \text{ H}_2\text{O}}$$

Current Heat Consumption of Dehairer.

60,000 # steam to maintain 140°F for 10 hours

$$(60,000 \text{ \# steam}) \times (1150 \frac{\text{Btu}}{\text{\#}}) = 69.0 \times 10^6 \text{ Btu/day}$$

$$\boxed{6.9 \times 10^6 \text{ Btu/hr}}$$

So ∴ Singer off Gas Heat Recovery can supply:

$$\frac{5,622,200 \text{ Btu/hr}}{6.9 \times 10^6 \text{ Btu/hr}} \times 100$$

$$\approx \boxed{80\%} \text{ of dehairer energy}$$

Cost Savings

@ \$5/10⁶ Btu

$$5.6 \times 10^6 \text{ Btu/hr} = \$28/\text{hr}$$

Assume ... 10 Hr. singer operation
5 day/week operation or 260 days/year

SAVINGS PER YEAR = \$73,000

Energy Savings based on carcass weight:

Hog throughput = 500 hog/hr
Hanging Weight = 163 #/hog

... 81,500 # hr. hog weight

$$\frac{5,622,000 \text{ Btu/hr}}{81,500 \text{ #/hr}} \Rightarrow 68 \frac{\text{Btu}}{\text{#}}$$

Recycle Pumps Calculation

Efficiency = 0.60

Discharge = (200 gal/min) or (27.75 $\frac{\text{lb}}{\text{sec}}$)

Friction losses = 10 $\frac{\text{ft lb}_f}{\text{lb}}$

McCabe & Smith pp. 79-80

simplified Bernoulli's Equ:

$$W_p \eta = \frac{z_b}{g_c} + \frac{\bar{v}_b^2}{2g_c} + h_f$$

pump work eff. ht. to pump up to velocity in 2" pipe friction losses

$$\text{Velocity in pipe} = (27.75 \frac{\text{lb}}{\text{sec}}) (\frac{\text{ft}^3}{62.4 \text{ lb}}) \times \frac{1}{(.0233 \text{ ft}^2)}$$

$$= 19.08 \text{ ft/sec}$$

cross sec.
area of 2"
schedule 40

$$0.60 W_p = 20 \frac{q}{gc} + \frac{19.08^2}{64.34} + 10$$

$$W_p = 59.43 \frac{\text{ft lb}_f}{\text{lb}}$$

$$P = \frac{(27.75 \frac{\text{lb}}{\text{sec}}) \times (59.43 \frac{\text{ft lb}_f}{\text{lb}})}{550 \frac{\text{ft lb}_f}{\text{sec}}}$$

$$\text{Hp}$$

$$P = 2.998 \text{ Hp}$$

$$P = 3 \text{ Hp}$$

APPENDIX C

ECONOMIC ANALYSIS OF ENERGY CONSERVING PROCESSES IN MEAT

PROCESSING: SKINNING VERSUS SCALDING OF HOGS

Economic Analysis of Energy Conserving Processes
in Meat Processing: Skinning Versus Scalding of Hogs

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The conventional process of removing hair from hogs in slaughtering involves the use of hot water for scalding and natural gas for singeing. An alternative process involves direct skinning of the carcasses. Skinning involves a lower capital investment, uses less energy, and loses some product while providing more valuable hides.

The analysis of skinning vs. scalding presented in this paper follows along three avenues. First the economics of the processes are demonstrated comparing the alternatives as if one were building a new plant. Second, the processes are examined in the context of a replacement problem, looking at the economics of replacing an existing scalding system with a skinning system. Third, the effects of key variables such as energy price inflation, pigskin values, and labor costs are examined.

Method of Analysis

The basis for the economic analysis will be net present value using after-tax cash flows. When comparing mutually exclusive investments of equal lives, the decision rule is to choose the investment with the highest net present value, thus one can examine the difference in net present values. Making use of the fact that the difference in the net present values of two sequences of cash flows is equal to the net present value of the differences

in the cash flow wequences allows one to exclude things that are constant under both alternatives from the analysis without introducing error.

The replacement question becomes somewhat complicated, for one usually is explicitly introducing unequal lives. All methods of investment comparisons utilize implicit or explicit assumptions about reinvestment. The popular annuity equivalent (equivalent annual cost) assumes that the alternative investments being considered can be duplicated at the same cost throughout time. This assumption is obviously unrealistic when there is inflation and when one of the alternatives is to keep an existing process.

To overcome these problems an alternative approach is used. The analysis is performed using geometrically increasing cash flows (based upon the rate of inflation) rather than equal cash flows. The key assumption required for this method is that replacement investments require capital outlays that increase at the rate of inflation.

In the skinning vs. scalding replacement problem considered here, the situation is one of the industry currently using scalding, thus the analysis will consider the timing of the change from scalding to skinning. We will be considering the conditions under which it would be economical to change to skinning before the end of the scalding equipment life.

Data and Assumptions

A basic set of data and assumptions will underlie the investment analysis. These are presented in this section. Further assumptions will be made later when the replacement analysis is presented.

The Capital Investment

The capital investment being considered is that which is unique to hog skinning and hog scalding, respectively. Investment that is similar under

either system is excluded. Estimates of the capital investment required by scalding and skinning are \$563,080 and \$135,030, respectively in 1978 dollars (see Table 1). The data, estimated by Judge, Salem, and Okos, are for a plant with 600 head per hour capacity. With 10 hours of operation per day and approximately 5 1/3 days per week, the capacity per year is 1,664,000 head. The skinning process obviously requires a substantially lower capital investment. The capital investment for the scalding alternative includes equipment (skinners) from the cutting process which would no longer be needed under the skinning alternative.

For purposes of the analysis here, it is assured that the equipment has a useful life of 10 years. It is assumed that the cost of removing the equipment at the end of 10 years would be equal to its value, thus there is a zero cash flow associated with the terminal value of the equipment. The analysis will not include major improvements to equipment which would extend the life beyond 10 years. It is believed that this is a reasonable, if not literally correct, representation of the economic environment.

The level of maintenance and repairs is assumed to be 10% of the initial investment, increased by the inflation rate past the base year. Higher maintenance and repair (as a proportion of the original investment) would tilt the economic advantage further in favor of skinning.

Income Taxes

As indicated in the methodology section, the cash flows used in the analysis will include income tax effects. It will be assumed that the company is in the 48% income tax bracket. The income tax shield provided by depreciation will be calculated using a 10 year equipment life, zero salvage value, and sum-of-the-year's digits depreciation method. A faster method of

depreciation write-off is available (double-declining balance with switching to straight-line after 5 years). The faster method would give a very small incremental advantage to the more capital intensive scalding.

Labor

Labor cost is one of the variables for which little dependable data are available. The base assumption is that once operating the labor cost will be the same for both skinning and scalding. This assumption implies there would be more labor used in the skinning operation than the scalding operation by itself but this would be made up by using less labor in the cutting process under the skinning alternative.

There would also be costs associated with training the labor force. If we were considering a new plant, training of the labor force would be required under either alternative. It is probably reasonable to assume this is a comparable cost. However, when replacement of scalding with skinning is considered, this cost should be included.

Cost of Capital

The cost of capital discount rate used in calculating net present values is 15%. If one were to assume a 12% before-tax cost of debt capital and a capital structure consisting of 50% debt and 50% equity, the 15% discount rate used would imply approximately a 24% after-tax rate of return on equity. In terms of returns on other investments, this would be approximately equivalent to a 29% before-tax rate of return.

Energy and Utilities

The skinning alternative uses substantially less natural gas, electricity, and steam than scalding but uses more water and sewage (see Table 2).

Using the base prices from Table 3, the cost per hog of energy and utilities is \$.0261 for skinning and \$.0643 for scalding. The prices will be escalated in the analysis at the rates shown in Table 3.

Product Differences

The economic analysis applied to this problem is essentially that of finding the cost minimizing investment. However, when there are differences in the returns these differences must be included in the comparison. There are differences in the products produced by skinning and scalding. With skinning, certain minor portions of the hog are lost and belly damage occurs on a portion of the hogs slaughtered. However, with skinning there is more higher quality pigskin produced. Values of these items estimated by Judge, Salm, and Okos can be found in Table 4. At current prices for pigskin the additional products from skinning far exceed the products lost (see Table 4). However, it is not clear that the market for pigskin could absorb the additional quantity of skins without affecting price significantly.

Inflation Assumptions

Energy prices will be inflated at the rates shown in Table 3. All other cash flows will be inflated at 6%.

Economics of New Skinning and Scalding Processes

Under the assumptions stated above the skinning alternative is much preferred to scalding with a \$19.4 million greater net present value (see Table 5). However, there are two key assumptions that should be explored in more detail. These are labor requirements and the value of pigskins.

Product differences (item 6, Table 5) are by far the largest portion (96.4%) of the difference in net present values of skinning and scalding. The value per hog used for the pigskins was \$5.00 for the base year (with a

6% annual rate of increase). Wide adoption of skinning by the industry would change the market for pigskin significantly. There is little information available on the potential expansion of the pigskin market or at what price the potential quantities of pigskins could be utilized.

Break-Even Pigskin Value

One useful piece of information that can be determined from the data is the pigskin price required to make an investor indifferent between the two technologies. This is the value of pigskins that would make the difference in net present values zero and is in this sense a break-even pigskin value between the two technologies.

The credits for product differences could go down by \$19,375,706 (from \$29,686,718 to \$10,311,012). Maintaining the assumption of a 6% per year increase in value, this is equivalent to \$1,571,801 per year. Converting this amount to a before-tax amount per hog, the credits must come to \$1.82 per hog. Thus, if the value of pigskins from the skinning process were worth \$1.59/hog or greater in the base year (with the inedible products still worth \$.23) the skinning method would be preferred.

An alternative method of valuing the pigskins would be to use the gelatin skin value. This would place a reasonable lower bound on the pigskin value. This is, however, only \$.80 per hog (see Table 4) and there would be additional processing costs. Thus, there would need to be a market for the pigskins which would clear at a price at least twice as high as the render value of the skins.

Labor

It is probably most useful to consider the question of variable labor cost and the break-even pigskin value simultaneously. If we hold the 6%

rate of inflation assumption for labor, we can simply look at the relationship between labor cost per hog and break-even pigskin value. The relationship is linear. Any labor savings associated with skinning reduces the break-even pigskin value by an equal amount, similarly any additional labor costs increases the break-even pigskin price.

An additional factor would be the cost of training the labor force. If this were not the same for both alternatives (the assumption thus far) adjustments in the data should be made. It is probably reasonable to assume that the skinning process would require more initial training of the labor force. While we are still not examining the replacement question per se, we have been comparing one new process to an alternative new process, it might be reasonable to assume that situations could occur where management is faced with the decision to replace worn out scalding equipment with either new scalding equipment or skinning equipment. In this case there might be more labor cost in the change-over to skinning. This one time labor cost involved with training can be converted to an annual equivalent over the 10 year life of the investment. The amount of this cost necessary to be equivalent to \$.20 per hog is \$1.67 million. This type of cost appears to be insignificant relative to the break-even pigskin value. Figure 1 shows the relationship between the difference in skinning and scalding variable labor cost and the break-even pigskin value per hog at various levels of one-time changeover labor cost.

Replacement Considerations

The economics of replacing a scalding system with a skinning system are dominated by the pigskin value assumed. Thus, it is probably most informative to see how the breakeven pigskin price varies with the situation in

terms of the age and associated book and salvage values of existing scalding equipment. One additional factor, lost revenue during the change-over from scalding to skinning will be considered.

The General Problem

Consider replacing a machine with T years of life remaining with a machine that lasts N years. This may be considered a special case of mutually exclusive repeatable investments with different but known lives. A currently owned machine with an equivalent annual cost of $\$X$ and a new machine with an equivalent annual cost of $\$Y$ is illustrated below:

If Y is less than X , then the machine would be replaced. In general X is a function of T , that is, the components which influence the costs of an existing process are functions of the age of the process. A validating assumption, when the analysis consist only of comparing X and Y , is that the investments can be replicated exactly throughout time. This is obviously unrealistic in the case of replacement.

An alternative and more appropriate framework which permits analysis similar to the comparison of X and Y is to consider the problem as minimizing the cost (or maximizing net present value) over an infinite time horizon. The replacement assumptions will be 1) that all replacements are made with skinning equipment which differs from the previously analyzed new equipment only in that the prices will be inflated at 6% per year (or in the case of

the energy items according to the previous assumptions), and 2) that there will be a cost component associated with changing from scalding to skinning that will not be incurred upon future replacements of skinning equipment.

Under these assumptions the geometric equivalents of the net present values can be compared. The formula for converting a present value (P) into an equivalent geometrically increasing cash flow stream (G) is as follows.

$$G = P * \left[\frac{r^*}{1 - (1+r^*)^{-M}} \right], \text{ where}$$

$$r^* = \frac{1+r}{1+i} - 1,$$

r = the cost of capital, and

i = the inflation rate.

Cash Flows Associated With Existing Equipment

Equipment that is already owned has no explicit capital investment. However there are several possible "opportunity" cash flows. These are the current salvage value and the income tax effects of scrapping or selling the equipment. The income tax effects of salvaging the equipment include a tax write-off of the difference between the book and scrap value (assuming the latter is lower than the book value) and possible recapture of investment credit.

In the case of scalding and skinning being considered here an assumption of a zero scrap value should be a reasonable lower bound. For illustrative purposes the present value of the cash flows associated with an existing 5 year old scalding process that will last an additional 5 years are shown in Table 6. The present value of the cash flows associated with the base skinning process are shown in Table 7.

Replacement Analysis

When the pigskin value of \$5.00 per hog is used, immediate replacement of scalding equipment with a skinning process is preferred regardless of the age of the scalding equipment. The basis of comparison is the geometric equivalents of the net present values.

For a five year old process the geometric equivalent of the present value is \$1,618,407. This is substantially less than the geometric equivalent of the skinning investment, \$4,099,370.

Breakeven pigskin values per hog have been calculated for various age scalding processes (see Table 8). The breakeven pigskin values are substantially below the \$5 current market value. The age of the scalding equipment has no significant impact on the breakeven value (see Table 8). The costs due to factors such as labor training and revenue lost during plant shutdown increase the breakeven pigskin value by about \$.05 per \$1 million of expenditure (see Table 8).

The relationship between annual labor expense and the breakeven pigskin value is identical to the earlier analysis. Any labor savings per hog from the skinning process would reduce the breakeven pigskin value by a similar amount. Conversely, any additional labor cost associated with skinning would increase the breakeven pigskin value.

FIGURE 1. LABOR COST AND BREAKEVEN
PIGSKIN VALUE RELATIONSHIPS.

Table 1. Capital Investments Unique to Hog Scalding and Skinning Operations^a

SCALDING		SKINNING	
<u>Slaughter</u>		<u>Slaughter</u>	
Scald tank	\$49,800	Dehider knives (8)	\$5,600
Dunkers	25,000	Hock cutters (2)	4,600
Platform	22,600	Platforms	2,250
Conveyor (pull through)	27,000	Skin pullers ^b (4)	42,000
Unshakler	1,400	Washer and pump	13,000
Dehairer	151,000	Conveyor	<u>27,000</u>
Hair conveyor	2,500	Subtotal	96,450
Platforms	14,300	Installation (40%)	<u>38,580</u>
Conveyor (gambreling)	18,000	Grand total	\$135,030
Singer	19,000		
Polisher	22,000		
Platforms (shaving)	2,600		
Rail washer	1,500		
Slide and hopper	4,500		
<u>Cutting</u>			
Skinners			
Bacon	8,750		
Jowl, fat back	9,750		
Butt (2)	12,200		
Ham (2)	<u>10,300</u>		
Subtotal	402,200		
Installation (40%)	<u>160,880</u>		
Grand total	\$563,080		

^a 600 hogs/hr.

^b Alternative is four vertical drum skimmers: 12c/hog, 2,000 hrs/yr., 10 yrs = \$1,440,000 less maintenance.

Source: this table is taken directly from Judge, Salm, and Okos

Table 2. Energy and Utility Inputs Unique to Hog Scalding and Skinning Processes (Units/hog)

Item	Scalding	Skinning
<u>Water (gallons)</u>		
Scalding	2.6	
Dehairing	2.7	
Washing	4.0	22.5
Cleanup	<u>0.3</u>	<u>0.1</u>
	9.6 gal.	22.6 gal.
<u>Sewage (gal.)</u>	9.6 gal.	22.6 gal.
<u>Steam (lb.)</u>		
Scalding	3.2	
Dehairing	1.8	
Cleanup	<u>.3</u>	<u>0.1</u>
	5.3 lb.	0.1 lb.
<u>Electricity (KWH)</u>		
Dehairing etc.	0.24	
Polishing	0.03	
Skin pullers		0.02
Washing		0.06
Skinners	<u>0.01</u>	<u>0.08</u>
	0.28 KWH	0.08 KWH
<u>Natural Gas (cu. ft.)</u>	13.75 cu. ft.	0.0 cu. ft.

Table 3. Energy and Utility Prices and Inflation Rates

Item	Cost/Units	Rate of Increase
Water	\$.25/1,000 gallons	6%
Sewage	\$.50/1,000 gallons	6%
Electricity	\$.04/KWH	8%
Steam	\$3.00/1,000 lbs.	6%
Natural Gas	\$2.18/1,000 cu. ft.	10%

Table 4. Product Losses and Credits for Hog Skinning Operations (\$/hog)

	<u>Losses</u>
Feet 3 lb. @ \$.16	\$.48
Tails 0.25 lb. @ .13	.03
Partial jowls 0.5 lb. @ .24	.12
Snouts 0.5 lb. @ .19	.10
Ears 0.5 lb. @ .21	.11
Fat removed with skin 1 lb. @ .20	.20
Gelatin skin value 8.0 lb. @ .10	.80
Belly damage (4-10% incidence) ^{a/}	<u>.10</u>
Total	\$1.94
	<u>Credits</u>
Inedible feet, fat, etc. 5.75 lb. @ .04	\$.23
Leather skins	<u>5.00</u>
Total	<u>\$5.23</u>
Net Gain	<u>\$3.29</u>

^{a/} 3 lb. sliced bacon @ \$1.00/lb - 3 lb. bacon ends \$.75/lb. = \$.75;
\$.75 ÷ 15 (incidence) = \$.05 x 2 (bellies/hog) = \$.10

Source: Directly from Judge, Salm, and Okos

Table 5. Difference in Net Present Value of New Processes (Skinning minus Scalding)^a

Item	Present Value
1. Initial Investment	\$ 428,050.00
2. Investment Credit	-37,221.70
3. Depreciation Tax Shield	-124,056.21
4. Maintenance and Repairs	146,117.60
5. Energy and Utilities	287,997.76
Water and Sewage \$ -55,343.31	
Steam 88,549.29	
Electricity 49,805.96	
Natural Gas 204,985.82	
6. Product Differences	18,674,819
Losses \$ -11,011,899	
Credits \$ 29,686,718	
Difference in NPV	<u>\$19,375,706.45</u>

^a/ For details of calculations see the appendix.

Table 6. Present Value of Costs For An Existing 5 Year Old Scalding Process

Item	Present Value
1. Initial Opportunity Cash Flows	\$ -41,056
Salvage Value	\$ 0.00
Tax Shield	-55,082
Investment Credit Recapture	14,026
2. Depreciation Tax Shield	40,341
3. Maintenance and Repairs	-115,442
4. Energy and Utilities	-121,055
a. Water and Sewage	\$12,771
b. Steam	28,202
c. Electricity	20,954
d. Natural Gas	59,128
5. Product Difference	6,616,564
	<u>\$ 6,379,383</u>

Table 7 Present Values For Base Skinning Investment^a

<u>Items With 6% Inflation</u>	<u>Present Value</u>
1. Initial Investment	\$ -135,030
2. Investment Credit	11,742
3. Depreciation Tax Shield	39,134
4. Maintenance and Repairs	-46,061
5. Water and Sewage	-50,030
6. Steam	-885
	<u>\$ -181,130</u>
 <u>Items With 8% Inflation</u>	
7. Electricity	\$ -10,360
	Present Value Without Product Credits \$ <u>-191,490</u>
8. Product Credits at \$5.23/hog	\$ 29,686,718
	Present Value \$ 29,495,228

^aSee the appendix for details of the calculations.

Table 8 Break-Even Pigskin Value Per Hog for Replacement of Scalding Processes With Skinning Processes

Age of Scalding Equipment	\$0 Salvage Value ^{a/}			50% of Book Value ^{a/}
	\$0 ^{b/}	\$1 Million ^{b/}	\$2 Million ^{b/}	\$1 Million ^{b/}
(Years old)	(Dollars per Hog)			
1	1.67	1.72	1.77	1.70
2	1.67	1.72	1.77	1.71
3	1.67	1.72	1.77	1.71
4	1.68	1.73	1.78	1.72
5	1.67	1.73	1.78	1.72
6	1.68	1.73	1.78	1.72
7	1.67	1.72	1.78	1.72
8	1.67	1.73	1.78	1.72
9	1.68	1.73	1.78	1.72

^{a/} Value of scalding equipment used as the opportunity cash flow associated with keeping the scalding equipment. Book value is based upon sum-of-the-years digits depreciation.

^{b/} One time cost of changing from scalding to skinning. This would include costs such as retraining of the labor force and revenue lost during the change-over.

Appendix

**Details of Discounted Cash Flows
Skinning Versus Scalding**

Base Year Amounts (without tax adjustments)**1. Initial Investment**

Scalding	\$563,080
Skinning	135,030

2. Investment Credit

Scalding	\$56,308
Skinning	13,503

3. Maintenance and Repairs

Scalding	56,308
Skinning	13,503

4. Utilities & Energy

	<u>Water and Sewage</u>	<u>Steam</u>	<u>Electricity</u>	<u>Nat. Gas</u>
Scalding	\$6,230.02	\$13,757.95	\$9,691.14	\$25,936.77
Skinning	14,666.50	259.58	2,768.90	0.00

5. Product Differences

Scalding	\$ 3,228,160	(\$1.94/head)
Skinning	\$ 8,702,720	(\$5.23/head)

Present Value of Cash Flows: For New Investment
Skinning minus Scalding

1. Initial Investment (year zero)

$$\begin{array}{r}
 \$ -135,030 \\
 +563,080 \\
 \hline
 \$ 428,050 * 1 = \qquad \qquad \qquad \$428,050
 \end{array}$$

2. Investment Credit (year one)

$$\begin{array}{r}
 \$ 13,503 \\
 - 56,308 \\
 \hline
 \$ -42,805 * (1.15)^{-1} = \qquad \qquad \qquad \$ -37,221.7
 \end{array}$$

3. Depreciation tax shield (years 1-10) =

10
Σt = 55
t=1

\$-124,056

					<u>PV</u>
1	7,782.73	*	10	* .48 * (1.15) ⁻¹ =	\$32,484.43
2	7,782.73	*	9	* .48 * (1.15) ⁻² =	25,422.59
3	7,782.73	*	8	* .48 * (1.15) ⁻³ =	19,650.31
4	7,782.73	*	7	* .48 * (1.15) ⁻⁴ =	14,951.33
5	7,782.73	*	6	* .48 * (1.15) ⁻⁵ =	11,143.85
6	7,782.73	*	5	* .48 * (1.15) ⁻⁶ =	8,075.25
7	7,782.73	*	4	* .48 * (1.15) ⁻⁷ =	5,617.57
8	7,782.73	*	3	* .48 * (1.15) ⁻⁸ =	3,663.63
9	7,782.73	*	2	* .48 * (1.15) ⁻⁹ =	2,123.84
10	7,782.73	*	1	* .48 * (1.15) ⁻¹⁰ =	923.41/\$124,056.21

4. Maintenance & Repairs (years 1-10)

$$\begin{array}{r}
 \$ -13,503 \\
 +56,308 \\
 \hline
 \$ 4,280.50 * .52 * \frac{1 - (1.15)^{-10}}{1} = \qquad \qquad \qquad \$ 146,117.6
 \end{array}$$

(6.56)

$$1 + i = \frac{1.15}{1.06} = 1.0849$$

5. Utilities & Energy

a) Water and sewage

(difference in 1,000 gal./head) + (head/year) * (1-tax rate) * base price/1000 gal

$$(13.0/1,000) * (1,664,000) * .52 * .75 = \$ 8,436.48$$

$$\$ -8,436.48 * 6.56 = \text{-----} \$ -55,343.31$$

b) Steam

(difference 1,000 lbs. steam use) * head * (1-t)

$$(5.2/1,000 * 1,664,000) * .52 * 3.00 = \$ 13,498.37$$

$$\$ 13,498.37 * 6.56 = \$ \underline{88,549.29}$$

c) Elect.

$$.20 * (1,664,000) * .52 * .04 = \$ 6,922.24$$

$$6,922.24 \quad \frac{\overset{7.195}{1 - (1.06481)^{-10}}}{.06481} = \$ \underline{49,805.96}$$

$$\left(\frac{1.15}{1.08}\right) - 1 = .06481$$

d) Natural Gas

1,000 cu. ft. * head * (1-t) * Base Price

$$(13.75/1,000) * (1,664,000) * .52 * 2.18 = \$25,936.77$$

$$25,936.77 * \frac{\overset{7.895}{1 - (1.1)^{-10}}}{1} = \$204,985.82$$

$$1 = \frac{1.15}{1.1} - 1 = .04545$$

6. Product Credits and Losses

a) Losses

$$(\text{Value/head in Base Year}) * \text{Head} * (1-t)$$

$$\$1.94 * 1,664,000 * .52 = \$ -1,678,643.20$$

$$-1,678,643.2 * \overbrace{1 - \frac{(1+i)^{-10}}{i}}^{6.56} = -11,011,899.39$$

$$i = \left(\frac{1.15}{1.06} \right) - 1 = .0849$$

b) Credits

$$(\text{Value/head}) * \text{head} * (1-t)$$

$$\$5.23 * 1,664,000 * .52 = \$ 4,525,414$$

$$4,525,414 * 6.56 = \underline{\$29,686,718}$$

Present Value of Costs Associated With Existing Machine

$B(t)$ = book value at t assuming declining balance depreciation

$$B(t) = B_0 - \sum_{i=1}^t D_i \quad \text{for } 1 \leq t < N$$

$$B(t) = S_0, \text{ for } t \geq N$$

$$D_1 = (N + 1 - 1/(\sum_{j=1}^N j)) (B_0 - S_0)$$

N = useful life for depreciation purposes

B_0 = Initial Basis

S_0 = Salvage value used for depreciation purposes

1. Initial Opportunity Cash Flows

a. Current salvage value, assumed to be \$0

b. Tax shield = $(B(t) - S_t) * \tau$ $S_t \leq B(t)$

τ = marginal income tax rate

S_t = Sales value at time t

Assumed 5 year old process, book value after 5 years is
\$153,567 assuming sum-of-the-years digits depreciation

$$\$153,567 * .48 = \$73,712$$

c. Investment credit recapture

$$I(t) = -\delta B_0 \quad 1 \leq t < 3$$

$$= -\delta B_0 (2/3) \quad 3 \leq t < 5$$

$$= -\delta B_0 (1/3) \quad 5 \leq t < 7$$

$$= 0 \quad 7 \leq t$$

where δ is the investment credit rate.

c. (cont.) In this case $t = 5$, thus:

$$.1 * 563,080 * (1/3) = \underline{\$18,769.}$$

2. Depreciation Tax Shield (last 5 years of the depreciation schedule)

$$563,080 \div 55 = \$10,237.82$$

$$\begin{aligned} \$10,237.82 * 5 * (1.15)^{-1} * .48 &= \$21,365.88 \\ 10,237.82 * 4 * (1.15)^{-2} * .48 &= 14,683.22 \\ 10,237.82 * 3 * (1.15)^{-3} * .48 &= 9,693.41 \\ 10,237.82 * 2 * (1.15)^{-4} * .48 &= 5,619.37 \\ 10,237.82 * 1 * (1.15)^{-5} * .48 &= \underline{2,443.20} \\ &\underline{\$53,985.08} \end{aligned}$$

3. Maintenance and repairs

$$\begin{aligned} \$56,308 * \underbrace{\frac{1 - (1+i)^{-5}}{i}}_{3.942} * .52 &= \underline{\$115,442} \end{aligned}$$

$$1 + i = \left(\frac{1.15}{1.06}\right) = 1.0849$$

4. Energy and Utilities

a) water and sewage $\$6,230.02 * 3.942 * .52 = \$12,771$

b) steam $13,757.95 * 3.942 * .52 = 28,202$

c) electricity
 $(1+i) = \frac{1.15}{1.08}, \frac{1 - (1+i)^{-5}}{i} = 4.158$

d) natural gas $25,936.77 * 4.384 * .52 = 59,128$

$$(1+i) = \frac{1.15}{1.10}, \frac{1 - (1+i)^{-5}}{i} = 4.384$$

References

Judge, M. D., C. P. Salm and M. R. Okos, "Hog Skinning Versus Scalding," paper presented at the Meat Industry Research Conference, March 23-24, 1978, University of Chicago.