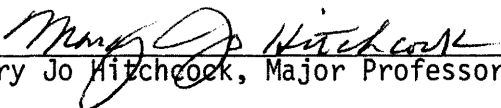
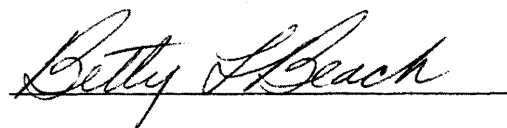


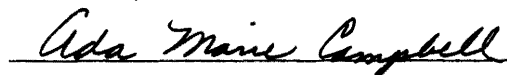
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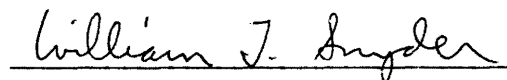
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Mary Jo Hitchcock, Major Professor

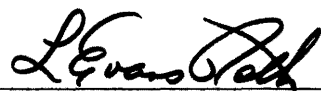
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Vice Chancellor
Graduate Studies and Research

ENERGY CONSUMPTION ASSESSMENT IN THE CONTINUUM
OF STORAGE, PREPARATION, AND SERVICE
OF FOOD PRODUCED IN VOLUME

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Martha Jane Ault Barclay

June 1979

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ABSTRACT

Foodservice management has become concerned about energy utilization as energy demands and associated energy costs increase due to decreasing supplies of traditional energy resources. Identification of energy utilization has become of critical importance to foodservice managers. The purposes of this study were to develop a schematic energy flow decision model from the identification of the food product flow through a conventional foodservice system, to meter the energy consumption along the food product flow continuum, and to project the amount of energy consumed along the food product flow for selected menu items in the conventional, commissary, ready-prepared, and assembly-serve foodservice systems.

This study was conducted from July to December, 1978, at the University of Tennessee, Knoxville Food Services. Approximately 1500 meals were served each day during the summer quarter and over 4500 meals were served each day during the fall quarter. Menu items selected for this study included seven entrees, a hot cereal, a soup, and two vegetables. A food product flow was developed for each product identifying areas, equipment, and duration of equipment usage. Quantitative energy consumption data were obtained by metering the flow of natural gas, electrical currents, and condensate flow along the continuum from receiving through production and service for each food product. The equipment metered included an electric grill, deep-fat fryer, steam table, warming oven, slicer, compressors for refrigerators and freezers, steam-jacketed kettles, a jet steamer, gas rotary

oven, and gas convection oven. Energy consumption required for selected menu item preparation and service in a conventional system was calculated using the schematic model and energy data collected. Energy consumption for two entrees was projected for the commissary, ready-prepared, and assembly-serve foodservice systems with modified schematic energy flow models and energy consumption data collected.

The schematic model developed was found to be useful in predicting energy and food product flows in the four foodservice systems. The mean energy consumption per kilogram product ranged from 528 to 6769 Btu in the conventional system. Equipment requiring natural gas was the most energy intensive. The electrical steam table was the most energy intensive piece of electrical equipment. The steam equipment was the least energy intensive. Under identical conditions, the rotary oven consumed more energy than the convection oven to prepare the same quantity of meatloaf. Factors affecting energy consumption in foodservice systems included the design and composition of the equipment, the amount of time allowed for equipment warm-up, the amount of food prepared in equipment, and the decisions made concerning the use of the equipment by personnel. Energy resource requirements for product preparation can be projected for the conventional, commissary, ready-prepared, and assembly-serve systems through the use of the energy flow decision models. The results of this projected energy consumption data within foodservice systems indicate that the assembly-serve system would require the least amount of energy per kilogram product served, and the commissary foodservice system would require the greatest amount of energy. The efficient use of energy should be

integrated into the design of foodservice systems, management decisions, and training programs.

The methodology developed would allow foodservice management to follow the energy and food product flows through a foodservice system and to forecast energy utilization. Informed decisions can then be made about purchasing and utilization of equipment and employee training programs.

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GLOSSARY

British Thermal Unit (Btu): The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Kilowatt (kW): A unit of power equal to 1,000 watts.

Kilowatt-hour (kWh): A unit of energy equal to one kilowatt in one hour.

Tempering: A controlled thawing process which allows food mass temperatures to rise from -23°C (-10°F) to between 1°C (34°F) and 3°C (38°F) (Friesen, 1973).

Food Product Flow: The alternate paths within foodservice operations which food components and menu items may follow, initiating with receipt of food items and ending with service of food to the client (Unklesbay, et al., 1977).

Food Processing: The processing, preparing, packaging and/or distributing of food by a commercial industry to consumers for consumption in the home or foodservice operation.

Foodservice Resources: The food, supplies, space, equipment, energy, personnel, money and time required to serve a nutritious meal that meets the quality standards established for the foodservice operation.

Foodservice System: A facility where large quantities of food intended for individual service and consumption are routinely provided, completely prepared.

Heat Processing: The application of heat to either cooked or uncooked and chilled menu items within a foodservice system to achieve the desired level of cooking of components and/or the appropriate food product internal temperature for service.

ENERGY CONVERSION FACTORS

1 Cubic Foot Natural Gas = 1000 British Thermal Units

1 Kilowatt-hour = 3412 British Thermal Units
per Hour

1 Pound Condensate = 1000 British Thermal Units

1 Horsepower = 0.745 Kilowatts

CHAPTER I

INTRODUCTION

The foodservice industry faces not only promising growth in sales but also constraints on the supplies [National Restaurant Association (NRA), 1979]. Traditional energy supplies are decreasing while the associated costs and the need for these resources are increasing noticeably. Expenditures for energy resources represented approximately 2 percent or less of the total operating budget for foodservice operations prior to 1970. In 1978, however, energy expenditures in some foodservice operations accounted for over 8 percent of the total foodservice operating budget. Projections indicate that expenditures for energy resources will continue to command an increasing amount of the operating budget. As the demand for meals away from home increases, so will the demand for traditional energy resources. Because of the noticeable increase in energy expenditures and the concurrent effect these expenditures have had on foodservice operation profits, controlling energy resources consumption has become a major concern of foodservice managers. The impetus to control energy consumption has been reinforced by the passage of the National Energy Act [Department of Energy (DOE), 1978]. This Act has forced all industries to become accountable for the energy they consume. Not only must energy resource consumption be identified, monitored, but also means for more efficient and effective control of the resource consumption must be investigated, developed, and implemented.

The foodservice industry has begun to identify how energy resources are consumed within foodservice facilities and to quantify the amount of energy consumed in the preparation of food products. In 1974, the National Restaurant Association contracted the Midwest Research Institute to investigate the energy requirements of meal preparation at home versus restaurant preparation [Midwest Research Institute (MRI), 1974a]. The results of this study indicated that some restaurants can prepare and serve meals with less energy expenditure than is possible in the home. Institutional foodservices such as university and hospital foodservices were not included in this study.

Another study investigated the energy consumption in both the processing plant and the foodservice facility when food was purchased at different stages of production (Dwyer et al., 1977). Results of this study identified energy intensive areas in the conventional, ready-prepared, and assembly-serve foodservice systems studied. The most energy intensive areas for these foodservice systems were hot food preparation areas, refrigeration, and warming areas. McProud (1977) also cited the hot food preparation and refrigeration areas as being energy intensive. The Midwest Research Institute (MRI, 1974b) indicated that the major areas for energy consumption in a foodservice operation not only included the food preparation and refrigeration but also included heating, ventilation and air conditioning (HVAC); sanitation; and lighting.

Quantification of the energy consumed within these energy intensive areas has only begun. The energy consumption along the continuum from the processing plant through the foodservice operation to the

service of products was projected with the assistance of the accounting model (Dwyer et al., 1977). However, these researchers indicated that measurement of actual energy consumption during each processing stage was not always possible in this study. McProud (1977) recorded the energy consumption by selected pieces of electrical and natural gas consuming equipment during the preparation of entrees. Romanelli (1976) recorded the quantity of energy consumed during the preparation of products by electrical equipment. Other research that has included instrumentation of the actual process steps within foodservice operation is minimal, if available.

Although the areas of intensive energy consumption have been identified, little more is actually known about the energy consumption within each of these areas. Very little research has included studies of energy consumption within institutional or hospital foodservice operations due to the number of variables that are necessary to control such as decisions made by personnel. Instrumentation of energy consuming activities has not been thoroughly investigated. Thus far, no one study has included the instrumentation of electrical, natural gas, and steam equipment. More baseline energy consumption data are needed to provide an accurate perspective on energy requirements within foodservice operations.

Because of this lack of energy utilization baseline data in conventional university foodservice systems, this research was conducted to collect needed energy consumption data that could be used to project energy consumption in alternate foodservice systems. The purposes of this research were to:

1. Develop an energy flow decision model for projecting energy consumption in foodservice systems.
2. Measure the energy consumed in a conventional foodservice system along the energy flow continuum from receiving through storage, production, and service of selected food products in volume.
3. Project energy consumption in other foodservice systems with modified energy flow decision models.

CHAPTER II

REVIEW OF LITERATURE

I. FOODSERVICE ENERGY SCENARIO

The foodservice industry is responsible for one-third of meals a family eats. These meals away from home account for approximately 26 percent of the dollars expended for food by a family (USDA, 1978). This demand for meals away from home is projected to continue to increase as a direct result of a growing number of secondary workers in the labor force and an increasing real family income (Jackson and Johnson, 1977). Forecasts indicate that one-half of the meals a family eats will be eaten away from home in the near future (Sherk, 1971; LeBovit, 1973). As a result, projections from the National Restaurant Association Washington Report (NRA, 1978) indicate the foodservice industry sales will reach over 100 billion dollars in 1979. These projections imply that the foodservice industry will have an increasing impact upon the family and upon the energy consumed for food preparation.

Energy utilization by various sectors of the U.S. economy was first identified in 1963 (Herendeen, 1973). The dollar sales transactions were converted into quantities of energy materials and were then balanced with material control totals. Major energy intensive sectors of the economy were identified. One of the most energy intensive sectors identified was the food and kindred product sector. The foodservice industry was considered a part of this sector.

Hirst (1973) focused upon the food and kindred product sector identifying the amount of energy used directly and indirectly in the food system except for the energy used in the construction of buildings and the capital equipment used in food production, processing, and transportation. The food and kindred product sector of the economy consumed 12 percent of the total U.S. energy available. The foodservice industry alone consumed approximately 2 percent of the total U.S. energy supply. Projections indicate that energy consumption within the foodservice industry will continue to increase. This growth is due to an increased demand for meals away from home.

In response to a growing industrial concern about energy consumption, the National Restaurant Association contracted the Midwest Research Institute to investigate differences in the energy consumption required to prepare food in the home versus away from the home in 1974 (MRI, 1974a). The away-from-home facilities surveyed included fast food operations, coffee shops, cafeterias, table service operations, and hotel/motel facilities. The results of this study indicated that energy required to prepare and serve meals in some restaurants was less than the energy required to prepare similar meals in the home.

II. ENERGY CONSUMPTION WITHIN FOODSERVICE SYSTEMS

The distribution of energy consumption within a foodservice operation was another major concern of the National Restaurant Association that was investigated by the Midwest Research Institute (MRI, 1974b). In this study, energy consumption within foodservice systems was found to be allocated to five major areas. These foodservice

areas and associated energy consumption percentages were: food preparation area, 45 percent; heating, ventilation, and air conditioning, 32 percent, sanitation, 12 percent; lighting, 8 percent; and refrigeration, 2 percent. Other studies indicated cooking, refrigeration, and heat processing activities were the most energy intensive activities [Dwyer et al., 1977; McProud, 1977; and Federal Energy Administration (FEA), 1975].

Energy consumption within foodservice facilities has not been monitored extensively because of the number of variables which must be controlled. Instrumentation has been reportedly incorporated into very few studies. Electrical consumption during the preparation of fried chicken in an electric deep-fat fryer, braiser, bake oven, and convection oven was metered with kilowatt-hour meters (Romanelli, 1976). The electric braiser was found to be the most energy intensive and the electric convection oven the least energy intensive. McProud (1977) investigated both the electrical and natural gas consumption within foodservice facilities. Standard rotating watt-hour meters and poly-phase watt-hour meters were used to monitor the energy consumption by a 3-quart mixer, a controlled environment chamber, walk-in refrigerator, walk-in freezer, and reach-in refrigerator. A standard diaphragm domestic gas meter was used to monitor the cubic feet of gas consumed by the forced air convection oven. The convection oven was found to be the most energy intensive, followed by the refrigeration units. Instrumentation during various processing stages was not always possible in the Dwyer et al. study (1977). In an investigation of the energy consumption by a zero pressure steam cooking unit versus a

12 - 14 pounds per square inch gauge (psig) (maximum) steam cooking unit, a fabricated single-pass, counter-flow copper coil condenser was attached to the exhaust of each unit (Mariscalco et al., 1977). A standard GE type M-30 demand meter electronically recorded the energy consumption. Results from this study indicated that the 12 - 14 psig steam cooking unit was slightly more efficient during thawing and 114 percent more energy efficient during cooking than the zero pressure steam cooking unit.

The compressors associated with refrigerator and freezer units were found to consume approximately 70 percent of the energy required to maintain a refrigerator or freezer unit at a preset temperature (Hoskins and Hirst, 1977). In order to maintain this constant temperature, these researchers analyzed the thermal load which had to be overcome. Thermal loads were defined as the sum of the heat gains. The heat gains included the heat from conductivity through the cabinet walls, from infiltration due to door openings or incomplete gasket seals, from temperature reduction, respiration load, latent heat of fusion, and other requirements for foods, and from equipment requirements within the units.

Various methods have been developed and used by institutions to identify energy utilization in foodservice operations and to encourage efficient equipment use. A method for approximating the kilowatt hours consumed by electrical equipment was developed by Romanelli (1976). This method involved monitoring the on-time of the thermostat signal light for a piece of equipment and multiplying this on-time by the kilowatt rating for this equipment. The kilowatt hours required from each piece of electrical equipment for each recipe preparation step could

be estimated by this method. If a recipe required the use of only electrical equipment, then the sum of the kilowatt hours for all preparation steps would equal the total kilowatt hours required to prepare a recipe. This approximation method was recommended for estimating the energy utilized per recipe and/or per day in a foodservice facility (Romanelli, 1978).

Another technique used to analyze the energy consumed from the processing plant through the foodservice operation to the service area was the energy accounting model developed by Dwyer et al. (1977). This model was predicated upon the first and second laws of thermodynamics. The first law of thermodynamics specifies that energy cannot be created or destroyed but only converted from one form of energy to another form of energy. The second law of thermodynamics states that every system left to itself changes in such a way as to approach a final state of equilibrium. The energy accounting model monitored the types and associated quantities of energy input and energy output of each processing stage. The difference between the input and output would equal the energy required to prepare a product during that particular preparation step. The energy required at each preparation step was added to determine the total amount of energy required to prepare a product beginning with the food processing plant activities through the foodservice operation to service. This accounting model was applied to the production of entrees in alternate foodservice systems. This study also included variation in the market form of product procured for a particular foodservice system. The foodservice systems used included a conventional foodservice system, ready-prepared (cook/chill and cook/freeze), and assembly-serve foodservice systems.

The amount of energy required to prepare entrees varied from 1265 Btu per kilogram for chicken tetrazzini and 1930 Btu per kilogram for barbecued chicken prepared in a conventional foodservice system to 2325 Btu per kilogram for baked chicken prepared in a cook/chill foodservice system and to 441 Btu per kilogram for preplated fried chicken prepared in an assembly-serve food service system. The amount of energy required to prepare beef loaves in the McProud study (1977) ranged from 8,942 Btu per kilogram in the conventional system to 13,892 Btu per kilogram in the cook/chill foodservice system, and 12,067 per kilogram for the thaw/heat/serve and 6,483 Btu per kilogram for the heat/serve assembly-serve foodservice systems.

Much of this energy required to prepare food in a foodservice operation represents wasted energy. Approximately 60 percent of the energy consumed for cooking is wasted by being transferred out the vent or into the room (FEA, 1975; Avery, 1974). Approximately 20 percent of the energy consumed for cooking equipment is lost to the atmosphere (FEA, 1975). High energy losses can be attributed also to inefficient conversion of electricity, natural gas, or oil to cooking heat; inefficient transfer of this heat from the source through the container to the food; and the poor energy conservation procedures (Krimmel, 1977). The Midwest Research Institute (MRI, 1974b) and the Federal Energy Administration (FEA, 1975) have published two of the many lists of procedures that would result in decreased energy consumption within foodservice operations, if followed. McProud (1977) investigated energy conservation procedures associated with the use of the convection oven. Decreasing the time required for loading a gas, forced air convection

oven was found to decrease energy consumption. Specific recommendations evolving from the Dwyer et al. (1977) study indicated that effective food processing schedules should be established, effective food storage administrative policies should be developed and implemented, effective food inventory policies should be followed, effective food production forecasting techniques should be developed, food process engineering techniques should be used, mathematical optimization models should be used to make food distribution decisions, and expedient processing sequences should be selected for both the food processing and foodservice industry to minimize energy consumption required for processing steps while maximizing food quality.

A result of these studies and recommendations has been increased awareness of energy utilization by different pieces of equipment. In existing facilities where equipment traditionally must depreciate out before being replaced, Hotchkin (1975) recommended four intermediate considerations to evaluate the effective use of the equipment. These considerations were the appropriate placement of equipment, maximum utilization of equipment, proper insulation of equipment, and adherence to equipment operating procedures by employees. Before purchasing new equipment, the energy consumption, initial investment, operating costs, capacity, and maintenance requirements should be considered (Hotchkin, 1975). An additional consideration would be the length of time required for warm-up (Krimmel, 1977).

These studies seem to indicate an awareness of the paucity of data concerning energy consumption within existing foodservice facilities. Many questions about management practices, manufacturer

and industrial recommendations, design of equipment, efficient utilization of equipment, and training of personnel remain unresolved. The type of foodservice system has been reported to influence the amount of energy consumed within a foodservice operation (Dwyer et al., 1977; McProud, 1977). Foodservice managers should be aware of the distinguishing features of each foodservice system.

III. FOODSERVICE SYSTEMS

The four major types of foodservice systems discussed in foodservice research include the conventional, ready-prepared, commissary, and assembly-serve system (Dwyer et al., 1977; Unklesbay et al., 1977; and McProud, 1977). Each system has unique features which characterize it from the other systems.

The distinguishing features of the conventional foodservice system were identified as the preparation of food just prior to meal service and the production and service of food items in the same facility. In this system, food may be procured at all stages along the food processing continuum, depending on the availability of adequate food production equipment and skilled labor. Due to the rising cost of labor, the trend during this decade has been toward the procurement of more extensively processed foods.

The ready-prepared foodservice system is characterized by food being prepared and then stored until service time when the food is reconstituted. The two main variations of this system are the cook/chill and the cook/freeze. In the cook/chill system, food is refrigerated or chilled following preparation, whereas, in the cook/freeze system

food items are frozen following preparation. The market form of products purchased for the ready-prepared system may vary from ingredients with minimal processing to ingredients with extensive processing. The amount of energy expended in the processing plant should be inversely related to the amount of energy expended in the food preparation area (Dwyer et al., 1977; Unklesbay et al., 1977).

The major characteristics of the commissary system were identified as centralized procurement and production units with distinct, decentralized service areas remote from the commissary unit. Food is purchased in large quantities with little, if any, previous processing.

The assembly-serve system is characterized by the procurement of many items that require minimal cooking within the foodservice facility. Two types of assembly-serve systems exist. These types are the thaw/heat/serve and the heat/serve systems. Food for the assembly-serve systems is typically procured in the advanced stages of processing. The three major forms of food purchased for this type of system were identified as the bulk form, the preportioned form, and the preplated form. Most of the energy expended for this system should occur in the processing plant. The additional energy expenditure by the processing plant is included in the cost of each menu item purchased by the foodservice operation.

These four foodservice systems encompass the foodservice system designs of this era. The ready-prepared system has been documented as energy intensive and the conventional system as less energy intensive (Dwyer et al., 1977; McProud, 1977). Caution is given about classification of assembly-serve system as the least energy intensive

due to the redistribution of the energy consumption to the processing plant (Dwyer et al., 1977). Data relevant to energy consumption in the commissary system are minimal. More data are needed to give an accurate perspective to energy consumption within foodservice facilities.

CHAPTER III

PROCEDURE

The purposes of this study were to develop a schematic energy flow decision model from the identification of the food product flow through a conventional foodservice system, to meter the energy consumption along the food product flow continuum, and to project the amount of energy consumed along the food product flow for each selected menu item in the conventional, commissary, ready-prepared, and assembly-serve foodservice systems. Energy consumption along the food product flow was measured by metering electrical, gas, and steam equipment used in the storage, production and service of entrees at the University of Tennessee, Knoxville Presidential Court Cafeteria facility. The cafeteria was divided into two sides, a north side and a south side. Each side had three hot foodservice areas. A layout of the production and service areas with associated equipment is shown in Appendix A, Figure 2.

I. PRODUCT SELECTION

Food preparation, refrigeration, and warming activities require at least 94 percent of the energy consumed in foodservice systems (Dwyer et al., 1977). Entrees were selected for this study because their preparation includes all the major energy intensive areas. These areas include storage, hot food preparation, holding and service. The University of Tennessee uses three-week-cycle menus in the summer and four-week-cycle menus in the fall in their conventional foodservice

systems. The menus were reviewed to identify entrees requiring the use of a variety of equipment in the storage, preparation, holding and service areas. Products other than entrees were also selected for use in this investigation so that energy utilization by steam equipment could be studied. In order to be selected, products had to be served at least once a week. Products studied were prepared from standardized recipes and ingredients purchased according to specifications developed by the University of Tennessee, Knoxville Food Services.

The entrees selected were roast beef, baked ham, meatloaf, fried chicken, egg products. Other products used in this study were bacon, sausage, corn-on-the-cob, peas, vegetable soup, and oatmeal. Meatloaf was the only menu item prepared in two different pieces of equipment: the gas, forced air convection oven and the gas rotary oven. All other products were prepared with only one type of food preparation equipment.

II. PRODUCT FLOW ANALYSIS

A food product flow analysis was conducted to identify variables influencing energy consumption by equipment within each foodservice area. These areas were receiving, storage, preparation, holding, and service. The decision model was developed by identifying the areas in the foodservice facility with associated equipment and sequential activities. Specific variables associated with each piece of equipment and area are listed in Table 1. The ambient temperature was a variable uniquely associated with refrigerators and freezers. The thermostat signal light was monitored only on electric equipment. Other variables included power ratings, equipment dimensions, thermostat setting,

Table 1. Foodservice Areas, Selected Equipment and Associated Variables Monitored

Area	Equipment	Associated Variables		
Receiving and Storage	Refrigerators Freezer	Power Rating Dimensions Business/Non-Business Hours Thermostat Setting	Ambient Temperature Initial Product Temperature Product Stored Quantity of Product Stored Duty Cycle	
Preparation	Refrigerator Freezer	Same as Receiving and Storage Same as Receiving and Storage		
	Grill Deep-Fat Fryer Rotary Oven Convection Oven	Power Rating Dimensions Product Product Temperature	Thermostat Setting Duty Cycle Quantity of Product Prepared Equipment Activity	
	Slicer	Power Rating Product	Product Temperature Quantity of Product	
	Steam Jacketed Kettles Jet Steamers	Power Rating Capacity Product	Product Temperature Quantity of Product Equipment Activity	
Holding and Service	Warming Oven Steam Table	Power Rating Dimensions Product	Product Temperature Quantity of Product Thermostat Setting Number of Wells Filled ¹ Percent Fill of Oven ²	Duty Cycle Equipment Activity

¹For Steam Table

²For Warming Oven

equipment activity (warming-up, cooking, idling), products studied, temperature of the products prior to entering the equipment, quantity of product processed at any one time, number of servings of each product prepared, duration of equipment use by each product; and the person responsible for product preparation. The 24-hour clock time was recorded as well as the beginning, ending, and 5-minute interval meter readings. The steam equipment and slicer were not operating for consecutive 5-minute periods, so 5-minute interval readings could not be taken. Interval readings were taken with all other electrical and natural gas consuming equipment. Product storage, preparation, holding, and service phases required different equipment and different variables to be monitored depending upon the equipment used in each area and the products studied.

Electric, natural gas, and steam consuming equipment were used in this facility. Electric equipment was used in storing, preparing, portioning, holding, and serving food. Natural gas and steam equipment were used in the preparation of products. All of the equipment was 11 years old except the grills and the convection ovens which were one year old, and the jet steamer which was six months old. The equipment was maintained routinely by the in-house maintenance staff. The foodservice areas and associated equipment with model number data and power rating data are listed in Table 9 in Appendix A.

Receiving and Storage Areas

The equipment used in the receiving and storage areas included the meat walk-in refrigerator; the fruit, vegetable, and dairy walk-in refrigerator, and the walk-in freezer. All three were Jamison coolers

with approximately 1280 cubic feet and were equipped with an electric fan for air circulation. The fans were not metered for this investigation. The meat refrigerator and the freezer were located within the storeroom that was locked on weekends. The receiving and storage areas were located two floors below the main preparation area which, in itself, limited the traffic flow into and out of these units. Traffic flow was not restricted to this equipment, except for weekends.

Each refrigerator required a Dunham-Bush 2-horsepower compressor motor. The freezer was powered by a Dunham-Bush 5-horsepower compressor motor. The refrigerators' thermostats were set to maintain the temperature at $2 \pm 3^{\circ}\text{C}$ ($36 \pm 5^{\circ}\text{F}$). The freezer thermostat was set to maintain the temperature between -23°C (-10°F) and -18°C (0°F).

Preparation Area

The preparation area was located two floors above the receiving and storage areas. Food products were delivered to the preparation area at least four hours prior to service. These products were either stored, preprepared, or prepared immediately.

The preparation meat walk-in refrigerator, maintained at 2°C (36°F), was powered by a Dunham-Bush 1.5-horsepower compressor motor. This Jamison cooler contained approximately 918 cubic feet, and was equipped with an electric fan for air circulation. The fan was not metered. This cooler was accessible to all foodservice personnel and was located adjacent to the main preparation area.

The Jamison walk-in freezer in the preparation area was powered by a Dunham-Bush 3-horsepower compressor motor. This freezer was approximately 807 cubic feet and was equipped with an electric fan for

circulation. The fan was not metered. This freezer was adjacent to the main preparation area and was accessible to all foodservice personnel.

Three grills, each model CG59 by General Electric, were located in the main preparation area. Each grill was 72 inches by 24 inches, requiring 32.4 kilowatts for the entire grill, a 208 volt AC 3-phase circuit. Only one-half of the grill was metered because three current lines for each half of the grill were connected to one fuse. Each kilowatt-hour meter could be attached to only one fuse at a time. The kilowatt rating for one-half of a grill was 16.2. All three grills were used for early morning preparation. Egg products were prepared on the grills from refrigerated, frozen, and room temperature ingredients. Energy consumption by the grill was monitored only during egg preparation for breakfast. The grills were all turned on to 149°C (300°F) at approximately 5:00 a.m. when the production unit was opened and remained on until being turned down or off at 10:30 a.m. when the breakfast service period was over.

Six deep-fat fryers were located in the main preparation area. Each fryer was a model 1404MA by Toastmaster, requiring 12.5 kilowatts, a 208 volt AC 3-phase circuit, and 60 cycles. The fryers were turned on when a product was being prepared in them and were left on during the entire service period. No covers were used to contain the heat in the fryers.

The slicer used in the preparation area was a Hobart model 1712 requiring a 1/3-horsepower motor, a 208 volt AC 3-phase circuit, 60 cycles, and 1.32 amps. This slicer was used to slice meats, cheeses, fruits, and vegetables. This slicer was metered during the slicing of all of these products.

A Middleby-Marshall model 906 oven rated at 85,000 Btu per hour with a 1/4-horsepower drive motor, a 110 volt AC single-phase circuit, was metered for only the gas consumption during the preparation of roast beef and meatloaf. The rotary oven was serviced as needed by the in-house maintenance personnel. The rotary oven was turned on only when menu items were prepared in the oven.

Four Blodgett gas, forced air convection ovens, model FA-102, were located in the main preparation area. The maximum gas flow rate per hour was 170,000 Btu. A blower was located inside the oven, and the blower required a 3/4-horsepower motor, 110 volts AC single-phase circuit, with 60 cycles. This blower was turned on only during the cooking of products. The blower was not metered for this investigation, but a noticeable increase in the gas flow rate occurred when the blower was turned on. Each oven also contained a 40-watt bulb inside that was not metered.

Holding and Service Areas

Twelve General Electric model CF30 pass-through warming ovens were located between the main preparation area and the service area. Each oven required 1.2 kilowatts, 110 volt AC single-phase circuit, and 5.8 amps. Each morning the ovens were turned to 121°C (250°F) when the preparation area was unlocked at 5:00 a.m. and remained on in each side of the cafeteria until the end of the service period on that side.

Three General Electric model L12 steam tables were located on each side of the cafeteria serviced by the main preparation area. Each steam table required 1650 kilowatts, 110 volt AC single-phase circuit. The tables were turned on at approximately 5:00 a.m. and

turned off when the lines closed. The dials were all turned to the "High" setting when the steam tables were turned on. Very little water, if any, was used in the nine wells in each steam table.

III. METER INSTALLATION

Electric, gas, and condensate meters were installed during July, 1978, on selected equipment to monitor the energy consumed. The specific types of meters used in this investigation are described in Table 2. Only three electric meters could be installed concurrently because of the possible interference with electrical service when more than three meters were installed in this facility. The kilowatt-hour meters were periodically rotated to three different pieces of electrical equipment until all electrical equipment requiring metering for this study had been metered. The meters were connected to the current line in various manners based on convenience of installation and safety precautions.

Kilowatt-hour meters were placed in the fuse panel area in the current line preceding the circuit breaker for the grill, the deep-fat fryer, warming oven, and the steam table. This installation is shown in Appendix B, Figure 3. The kilowatt-hour meter was connected between the wall receptacle and the slicer as shown in Appendix B, Figure 4. The slicer plug was connected to the meter and the meter plug was connected to the slicer wall receptacle. The kilowatt-hour meters were incorporated into the current line also for the refrigerators and the freezers. An initial meter reading was taken before the grill, deep-fat fryer, warming oven, steam table, and slicer were turned on. Five-minute interval readings were taken for each piece of equipment except for the slicer.

Table 2. Meters Used to Monitor Energy Resource
Consumption in a Foodservice Facility

Meter Type	Model	Description
Kilowatt-Hour	MT 145	120 volt, 3 phase (3 coil) self-contained Duncan Meter
Natural Gas	No. 1A	Sprague Gas Meter Maximum Flow Rate is 200 cubic feet per hour
Condensate	00-11	Niagara Nutating Disc Liquid Meter

Readings were taken at 5-minute intervals for a minimum of five hours during a 3-day period for each refrigerator and freezer in both the receiving and storage areas and the preparation area. A minimum of 20 consecutive readings was taken for each replication day. Meter readings for all refrigerators and freezers were taken during both the business hours (5:00 a.m. to 7:00 p.m., Monday through Friday; 6:00 a.m. to 7:00 p.m., Saturday; and 6:30 a.m. to 3:00 p.m., Sunday) and the non-business hours (after 7:00 p.m., Monday through Saturday; after 3:00 p.m. on Sunday) to reflect a typical situation.

The number of readings for each piece of preparation equipment varied depending upon the time required for product preparation. The grill was metered for energy consumption approximately 22.5 hours during four days of observations. A minimum of 69 consecutive 5-minute interval readings was taken at each replication. Each replication represented the time the grill was turned on in the morning and turned off or down at 10:30 a.m. The deep-fat fryer was metered for more than 12.5 hours during three replications of fried chicken preparation. A minimum of 32 consecutive 5-minute interval readings was taken during each replication. A replication represented the time required to prepare the total amount of chicken from the frozen state to the finished product. The slicer was metered before turning the slicer on and at the end of each slicing period. No interval readings were taken for this piece of equipment.

The gas meters were installed in the gas input line for the rotary oven and the convection oven as shown in Appendix B, Figures 5 and 6 respectively. Initial meter readings were taken before the ovens

were turned on, at 5-minute intervals during the on-time, and at the end of the on-time and/or preparation period. Meter readings were taken for the rotary oven for approximately 11.5 hours during three replications of the preparation of roast beef and three replications of the preparation of meatloaf. A replication comprised the preparation of roast beef or meatloaf from the uncooked product to the finished product. A minimum of 24 consecutive 5-minute interval readings was taken per replication. Readings taken for the convection oven include 8.5 hours of preparation with a minimum of 10 consecutive readings per replication. A replication comprised the preparation of each product from uncooked ingredients to the finished product. Meatloaf, ham, bacon, and sausage were prepared in the convection oven during this investigation.

The condensate meters were installed in the condensate line of the steam equipment as shown in Appendix B, Figures 7 and 8. The steam jacketed kettle lines each contained a reservoir which delayed the expulsion of the steam into the condensate line. A condensate meter was installed in the condensate line behind the reservoir of each 20- and 60-gallon steam jacketed kettle. These kettles were metered during the preparation of a vegetable soup, oatmeal, and corn-on-the-cob. For the jet steamer, a copper coil was submerged in an ice bath and the coil was installed preceding the condensate meter. The jet steamer was metered during the preparation of green peas. Condensate meter readings were taken prior to and at the end of each preparation period. No interval readings were taken for any of the steam equipment.

Equipment for the holding and service areas was metered for a total of 6.5 hours during three replication periods. A replication period represented a minimum of two hours of consecutive readings. A minimum of 25 consecutive readings was taken for the pass-through warming oven, and for the steam table. Meter readings were taken both during and between meal periods for each piece of the holding and serving equipment.

IV. DATA COLLECTION

Data were collected between July and December, 1978, in the Presidential Court facilities at the University of Tennessee, Knoxville. Approximately 1500 meals per day were served during the summer and over 4500 meals per day were served during the fall quarter. Data collection included both the pilot study and three replications of the food product flow for each menu item.

Variables to be monitored were identified during the food product flow analysis preliminary phase. Variables throughout this investigation for each piece of equipment were the power ratings, the dimensions, and the thermostat setting for the preparation equipment. The ambient temperature and the time of day (during business or non-business hours) were recorded only for the refrigerators and freezers. Other variables included: the product, the initial product temperature, and the quantity of the product. Other data recorded included the beginning and ending meter readings, 5-minute interval meter readings, and 5-minute duty cycles. Sample data collection forms are shown in Appendix C.

Energy resource consumption in the dry storage area for lighting, heating, ventilation, and air conditioning was not included in this study. This energy consumption is generally associated with general building maintenance rather than specific product preparation.

Data collected for the variables were placed on the computer with the DECsystem-10. These data were transferred with the assistance of two programs written in PL/I language to the IBM 360/65 computer to be reorganized for statistical analysis using a series of two statistical analysis system (SAS-76) programs (Barr et al., 1976).

V. ANALYSIS OF DATA

Refrigerators and Freezers

The number of kilowatt hours consumed during the duty cycles of both the business hours and the non-business hours were calculated for each refrigerator and freezer. These quantities were converted to British thermal units (Btu's). The duration of the duty cycle (on-time) per hour was monitored, and the percent duty cycle was calculated from these data. The mean number of Btu's per 5-minute duty cycle was calculated and the hourly Btu consumption was calculated for these mean data. The formula used to calculate the mean hourly energy consumption for each cooler was as follows:

$$HEU = \frac{M(\%DC) (BH) + M(\%DC) (NBH)}{Hr.}$$

where,

HEU = Mean Hourly Energy Consumption

M = Mean Interval Reading for One Hour of a Duty Cycle Period

%DC = Percent Duty Cycle

BH = Number of Business Hours

NBH = Number of Non-Business Hours

Hr. = Number Hours per Day (24 Hours).

The energy consumed by the refrigerators and freezers was apportioned by dividing the mass of the products used for the menu items on a particular day by the maximum cooling load allowed assuming 13.61 kilograms (30 pounds) of product per cubic foot (Kotschevar and Terrell, 1977), and then multiplying the result by the mean hourly energy use of the equipment and the duration of the equipment use time, as indicated by the following formula:

$$APE = \left[\frac{(\text{Kg. Product Mass})}{(\text{Kg. Maximum Cooling Load Allowed})} \right] (HEU)(NH)$$

where,

APE = Apportioned Energy for a Product

HEU = Mean Hourly Energy Consumption

NH = Number Hours Product Refrigerated
or Frozen

Regression analysis followed by an f-distribution test was used to determine if any particular variable monitored was a significant influence upon the amount of energy consumed by the coolers.

Grill and Deep-Fat Fryer

The number of kilowatt hours consumed during the preparation of a product was calculated for the grill and deep-fat fryer. The number of kilowatt hours was converted to equivalent Btu's. The mean amount of Btu's required to prepare each product was calculated from the data. The kilograms of each product prepared were divided into the amount of energy required to prepare the product. From the variables monitored, the percent of time the equipment was empty was calculated and the variables that significantly influenced the amount of energy consumed were determined by regression analysis followed by the f-distribution statistical test. One variable, the percent fill of the fryer basket, was the mass of the frozen fried chicken cooked in one basket divided by the maximum precooked mass of chicken quarters which would fill the basket, multiplied by 100. The formula was

$$\%F = \frac{BFW}{MBFW} \times 100$$

where,

$\%F$ = Percent Basket Fill

BFW = Gram Mass of Frozen Chicken Before Cooking

MBFW = Maximum Gram Mass of One Basket of Frozen
Chicken Before Cooking.

Rotary and Convection Ovens

The cubic feet of natural gas required to prepare a product were calculated and converted to British thermal units of energy with 1000 Btu equal to one cubic foot of gas. The mean amount of energy required to prepare a product was calculated. Significant influences on the

amount of energy consumed were determined for this equipment by regression analysis followed by f-distribution tests. The amount of energy required to prepare meatloaf in a rotary oven was compared to the amount of energy required to prepare meatloaf in the convection oven by calculating the percent difference between the two amounts.

Steam Equipment

The pounds of condensate from the steam required to prepare products in the steam equipment were determined from the difference between beginning and ending meter readings. The pounds of condensate were converted into Btu's of energy with 1000 Btu equal to one pound of condensate. The mean amount of energy required to prepare each product was calculated from these data.

Warming Oven

Energy utilization in the warming oven was apportioned for each product using the following formula:

$$AEO = \frac{PW}{MPW} \times NFP \times MBFP$$

where,

AEO = Apportioned Energy of Warming Oven

PW = Product Mass in Kilograms

MPW = Maximum Product Mass per Full Load in Oven
(Recommended by Manufacturer)

NFP = Number of 5-minute Periods the Product was
Held in the Oven

MBFP = Mean Btu Consumption per 5-minute Period

Electric Steam Table

The energy consumed by the steam table was apportioned to each menu item on the steam table according to the following formula:

$$APS = \frac{NW}{9} \times NFP \times MBFP$$

where,

APS = Apportioned Energy of Steam Table

NW = Number of Wells Used

9 = Maximum Number of Possible Wells Available

NFP = Number of 5-minute Periods each Product Studied
was Held on the Steam

MBFP = Mean Btu Consumption per 5-minute Period.

Total Apportioned Energy

The total apportioned energy required in the foodservice operation for the menu items studied was calculated by adding the apportioned Btu's per kilogram of each product from each area: receiving, storage, preparation, holding, and service. This total number of Btu's was the amount of energy required along the food product flow for one kilogram of each menu item in this conventional foodservice system.

VI. MODIFICATIONS FOR ALTERNATE FOODSERVICE SYSTEMS

A food product flow analysis was simulated for meatloaf and fried chicken in a commissary, ready-prepared (cook/chill), and assembly-serve foodservice systems. Foodservice areas and associated equipment were identified for each system. Assumptions were made that the quantity of food prepared, the equipment and associated 5-minute interval

energy consumption data, and the foodservice personnel would remain the same as in the conventional foodservice system. Only the food product flow would vary. The commissary system also required some motorized transportation. The University Transportation Services provided data relevant to the present transportation vehicles used by the University Food Services to transport food items from the bakery to the Presidential Court facility. One truck used was a 1976 Chevrolet, Custom Deluxe Series 30, 10,000 gross vehicle weight (GVW). Personnel from the Transportation Services stated that this truck traveled between five and eight miles per gallon of gasoline. The distance between the bakery and the Presidential Court was 2.1 miles round trip. The formula developed to apportion the energy consumed for this transportation of food was:

$$AE_t = \frac{(CF_g) \left(\frac{D}{\text{mpg}} \right)}{\left[\frac{\text{Kg. Product}}{\text{Total Kg. of Menu Items}} \right]}$$

where,

AE_t = Apportioned Energy for Transportation

CF_g = Conversion Factor used for Fuel

D = Round Trip Distance

mpg = Miles per Gallon Rating for Vehicle

The amount of gasoline required to transport the food items was calculated by dividing the number of miles the items must be transported by the miles per gallon to obtain the number of gallons of gasoline used. The number of gallons of gasoline was multiplied by 125,000 Btu per gallon gasoline to obtain the number of Btu's consumed. The number of

Btu's was apportioned for the amount of chicken and meatloaf transported. The kilogram mass of the entree (chicken or meatloaf) was divided by the total kilogram mass of the hot food menu items served. The number of Btu's consumed by the vehicle was multiplied by this fraction to apportion the energy. It was assumed that the other food products were the same as those served in the conventional system on the same day as these products were served and in the same quantities.

Other methods developed to apportion energy consumption by specific equipment for menu items in the conventional foodservice system were used for these three foodservice systems as needed. The data collected from the food product flow and metering of equipment in the conventional system were the basis for forecasting energy consumption in the commissary, ready-prepared, and assembly-serve systems.

CHAPTER IV

RESULTS AND DISCUSSION

A schematic energy flow decision model was developed based upon the food product flow through a conventional foodservice system. Energy consumption was measured for selected products along the continuum of storage, preparation, holding, and service in a volume foodservice facility to assist in forecasting the amount of energy required to prepare and serve a product in a conventional foodservice system. The schematic energy flow decision model was modified to project the energy consumption in other foodservice systems.

I. SCHEMATIC ENERGY FLOW DECISION MODEL

The major areas of foodservice systems include receiving, storage, preparation, holding, and service areas. The specific areas of any one foodservice system may be more or less inclusive. All foodservice systems contain receiving, storage, holding, and service areas, but the preparation area may be either on-premise or off-premise, or even in the processing plant. Each of the major foodservice areas was included in the energy flow model as shown in Figure 1. Monitoring the energy consumption within each area began with entrance of the product into that foodservice area and ended when the product left the designated geographical location of the area. Omission of areas and recycling through areas was possible in the model as designed. The model was developed based on food product flow data for a conventional foodservice system.

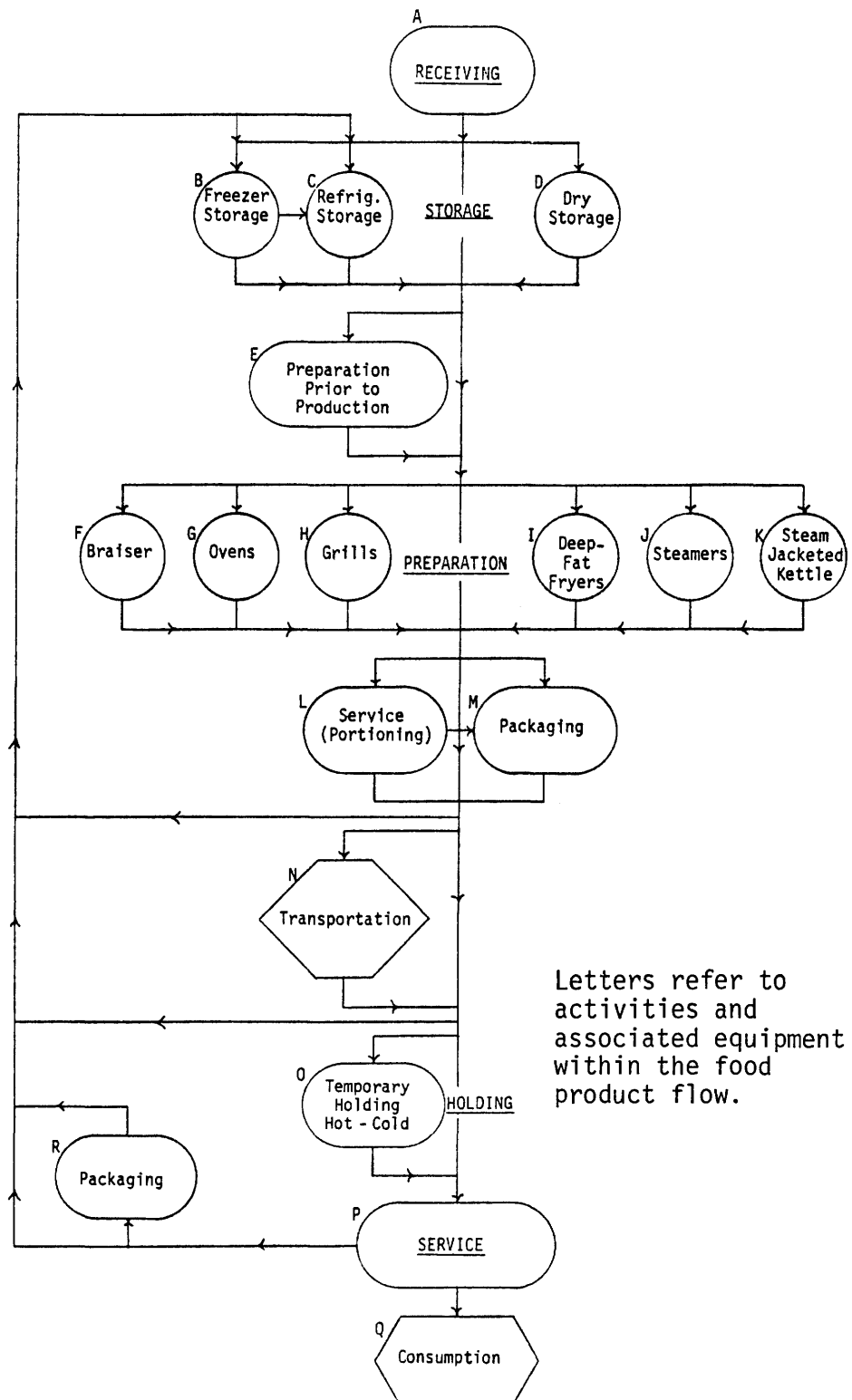


Figure 1. Schematic Energy Flow Decision Model

Receiving and Storage Areas

Products were received at specified times prior to preparation and/or service. Equipment that did not require fossil fuel energy resources was used to receive the food items and transport these items to the appropriate areas. The receiving and storage areas included dry storage and refrigerator and freezer storage units. Electrical energy resources supplied the power for this area. Dry storage required fans that circulate the air. The refrigerator and freezer units required compressors, condensers, and fans for air circulation. The energy required by each unit depended upon the cooling load. Factors that determine the cooling load of refrigerators and freezer units include the wall heat gain, the number of air changes required depending upon the extent of traffic in and out of the units, product load, and miscellaneous loads such as electrical equipment (Hoskins and Hirst, 1977). These factors were considered but were not monitored. The regularity and extent of maintenance of the equipment in all storage units could influence the energy consumption by each piece of equipment. The equipment in this facility was checked daily by the maintenance staff and repairs were made as needed.

Preparation Area

Products were received at specific times for storage prior to the time for preparation and/or service. From receiving and storage, food was transported directly to the preparation area for preparation prior to cooking or for final preparation prior to service. Preparation requirements may include chopping, grinding, slicing, and mixing of

products. The equipment used in the preparation area required electricity. The market form of product purchased influences and is influenced by the availability of equipment, energy resources, and labor in the preparation area. The more processed the product prior to receipt, the less the need for prepreparation.

Products requiring hot food preparation were transported to the appropriate equipment for preparation from either the receiving and storage areas or the prepreparation area. Equipment used in hot food preparation required either electricity, natural gas, or steam. The equipment used for preparation varies depending upon the design of the foodservice facility and the energy resources available for food preparation. Typical equipment used in the hot food preparation area included braisers, grills, rotary ovens, convection ovens, other types of ovens, deep-fat fryers, steam jacketed kettles, trunions, jet steamers, broilers, and fans contained in hoods. Factors relevant to the energy consumption by electrical, natural gas, and steam equipment as identified by this research were shown in Table 1, p. 17. Factors related to energy utilization by electrical equipment included the design and composition of the equipment, power rating, type of circuit, number of circuit phases, and cycles, dimensions of equipment, and heated surface area exposed to the atmosphere. Factors affecting the energy consumed by the equipment requiring gas include the gas flow rate required, design and composition of the equipment, and door operation. Factors relevant to the energy utilized by steam equipment included the steam pressure required, the maximum temperature of the steam, and the insulation of the kettles and steamers. Maintenance of equipment also affects the

performance and energy utilized by each piece of preparation equipment.

From the preparation area, products typically were transported directly to the service (portioning) area and/or a packaging area. The equipment required for portioning and packaging in the service preparation area was only small electrical equipment. The portioned and packaged menu items were then transported via non-motorized carts or trucks to the holding, storage, or service areas as needed. Generally the products were transported to a holding or service area directly in this foodservice system.

Products not requiring hot food preparation equipment were transported directly to service preparation, packaging, or holding and service areas. Menu items such as sandwich meats and cheeses required only prepreparation, and then were transported to holding and service areas.

Holding and Service Areas

Food was held prior to service in this conventional foodservice system. Pass-through warming ovens, refrigerator and freezer units were used to hold products prior to service. Electricity was the energy resource used by the holding equipment. Service areas included electrical and/or steam equipment. Equipment associated with service areas included steam tables, refrigerated vending machines, microwave ovens, and freezing units.

Modified Energy Flow Decision Models

A modified schematic energy flow decision model was developed for each of the menu items studied. The model for each product with

associated number of servings and average kilogram mass of the product prepared is shown in Appendix D, Figures 9 - 19. The major foodservice areas, associated equipment, and duration of equipment use for each menu item are also shown in Appendix E, Table 10.

Menu items selected for this investigation were roast beef, baked ham, meatloaf, fried chicken, egg products, bacon, sausage, corn-on-the-cob, green peas, vegetable soup, and oatmeal. The University Food Services established the market form, and specifications of each product purchased.

Food products were received on Monday for Tuesday and Wednesday service; Wednesday for Wednesday, Thursday, and Friday service; and Friday for Friday, Saturday, Sunday, and Monday service. The products were transported either directly to the receiving and storage areas or to the preparation area. All products placed in the receiving and storage refrigerator and freezer units remained there between 8 and 56 hours before being transported to the preparation area. Products transported to the preparation area were either used immediately or stored from 4 to 36 additional hours in either the meat walk-in refrigerator or the walk-in freezer. Equipment used to prepare menu items in the preparation area included electric grills, deep-fat fryers, steam jacketed kettles, gas rotary oven, gas convection oven, and jet steamers. All products were placed in warming ovens until needed on the steam table line or were transported directly to the steam table for service.

Food items remaining from an excess of production were recycled through the schematic model, omitting some steps, such as prepreparation

and preparation. Menu items such as bread products were transported directly from receiving to service and were recycled back to the storage area, then to the prepreparation area to be used in some product such as dressing. This dressing was portioned, served and either recycled to storage until the following meal service to be consumed or discarded. Although the model allows for recycling of menu items, the monitoring of this recycling was not included in this study.

II. METERING THE EQUIPMENT

Electrical, natural gas, and steam consuming equipment were metered along the food product flow continuum. The mean energy consumption by foodservice equipment per 5-minute duty cycle were determined as shown in Table 3. These results indicate that natural gas consuming equipment was the most energy intensive. These data were then apportioned for menu items used in this study. A total apportioned energy was calculated for each menu item based upon the equipment used, the duration of equipment usage, energy utilized by equipment during processing of food items, and quantity and temperature of food items prepared. A discussion of each of the major foodservice areas in this conventional foodservice system and the energy consumption associated with each area follows. Factors affecting energy consumption of equipment are shown in Table 4.

Receiving and Storage Areas

The equipment located in the receiving and storage areas included the meat walk-in refrigerator; the fruit, vegetable and dairy walk-in refrigerator; and the walk-in freezer. Over five hours of 5-minute

Table 3. Mean Energy Consumption by Foodservice Equipment During a 5-Minute Duty Cycle

Area	Equipment	Energy Resource Consumed	Energy Consumed Per 5-Minute Interval (Btu)
Receiving and Storage	Compressor ¹	Electricity	460
	Compressor ²	Electricity	370
	Compressor ³	Electricity	772
Preparation	Deep-Fat Fryer	Electricity	906
	Grill	Electricity	573
	Slicer	Electricity	--- ⁶
	Rotary Oven	Natural Gas	4297
	Convection Oven	Natural Gas	2995
	Compressor ⁴	Electricity	409
	Compressor ⁵	Electricity	644
	Steam Jacketed Kettle	Steam	--- ⁶
	Jet Steamer	Steam	--- ⁶
Holding and Service	Warming Oven	Electricity	424
	Steam Table	Electricity	2123

¹Receiving and Storage Walk-In Vegetable and Dairy Refrigerator

²Receiving and Storage Walk-In Meat Refrigerator

³Receiving and Storage Walk-In Freezer

⁴Preparation Walk-In Meat Refrigerator

⁵Preparation Walk-In Freezer

⁶Data not Obtainable

Table 4. Factors Affecting Energy Consumption by Electrical, Natural Gas, and Steam Equipment in a Foodservice System

Area	Equipment	Factors Affecting Energy Consumption	Significance Level (P=) or (P <)
Receiving and Storage	Refrigerators Freezer	Thermostat Setting	(P = .0001)
		Thermostat Setting	(P = .0001)
Preparation	Refrigerator Freezer	Thermostat Setting	(P = .0001)
		--- ¹	--- ¹
	Grill	Minutes on per 5-Minute Interval	(P = .0001)
		Kilogram Mass of Batch	(P < .10)
	Deep-Fat Fryer	Percent Basket Fill	(P = .0001)
		Kilogram Mass of Batch	(P < .01)
		Thermostat Setting	(P < .01)
		Cook Responsible for Product Preparation	(P < .05)
	Convection Oven	Kilogram Mass of Batch	(P = .0001)
		Cook Responsible for Product Preparation	(P = .0001)
	Rotary Oven	Thermostat Setting	(P = .0001)
		Cook Responsible for Product Preparation	(P = .0001)
Holding and Service	Steam Jacketed Kettles	--- ¹	--- ¹
		--- ¹	--- ¹
		--- ¹	--- ¹
	Jet Steamer Slicer	--- ¹	--- ¹
		--- ¹	--- ¹
Holding and Service	Warming Oven Steam Table	Thermostat Setting	(P = .0001)
		--- ¹	--- ¹

¹No specific variable identified as significantly influencing the energy consumption by this equipment.

interval readings were taken for each unit. The mean reading for the duty cycle periods ranged from 370 to 772 Btu per 5-minute interval (Table 3). The duty cycle periods were determined for the non-business hours from the preset timers. The data collected from the readings revealed that the fruit, vegetable, and dairy refrigerator and the freezer cycled off approximately 48 percent of the time during the business hours and the meat refrigerator cycled off 34 percent of the time during the business hours. Due to security reasons, data could not be collected for the meat refrigerator during non-business hours. The percent of time during which the refrigerator and freezer units cycled off was indicated by the percent of the number of readings equal to zero Btu during the investigation of each cooler. The mean hourly energy consumption for each refrigerator and freezer compressor ranged from 5120 to 7520 Btu. A summary of the energy consumption along the food product flow for each menu item is shown in Table 5. The total apportioned energy for the menu items for each unit ranged from 58 to 1170 Btu with green peas requiring the least amount and meatloaf requiring the largest amount. The refrigerator and freezer units in the receiving and storage areas were located within the foodservice building two floors below the preparation area. The traffic into and out of the units was somewhat controlled merely by location. Each unit was seldom filled to capacity. All refrigerator and freezer units were maintained regularly by the in-house maintenance staff.

Oatmeal and vegetable soup were two menu items investigated which required only dry storage. Energy consumption data were not recorded for the dry storage areas.

Table 5. Summary of Mean Energy Consumption Along Food Product Flow in the Conventional Foodservice System for Selected Menu Items

Menu Item	Kilogram Mass	Receiving and Storage		Preparation		Holding and Service		Total Energy	
		Total Btu	Btu/Kg.	Total Btu	Btu/Kg.	Total Btu	Btu/Kg.	Total Btu	Btu/Kg.
Roast Beef	76.0	188	2	147,732	1865	38,732	489	186,652	2356
Meatloaf ¹	86.4	1170	13	135,696	1571	38,621	447	175,487	2031
Meatloaf ²	86.4	1170	13	88,003	1019	38,621	447	127,794	1479
Baked Ham	11.5	76	7	39,145	3404	38,621	3358	77,842	6769
Fried Chicken	98.4	281	3	123,943	1260	41,421	421	165,645	1684
Egg Products	105.0	200	2	106,128	1011	39,421	375	145,749	1388
Corn-on-Cob	40.7	116	3	6,911	170	38,621	949	45,648	1122
Oatmeal	8.0	0	0	626	78	10,092	1262	10,718	1340
Veget. Soup	26.4	0	0	3,850	146	10,092	382	13,939	528
Bacon	9.6	142	15	19,000	1979	19,310	2011	38,452	4005
Sausage	9.6	142	15	22,099	2302	19,310	2011	41,551	4328
Green Peas	36.0	58	2	19,296	536	38,621	1073	57,975	1611

¹The rotary oven was used to bake the meatloaf.

²The convection oven was used to bake the meatloaf.

The sum of the apportioned energy per kilogram of each product in the receiving and storage areas ranged from 2 Btu per kilogram of roast beef, green peas, or egg products to 15 Btu per kilogram of bacon or sausage (Table 5). The time periods associated with the energy consumption for each menu item were based on the hours of equipment use associated with each menu item as shown in Appendix E, Table 10. The mean number of British thermal units per kilogram product for the receiving and storage areas was 7.5 Btu per kilogram. The apportioned energy for each product for the receiving and storage areas was indicated beside the receiving and storage areas of each individual product schematic energy flow decision model, shown in Appendix D, Figures 9 - 19.

Preparation Area

In the conventional foodservice system studied, the preparation area was located two floors above the receiving and storage areas. Products were transported to the preparation area for storage prior to preparation. Little prepreparation was required for any of the products studied. Small equipment was not required for any of the prepreparation prior to cooking each product. The equipment monitored in the preparation area included a walk-in cooler and freezer, hot food preparation equipment, and portioning equipment. The apportioned energy for each menu item and associated preparation equipment is shown in Table 6.

Ingredients for menu items were transported to either the hot food preparation area directly from the receiving and storage areas or to the appropriate refrigerator or freezer unit at least four hours prior to preparation. Neither the refrigerator nor the freezer

Table 6. Mean Apportioned Energy Consumption by Equipment in the Preparation Area for Menu Items

Menu Item	Kilogram Mass	Equipment	Apportioned Energy Btu/Kg.	Total
Roast Beef	76.0	Refrigerator	8	
		Rotary Oven	1857	
		Slicer	- ¹	1865 ²
Meatloaf	86.4	Refrigerator	1	
		Rotary Oven	1567	
		Convection Oven	1015	
		Slicer	- ¹	1571 ^{2,3}
				1019 ^{2,4}
Baked Ham	11.5	Refrigerator	31	
		Convection Oven	3373	
		Slicer	- ¹	3404 ²
Fried Chicken	98.4	Freezer	24	
		Deep-Fat Fryer	1236	1260 ²
Egg Products	105.0	Refrigerator	8	
		Grill	1003	1011 ²
Corn-on-the-Cob	40.7	Freezer	19	
		Steam Jacketed Kettle	151	170 ²
Oatmeal	8.0	Steam Jacketed Kettle	78	78 ²
Vegetable Soup	26.4	Steam Jacketed Kettle	146	146 ²
Bacon	9.6	Refrigerator	8	
		Convection Oven	1971	1979 ²
Sausage	9.6	Refrigerator	8	
		Convection Oven	2294	2302 ²
Green Peas	36.0	Freezer	19	
		Jet Steamer	517	536 ²

¹Data not Obtainable²Total Apportioned Energy for Preparation Area³With Rotary Oven⁴With Convection Oven

compressor cycled off during business hours; i.e., no readings equal to zero Btu's were recorded during the business hours. The mean reading for the duty cycle was 409 Btu per 5-minute interval for the refrigerator compressor and 644 Btu per 5-minute interval for the freezer compressor as shown in Table 3, p. 41. The hourly energy consumption was 7840 Btu for the refrigerator compressor and 12,460 Btu for the freezer compressor. The apportioned energy for each product ranged from 4 Btu per hour for one kilogram of meatloaf to 31 Btu per hour for one kilogram of baked ham.

Three grills were used for egg product preparation at breakfast. The egg products prepared on the grill were fried eggs, scrambled eggs, and omelets. The kilogram mass of the egg products prepared ranged from 0.03 to 6.8 per batch. Between 5:00 a.m. and 10:30 p.m., the grill was on, but not in use approximately 15 percent of the time.

The energy consumed to warm up the grill was approximately 3427 Btu and required approximately five minutes. During each 5-minute interval, the mean Btu consumption was 573 as shown in Table 3, p. 41. Consumption was monitored beginning when the grill was turned on (5:00 a.m.) until the grill was turned off or temperature reduced at 10:30 a.m. The sum of energy consumed from the time eggs were first cooked on the grill until the time when the grill was turned off or down each morning was divided by the total kilograms prepared that morning to give the mean energy consumption per kilogram egg product. The number of minutes the grill was on per 5-minute interval was the only variable that correlated significantly with the amount of energy consumed ($P = .0001$). The pre-set thermostat temperature slightly influenced the number of minutes the

grill was on per 5-minute interval. The amount of food prepared at one time approached significance ($P < .10$) in its effect on the amount of energy consumed. The other variables monitored: initial temperature of the product being prepared, the person using the grill, and the equipment activity (cooking, warming-up, or idling) did not significantly affect the energy consumed by the grill. Variation among cooks as to procedures in use of equipment were observed, but differences in their use of energy were not significant.

The grill was open to the atmosphere causing a constant loss of heat to the atmosphere. This occurred to such an extent that the variables thought to be relevant to the amount of energy consumed possibly became less significant when compared to the amount of energy required to replace the heat loss to the atmosphere. During one replication, one person turned the grill to 204°C (400°F) to cook one omelet about 9:30 a.m. after the grill had been turned to 177°C (350°F) for over four hours. The amount of time required to cook this omelet was no different from the amount of time required to prepare the egg omelet at 177°C (350°F). This person was followed by another person who turned the grill down to 177°C (350°F) immediately. Still another person turned the grill thermostat setting to 93°C (200°F) when that portion of the grill was not in use while a different person left the grill thermostat turned to 177°C (350°F) when he went to breakfast. A noticeable variation in cooking habits was observed in this foodservice operation.

Precooked, breaded, frozen chicken quarters were routinely deep-fat fried at 177°C (350°F) between 5 and 10 minutes per fryer basket.

The deep-fat fryer was idle 33 percent of the time. No cover was placed over the fryer baskets during the cooking period or between cooking periods to minimize heat loss. The mean Btu consumption during the average warm-up time of 6.5 minutes was 3413. The mean Btu consumption was 906 during a 5-minute interval as shown in Table 3, p. 41. Energy consumption was monitored from the time the deep-fat fryer was turned on until the deep-fat fryer was turned off. The energy consumption data for the chicken were calculated based on the energy consumed from frying of the first batch of chicken through the end of the preparation period for each replication. Approximately 475 Btu per kilogram chicken were required when the fryer basket contained 3.42 kilograms of chicken. The percent fill of basket associated with the weight was 79. Approximately 585 Btu per kilogram were required to prepare 4.32 kilograms of fried chicken which filled the fryer basket 100 percent. The percent basket fill of the fryer was a significant influence upon the amount of energy consumed ($P = .0001$). The kilogram mass of the product prepared and the thermostat setting were significant influences upon the amount of energy consumed ($P < .01$). Significant variation in the amount of energy used to prepare chicken in each replication existed between the cooks ($P < .05$). The monitored variables that were decided by the cook included the thermostat setting, the duration of the cooking period, the kilogram mass of the product placed in the fryer basket, and the percent basket fill. Some of these variables significantly influenced the amount of energy consumed. This implies that decisions made by the cook about how a product is prepared and in what quantities are significant ($P < .05$) influences upon the amount of energy consumed per product prepared.

The kilowatt-hour meter was not sensitive enough to detect any electrical consumption when meat, cheese, vegetables, and fruits were sliced. No further analysis was performed with the slicer.

A variety of products was prepared in the convection oven. The kilogram mass of the product prepared at one time varied as did the number of shelves utilized during the preparation and the cook responsible for the preparation of each food product. The thermostat was routinely set at 177°C (350°F). The electric blower located inside the convection oven and the light bulb were not metered for this study. The light bulb was rarely turned on, but the blower was turned on after the shelves had been completely filled with the product to be prepared and the doors of the oven had been closed. The gas flow was noticeably more rapid when the blower was activated.

No distinct warm-up period could be noted from the amount of energy consumed from the time the oven was turned on until the oven was turned off. The mean Btu consumption was 2995 for a 5-minute interval as shown in Table 3, p. 41. The convection oven was empty 35 percent of the time during this study. Only 11.5 kilograms of ham were prepared which resulted in an energy use of 3373 Btu per kilogram not including energy consumed during non-use periods. The average amount of energy required to prepare one kilogram of meatloaf was approximately 1015 Btu (Table 6). The difference between the amount of energy required per kilogram for ham versus meatloaf could be due to many factors such as the composition and density of the products. Bacon required 1971 Btu per kilogram and sausage required 2294 Btu per kilogram product. The kilogram mass of the product prepared and the cook responsible for the

product preparation had the most significant influence ($P = .0001$) upon the amount of energy consumed when a product was prepared.

Two rotary ovens were used in the preparation area. A mean of 76 kilograms of roast beef was prepared in the rotary oven at one time and 86 kilograms of meatloaf were prepared at one time. The thermostat setting used by the cooks varied from 149°C (300°F) to 204°C (400°F). The rotary oven was empty only 12 percent of the time. No specific warm-up time or energy utilization could be detected from the gas consumption data. The amount of gas consumed appeared to be rather consistent throughout the entire time the rotary oven was in operation.

The electrical motor drive system attached to the rotary oven to rotate the shelves was not metered. No difference in the speed of the gas flow was noted when the motor was on versus when the motor was off.

The mean Btu consumption per 5-minutes was 4297 for the rotary oven as shown in Table 3, p. 41. Approximately 1567 Btu were required to prepare each kilogram of meatloaf and 1857 Btu were required to prepare each kilogram of roast beef. The most significant influence upon the amount of energy consumed by this oven was the thermostat setting ($P = .0001$). Significant difference between the amounts of energy to prepare a product in the rotary oven by the cooks was noted ($P = .0001$) due to the variation in thermostat setting.

A variety of products was prepared in the steam jacketed kettles including ground beef products, vegetables, soups, cereals, and sauces. For this study the steam jacketed kettles were monitored during the preparation of corn-on-the-cob, vegetable soup, and oatmeal. The kettles were turned on only while a product was prepared. The stopcock at

the base of each kettle was open during the preparation of products. This caused some error in the results obtained due to the loss of some condensate out this orifice. The explanation given by employees for opening the stopcock was that the stopcock needed to be open so the temperature of the product being prepared could be raised to a boiling point.

The mean energy consumption per 5-minute interval was not taken for either the 20- or 60-gallon steam jacketed kettle because the kettles were not on at least 15 consecutive minutes for each replication of each product prepared. The mean amount of energy required ranged from 146 Btu to prepare one kilogram vegetable soup in the 60-gallon steam jacketed kettle to approximately 151 Btu required to prepare one kilogram of corn-on-the-cob in the same steam jacketed kettle. The oatmeal required 78 Btu per kilogram when prepared in the 20-gallon steam jacketed kettle. From the data collected, there was no indication that any one particular variable was associated with the amount of energy required to prepare these products in the steam jacketed kettle.

The jet steamer in this facility was used to cook vegetables and eggs, and to reheat products that had been left over from a previous meal. The mean energy consumption per 5-minute interval was not calculated because the jet steamer was never turned on more than three consecutive minutes. The average amount of energy required to prepare green peas was 517 Btu per kilogram for a 2 to 2.5 minute cycle. This amount of energy may not be completely correct because by attaching the meter to the condensate line, the defrost cycle was altered noticeably and the quality of product prepared was not acceptable.

The products used in this study and the energy consumption associated with the preparation area are shown in Table 6, p. 46, and in

Appendix D along each food product flow. The energy consumption in the preparation area per kilogram of each product ranged from 78 Btu for one kilogram of oatmeal to 3404 Btu for one kilogram of ham. Meatloaf prepared in the rotary oven required 154 percent of the energy required to prepare meatloaf in the convection oven in the same quantity at the same initial product temperature and final temperature, and the same thermostat setting.

Holding and Service Areas

The warming ovens were located between the main preparation area and the service line. The amount of food held in these pass-through ovens varied, but the ovens contained a maximum of four pans at meal time. The warming ovens were empty 50 percent of the time during this study. The mean Btu was 424 for one 5-minute interval, as shown in Table 3, p. 41. The most significant variable influencing the amount of energy consumed by these ovens was the thermostat setting ($P = .0001$). The apportioned energy for the oven ranged from 60 Btu for one kilogram of vegetable soup to 583 Btu for one kilogram of bacon as shown in Table 7.

Three steam table units were located on each side of the cafeteria. The steam tables were turned on approximately 45 minutes prior to the breakfast service on only one side of the cafeteria. Only when a specific line was used during a meal service were the steam tables along that side of the cafeteria turned on. The control dials were turned to "High" whenever the steam tables were turned on. The wells that were not in use were covered to minimize the loss of heat. Minimal, if any, water was placed in the base of each well.

Table 7. Mean Apportioned Energy Consumption by Equipment in the Holding and Service Areas for Menu Items

Menu Item	Kilogram Mass	Equipment	Apportioned Energy Btu/Kg.	Total
Roast Beef	79.0	Warming Oven Steam Table	71 418	489 ¹
Meatloaf	86.4	Warming Oven Steam Table	65 382	447 ¹
Baked Ham	11.5	Warming Oven Steam Table	487 2871	3358 ¹
Fried Chicken	98.4	Warming Oven Steam Table	85 336	421 ¹
Egg Products	105.0	Warming Oven Steam Table	61 314	375 ¹
Corn-on-the-Cob	40.7	Warming Oven Steam Table	138 811	949 ¹
Oatmeal	8.0	Warming Oven Steam Table	200 1062	1262 ¹
Vegetable Soup	26.4	Warming Oven Steam Table	60 322	382 ¹
Bacon	9.6	Warming Oven Steam Table	583 1428	2011 ¹
Sausage	9.6	Warming Oven Steam Table	292 1719	2011 ¹
Green Peas	36.0	Warming Oven Steam Table	156 917	1073 ¹

¹Total Apportioned Energy
for Holding and Service Areas

The mean Btu consumption per 5-minute interval was 2123 as shown in Table 3, p. 41. No particular variable was identified as significantly affecting the energy consumption by the steam table. The apportioned energy for the products in this investigation for the steam table ranged from 314 Btu for one kilogram of egg products to 2871 Btu for one kilogram of baked ham (Table 7).

The total amount of energy consumed in the holding and service areas ranged from 375 Btu for one kilogram of egg products to 3358 Btu for one kilogram of baked ham. The apportioned energy by area is shown in Table 5, p. 44, and in Appendix D.

Total Energy Consumption Per Menu Item

The mean sum of the apportioned energy consumed per menu item per area was greatest for the preparation area, followed by the holding and service areas and the refrigerator and freezer storage areas. The total amount of apportioned energy for the products prepared ranged from 528 Btu per kilogram for vegetable soup to 6769 Btu per kilogram for baked ham as shown in Table 5, p. 44, and in Appendix D, Figures 9 - 19.

The equipment temperature and the amount of product prepared appeared to be the two important influences upon the amount of energy required to prepare a product in the preparation equipment. The length of time required to prepare the same product varied depending on decisions made by the cook. A significant difference was noted between cooks in the amount of energy consumed to prepare a product in the deep-fat fryer, the rotary oven, or the convection oven due to the decisions made concerning the thermostat setting and the mass of the products to be prepared.

The total apportioned energy in the conventional system in the McProud (1977) study was found to be 8,942 Btu per kilogram of beef loaves in a partially filled convection oven. In this study, approximately 1479 Btu per kilogram were required to prepare meatloaves in the conventional foodservice system with a gas, forced-air convection oven that had a thermostat setting of 177°C (350°F). The amount of energy required to prepare deep-fat fried chicken in a commercial fast food operation with a deep-fat fryer was projected by Dwyer et al. (1977) to be 441 Btu per kilogram. The fried chicken in this study required 1684 Btu per kilogram when the deep-fat fryer was used with a thermostat setting of 177°C (350°F). Differences between this study and the McProud (1977) and the Dwyer et al. (1977) studies may be due to the fact that this study was conducted in a conventional university foodservice system and gas, electric, and steam equipment were metered. Differences could exist in the equipment designs, power requirements, and quantity of product prepared in equipment, preparation methods and associated storage, preparation, holding, and service time. A final difference could be in the research methodology used by each investigator.

III. MODIFIED SCHEMATIC ENERGY FLOW DECISION MODELS

The schematic energy flow model that was developed for the conventional system was modified for the commissary, ready-prepared (cook/chill), and assembly-serve systems as shown in Appendix D. Food product flow analyses were simulated for each system to identify areas and associated equipment. Meatloaf and fried chicken were the products selected for these analyses. Assumptions were made that the quantity of

each product prepared would remain the same as in the conventional system and that the equipment used in the receiving and storage areas, the preparation area (if any), and the holding and service areas would remain the same. The energy consumption per product during receiving and storage would be allocated by the same proportional methods as were used for the conventional system. The ingredients for each entree were assumed to be received by the same personnel, and stored the same periods of time as in the conventional system, unless otherwise specified. The cooks responsible for the preparation of the products were assumed to be the same as for the conventional system. The preparation equipment was assumed to be used for similar periods of time at the same temperature as specified for the conventional system. The methods used to calculate the energy per 5-minute interval were the same as used for the conventional system. The major differences between the commissary, ready-prepared (cook/chill), and the assembly-serve systems and the conventional system were the food product flows. Table 8 shows a summary of the energy consumption in each foodservice system for meatloaf and fried chicken. A discussion of the projected energy consumption for each menu item, meatloaf and fried chicken in each of the three foodservice systems follows.

Commissary System

The commissary system is characterized by the receiving, storage and preparation areas in one facility with transportation by some motorized vehicle to a remote facility for service. The energy flow model for this system is shown in Appendix D, Figures 20 and 21.

Table 8. Summary of Projected Energy Consumption Along Food Product Flow in the Four Foodservice Systems for Meatloaf and Fried Chicken¹

Foodservice System	Kilogram Mass	Receiving and Storage		Preparation		Holding and Service		Total Energy	
		Total Btu	Btu/Kg.	Total Btu	Btu/Kg.	Total Btu	Btu/Kg.	Total Btu	Btu/Kg.
MENU ITEM: MEATLOAF ²									
Conventional	86.4	1170	13	88,003	1019	38,621	447	127,794	1497
Commissary	86.4	1170	13	88,003	1019	38,621	447	132,125 ³	1547 ³
Ready-Prepared ⁴	86.4	1872	21	111,963	1295	38,621	447	150,584	1743
Assembly-Serve ⁵	86.4	1170	13	11,980	139	38,621	447	51,771	599
MENU ITEM: FRIED CHICKEN ⁶									
Conventional	98.4	281	3	123,943	1259	41,421	421	165,645	1683
Commissary	98.4	281	3	123,943	1259	41,421	421	172,692 ⁷	1755 ⁷
Ready-Prepared ³	98.4	983	10	147,903	1503	41,421	421	190,307	1934
Assembly-Serve ⁵	98.4	281	3	5,756	58	41,421	421	47,458	482

¹Commissary, Ready-Prepared (Cook/Chill), and Assembly-Serve System estimates based on data collected in conventional system; ²Convection Oven used, raw mass assumed to equal 86.4 kilograms; ³Includes 50 Btu/Kg. for transportation; ⁴Cook/Chill System; ⁵Thaw/Heat System; ⁶Raw mass assumed to equal 98.4 kilograms; ⁷Includes 72 Btu/Kg. for transportation.

The amount of energy required for the transportation was the only additional variable requiring calculation and apportionment. Approximately 1547 Btu per kilogram were consumed to prepare meatloaf and 1755 Btu per kilogram were required to prepare fried chicken in the commissary system. Transportation of each product caused an expenditure of 50 Btu per kilogram for the meatloaf and 72 Btu per kilogram for the fried chicken, as indicated in Table 8.

Ready-Prepared (Cook/Chill) System

This system was similar to the conventional system up through the preparation phase. In this instance, the products were cooled to room temperature before being refrigerated. These products were assumed to be chilled for 24 hours before returning to the preparation area to be reheated in the convection oven, prior to service. For example, the reheat period for chicken in the convection oven was assumed to be a minimum of 40 minutes at 177°C (350°F) for each product with the 5-minute interval mean Btu consumption the same as for the conventional system under identical conditions of a full oven at the same thermostat setting. The amount of energy along the food product flow, including the additional time for refrigeration of each product and additional reheating time in the convection oven was summed for each product as shown along the food product flow in Table 8 and in Appendix D, Figures 22 and 23. Approximately 1743 Btu per kilogram of meatloaf and 1934 Btu per kilogram of fried chicken were required. The preparation and storage areas were more energy intensive in the ready-prepared (cook/chill) system than in the conventional, commissary, or assembly-serve foodservice system.

Assembly-Serve System

This system assumes that the product is purchased in a market form that requires only heat processing prior to service. It also is assumed that the same facility was used, and the convection oven was used for heat processing the chicken and meatloaf. The amounts of energy required to store the product in a cooler, to heat process the entree, and to hold and serve the entree were summed to predict the amount of energy required to prepare each entree. The food product flow for this system is shown in Appendix D, Figures 24 and 25. Approximately 599 Btu per kilogram of meatloaf and 482 Btu per kilogram of fried chicken were required to prepare and serve these entrees as shown in Table 8. The holding and service areas were the most energy intensive areas within this foodservice system, assuming the same equipment was used to hold and serve the products as in the conventional system. This foodservice system appeared to be the least energy intensive of the foodservice systems investigated. However, this foodservice system may not be the least energy intensive if consideration is given to the amount of energy required for processing food from the processing plant through the foodservice operation to the service of the customer.

Results of Simulated Energy Flow Models

The modified schematic energy flow models allowed the energy flow through each alternate foodservice system to be sequentially followed. The energy consumption was estimated for meatloaf and fried chicken in each of the following foodservice systems: the commissary, the ready-prepared (cook/chill), and assembly-serve system. The estimated energy

consumption projected for the entrees ranged from 599 to 1743 Btu per kilogram for meatloaf and from 482 to 1934 Btu per kilogram for fried chicken. The assembly-serve foodservice system appeared to be the least energy intensive system and the ready-prepared (cook/chill) foodservice system the most energy intensive. The only variation between the quantity of energy consumed in the conventional system and the commissary system was the amount of energy required for transportation. The energy consumption per kilogram in the commissary system was similar to the amount of energy required per kilogram in the conventional system.

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS, AND SUMMARY

I. CONCLUSIONS

The energy required along the continuum of receiving, storage, preparation, holding, and service in the conventional foodservice system varied. The hot food preparation equipment requiring natural gas was the most energy intensive equipment in the foodservice facility as shown in Table 3, p. 41. The rotary oven was the single most energy intensive equipment in this study. Of the electrical equipment, the electric steam table was the most energy intensive. The equipment operated by steam was the least energy intensive. It appears that steam operated equipment should be used as much as is possible. Electrical equipment appeared to be less energy intensive. However, consideration must be given to the additional energy required to produce each kilowatt hour due to the inefficient conversion of traditional energy resources to electricity within the original generating system and then the inefficient transfer of electricity from the original generating system to the foodservice system.

Results from this study indicate the quantity of product prepared is a significant influence upon the amount of energy consumed in the convection oven and deep-fat fryer as shown in Table 4, p. 42. The thermostat setting was a significant influence on the energy consumed in convection, rotary, and warming ovens.

Decisions concerning the use of equipment made by the food preparation personnel were a significant influence upon the amount of energy required to prepare a product in the convection oven, rotary oven, and deep-fat fryer. The amount of energy required to prepare meatloaf at the same thermostat setting for the same time period was greater in the rotary oven than in the convection oven. An observation was made that traffic in and out of the coolers and freezers may have caused a noticeable difference in the mean hourly energy consumption rates.

The energy flow model allowed the energy consumption for each product to be followed as the product passed along the continuum from receiving through service in all four foodservice systems. This model provided the flexibility to analyze the energy consumption required to prepare products in each of the four foodservice systems, or only one system with more than one method of preparing products for service. Data required to use this model for types of systems other than a conventional system would include the mass of the product, type of equipment required, type and quantity of energy resources needed, and preparation method.

II. RECOMMENDATIONS

This study has caused a number of questions to surface which need to be resolved through further research. One such study that is needed is a cross-comparison in the amount of energy required to prepare a product in different pieces of equipment. Only meatloaf was investigated in this study. Alternate methods of product preparation should be investigated.

The amount of energy required by a piece of equipment when the quantity of product prepared in the equipment is varied should be investigated. Variable amounts of ham and meatloaf were prepared in the convection oven in this study. Some variation in the amount of energy consumed appeared, but studying the practical application of this variation was beyond the scope of this study.

The hot food preparation equipment and holding and service equipment were turned on, but empty, from 0 percent of time for steam equipment to approximately 50 percent of time for the pass-through warming ovens. Controls should be implemented for monitoring the on-time of equipment when the equipment is empty.

Studies should be conducted investigating the design and composition of equipment, particularly the grill, deep-fat fryer, convection oven, rotary oven, steam table, and refrigerators and freezers. Grills appear to be inherently inefficient because of the free convection heat transfer losses. Manufacturers need to study the design of grills to determine if the surface area exposed to the atmosphere could be minimized through zone control. The size of the heated cavity of the rotary oven needs to be studied to determine if the cavity can be decreased in size to minimize the amount of energy used. Methods need to be developed to control the on-time of equipment and the utilization of equipment. Foodservice managers should investigate whether they are getting correctly sized and designed equipment for their needs.

Employee training programs should be studied to determine the information that needs to be disseminated about energy conservation

and the decisions each person makes. Means of motivating employees to conserve energy need to be investigated.

Alternate techniques similar to the one developed by Romanelli for electrical equipment, for projecting the amount of energy consumed by gas and steam equipment should be investigated. By developing these alternate techniques, the energy flow model could be used in food-service operations to decide the most energy efficient method of producing products of a desirable quality.

More sensitive watt-hour meters need to be used to study the amount of energy required by small equipment such as the slicer because the quantity of energy consumed was too small to be detected with the kilowatt-hour meter used in this study. A more accurate method for measuring the amount of energy consumed to prepare products in the steam jacketed kettles and the jet steamer is needed due to interference of meters with the operation of the equipment. Methodology for apportioning total energy consumed to refrigerate or freeze products needs to be studied because of the many variables associated with this procedure.

The assembly-serve system required the least amount of energy per kilogram of product in the foodservice system, while the ready-prepared (cook/chill) system required the largest amount of energy per kilogram of product. The schematic energy flow model developed for each menu item provided a guide for following the flow of energy for each menu item through the foodservice systems. The energy consumed to prepare each product in each foodservice system could be compared using the schematic energy flow models. Based upon this comparison, the food-service manager could decide which foodservice system used energy more

efficiently and which equipment should be used in each foodservice area to minimize the energy utilization per kilogram of product while maintaining the quality of the product served.

This research investigated the actual energy consumption in a conventional foodservice operation by metering equipment used along the food product flow. Similar studies are needed for the other foodservice systems. This study only simulated the food product flow through the other systems; actual food product flows and corresponding energy utilization need to be monitored in the commissary, ready-prepared (cook/chill and cook/freeze), and assembly-serve systems.

These recommendations for further study have only touched upon the vast amount of research needed to determine methods of efficiently utilizing energy within a foodservice facility. More baseline data are needed to guide the development of these more effective methods.

III. SUMMARY

Effective control of energy consumption within each foodservice operation is predicated upon the identification of the energy flow through the system, quantification of the energy consumed to prepare menu items, forecasting energy consumption based upon this identification and quantification, and then identifying energy conservation opportunities. Research has only begun in each of these areas. The purposes of this research were to develop a schematic energy flow decision model, to meter the energy consumption along the food product flow for selected menu items, and to project the energy consumption in the commissary, ready-prepared (cook/chill), and assembly-serve foodservice systems.

A food product flow analysis was conducted to identify major foodservice areas, associated equipment, and associated variables for each piece of equipment. An individual food product flow analysis was developed for each selected menu item studied. Modified schematic energy flow models were developed based upon the food product flow for each menu item. The energy consumption by equipment used to store, prepare, hold, and serve each menu item studied was metered. Gas, steam, and electrical equipment were monitored. Apportioned energy for each product was calculated from the sum of the energy utilized along the food product flow continuum from receiving through service. Variables that had a statistically significant influence upon the energy consumption by each piece of equipment metered were identified. The schematic energy flow decision models for meatloaf and fried chicken were modified for the assembly-serve, ready-prepared (cook/chill), and commissary systems to project the energy required to prepare and serve each product.

The results of this study indicated that the schematic energy flow decision model facilitated the study of the energy flow through a system so that an analysis of the most efficient and effective means of preparing and serving menu items would be possible. The energy required along the continuum of receiving, storage, preparation, holding and service in the conventional system varied. The hot food preparation equipment was the most energy intensive in the foodservice facility. Energy utilization by the grill appeared to be associated with the amount of surface area exposed to the atmosphere. The quantity of food prepared at one time and decisions made by personnel

concerning the use of equipment appear to be the most significant influences upon the quantity of energy consumed by the convection oven, rotary oven, and deep-fat fryer. The amount of energy required to prepare meatloaf under identical conditions was greater in the rotary oven than in the convection oven. Steam equipment used the least amount of energy during the preparation of products.

The amount of energy consumed along the energy flow continuum ranged from 528 Btu per kilogram for vegetable soup to 6769 Btu per kilogram for ham. The mean amount of energy required per kilogram of product was 2385 Btu.

Projections indicate that the assembly-serve system would require the least amount of energy per kilogram meatloaf or chicken served (482 Btu per kilogram) and the ready-prepared (cook/chill) system would require the greatest amount of energy (1934 Btu per kilogram). The schematic energy flow decision model can be used to project the energy consumption in the four foodservice systems.

The results of this investigation provide additional baseline energy utilization data. The energy flow decision model should be used to analyze energy utilization in foodservice systems. Factors such as design and composition of equipment, amount of food prepared, amount of warm-up time, and decisions concerning the use of equipment made by personnel noticeably influence energy utilization. The efficient and effective use of energy should be integrated into the design of foodservice systems and associated equipment, management decisions, and educational programs.

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APPENDICES

APPENDIX A

FOODSERVICE LAYOUT AND ASSOCIATED EQUIPMENT

Figure 2. Layout of University of Tennessee Presidential Court Foodservice Facilities (Second Floor)

Table 9. Foodservice Equipment, Model Number,
Associated Power Rating

Equipment	Model Number	Power Rating
Refrigerators ¹	Condensing Unit, AH 20C	2.0 H.P
Refrigerator ²	Condensing Unit, AH 16C	1.5 H.P.
Freezer ³	Condensing Unit, AH 30L	3.0 H.P.
Freezer ⁴	Condensing Unit, AH 50EL	5.0 H.P.
Grill	General Electric, Model CF59	32.4 kw, 208 volt AC, 3-Phase.
Deep-Fat Fryer	Toastmaster, Model 1404MA	12.5 kw, 208 volt AC, 3-Phase, 60 cycles.
Rotary Oven	Middleby-Marshall, Model 906	85,000 Btu/hr with a 1/4 H.P., Single- Phase Drive Motor requiring 110 volt AC.
Convection Oven	Blodgett, Model FA-102	170,000 Max. Btu/hr with 3/4 H.P., Single-Phase, Blower requiring 110 volt AC.
Slicer	Hobart, Model 1712	1/3 H.P., 208 volt AC, 3-Phase, 60 cycles, 1.32 amps.
Steam Jacketed Kettle	Legion Utensils, Models TWT20 and TWT60	2/3 Kettle, Max. Allowable Pressure: 40 psi at 300°F.
Jet Steamer	Hobart, Model 3030	Max Allowable Pressure: 40 psi at 300°F.

Table 9 (continued)

Equipment	Model Number	Power Rating
Pass-through Warming Oven	General Electric Model CF30	1.2 kw, 110 volt AC, Single-Phase, 5.8 amps
Steam Table	General Electric Model L12	1650 kw, 110 volt AC, Single-Phase

¹Receiving and Storage Refrigerators, Meat
and Fruit/Vegetable/Dairy Products

²Preparation Refrigerator, Meat

³Receiving and Storage Freezer

⁴Preparation Freezer

APPENDIX B

METER INSTALLATION DIAGRAMS

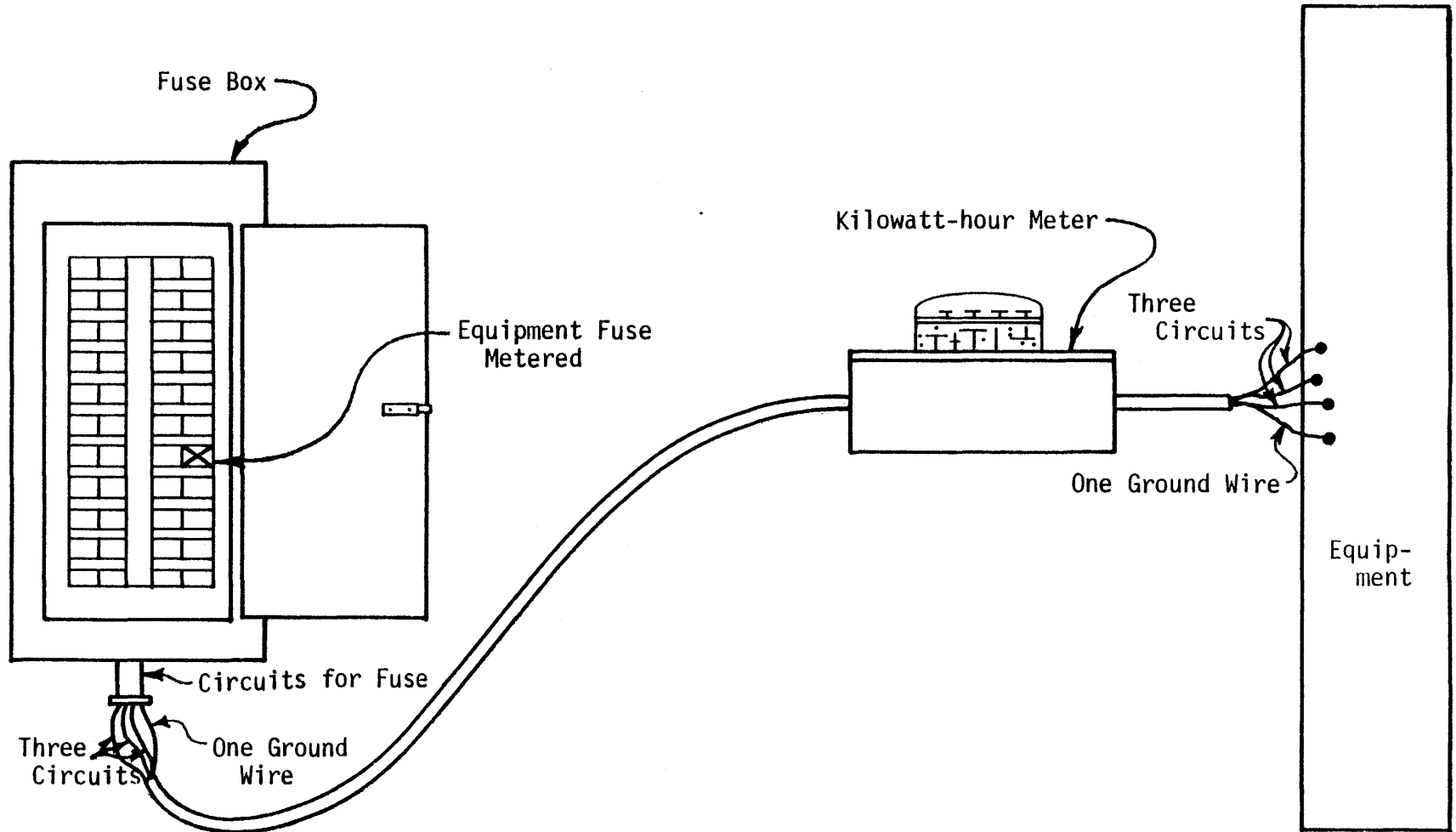


Figure 3. Kilowatt-hour Meter Installation in Fuse Panel Area

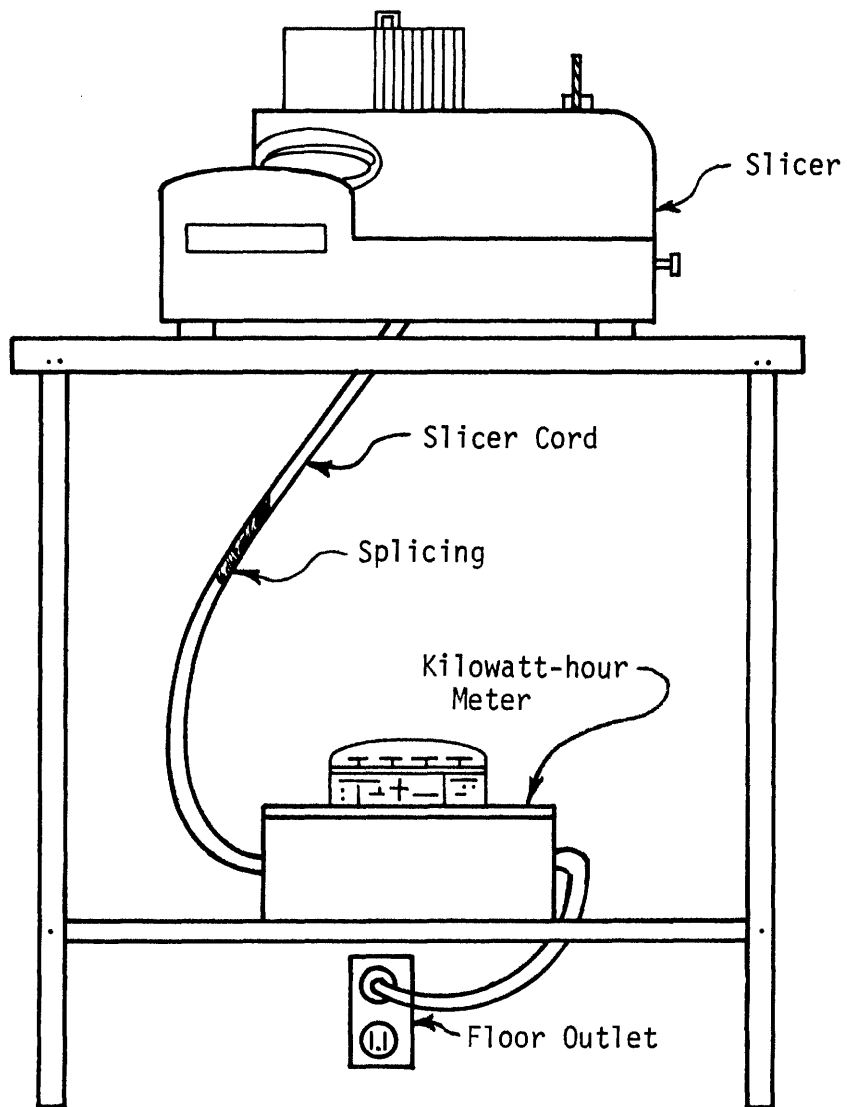


Figure 4. Kilowatt-hour Meter Installation for Slicer

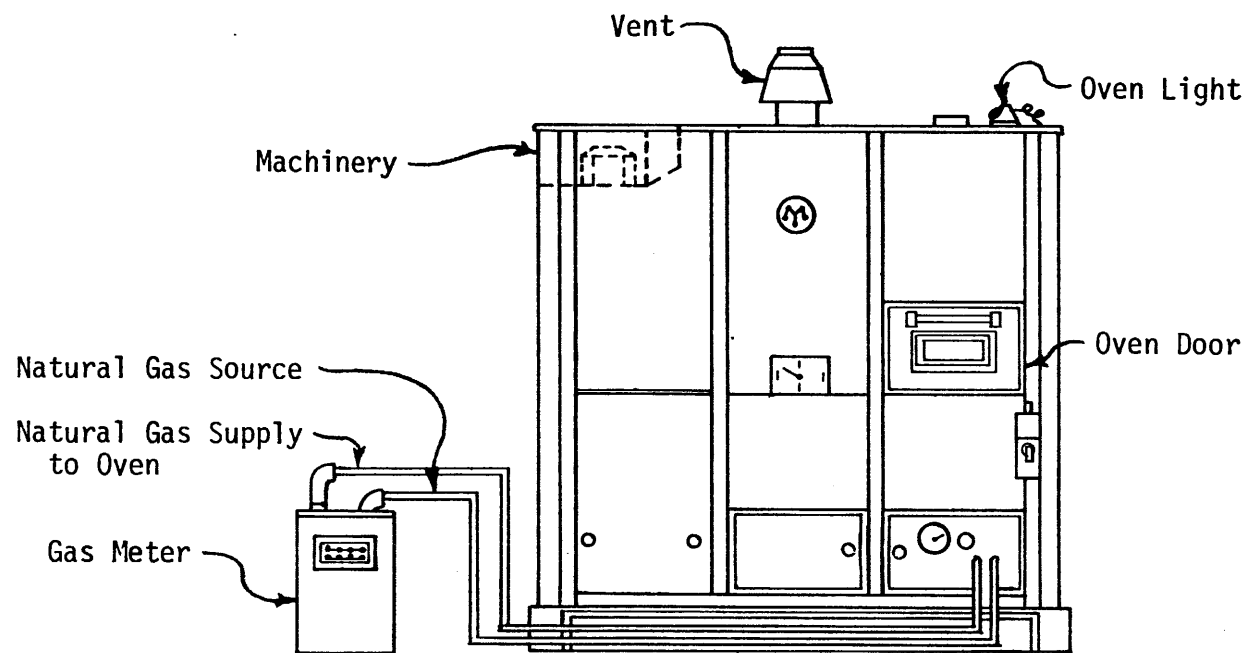


Figure 5. Gas Meter Installation for Rotary Oven

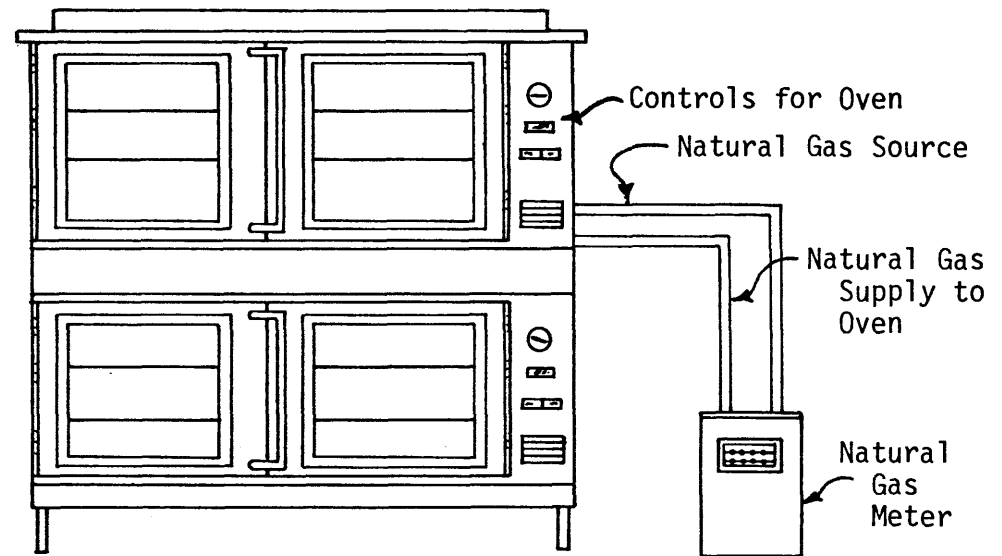


Figure 6. Gas Meter Installation for Convection Oven

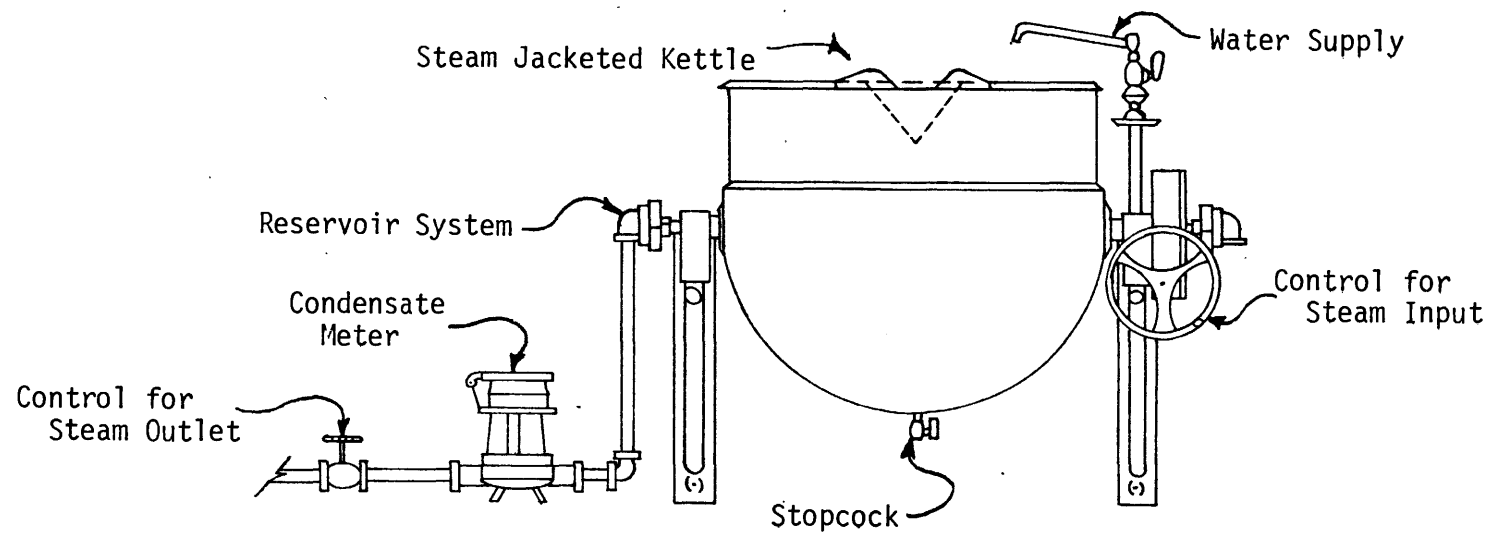


Figure 7. Condensate Meter Installation for Steam Jacketed-Kettle

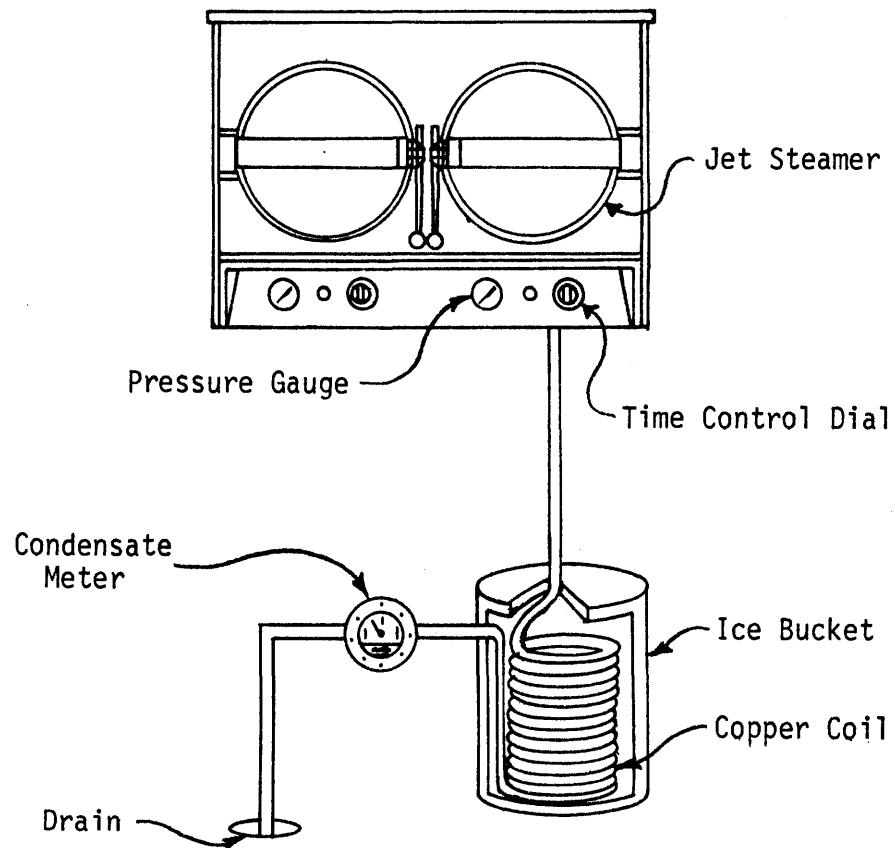


Figure 8. Condensate Meter Installation for Jet Steamer

APPENDIX C

DATA COLLECTION FORMS

FORM 1

Replication No. _____

ELECTRICAL EQUIPMENT DATA COLLECTION FORM

Equipment: _____ Date: _____

Power Rating: _____ Product Prepared: _____

Dimensions of Equipment: _____ Quantity Prepared _____

Thermostat Setting: _____ Initial Product Temperature: _____

Ambient Temperature: _____

Time of Day: Business Hrs./Non-Business Hrs.
(Circle One)

24-Hour Clock	Initial Reading	21.6 Watt Disc No. Rotations	5-Min. Duty-Cycle	Equip. Act.	Other
------------------	--------------------	---------------------------------	----------------------	----------------	-------

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slightly textured appearance, typical of standard notebook paper. There is no handwriting or other markings on the page.

End Meter
Reading: _____

Replication No. _____

Equipment: _____ Date: _____

Btu Consumption/Hr.: _____ Product Prepared: _____

Dimension of Equipment: _____ Quantity Prepared: _____

Thermostat Setting: _____ Initial Product Temperature: _____

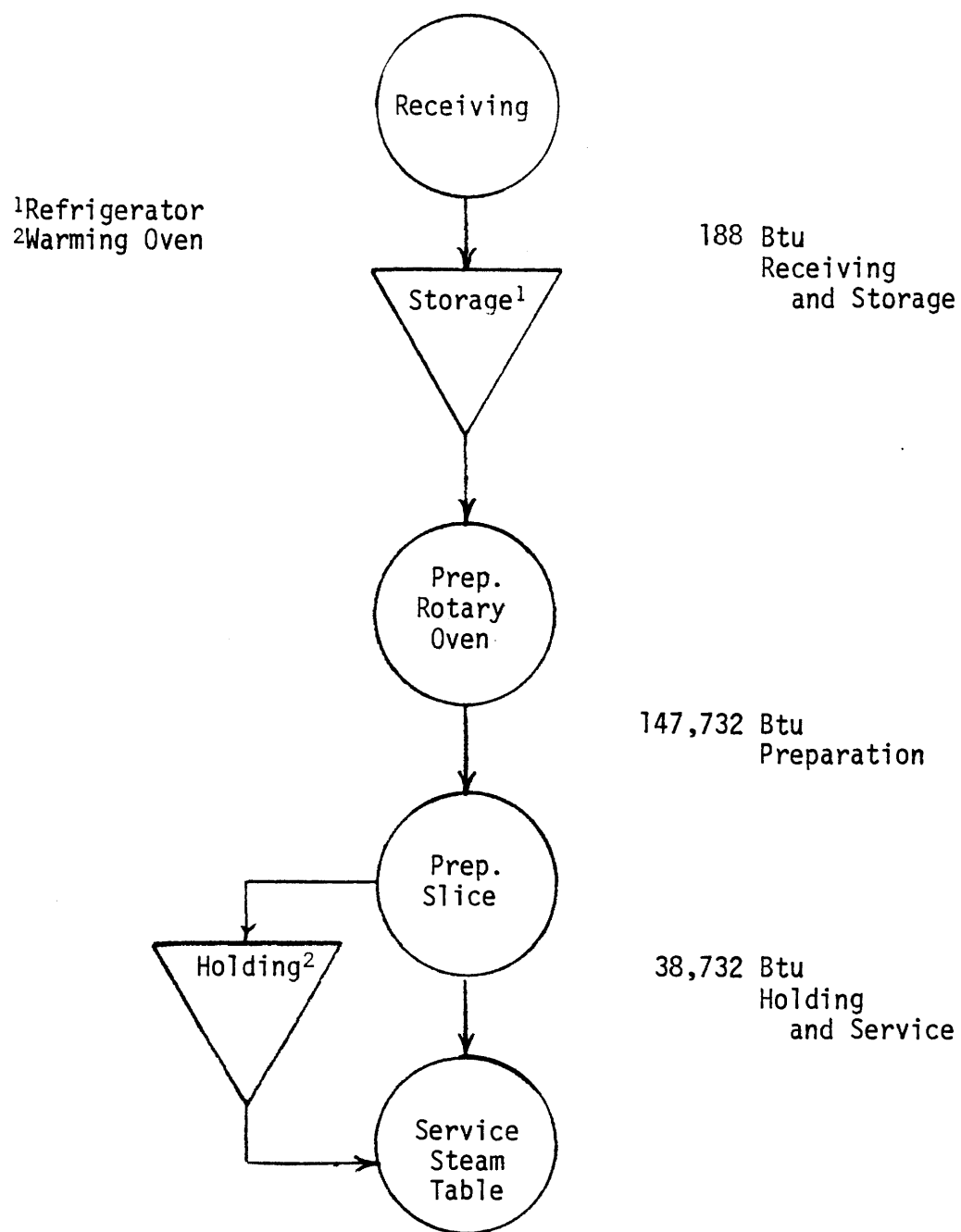
24-Hour Clock	Initial Mtr. Rdg.	No.Cubic Feet	5-Min. Duty Cycle	Equip. Act.	Other
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End Meter
Reading

24-Hour Clock	End Mtr. Rdg.	Initial Mtr. Rdg.	Difference in Mtr. Rdg.	Other Information
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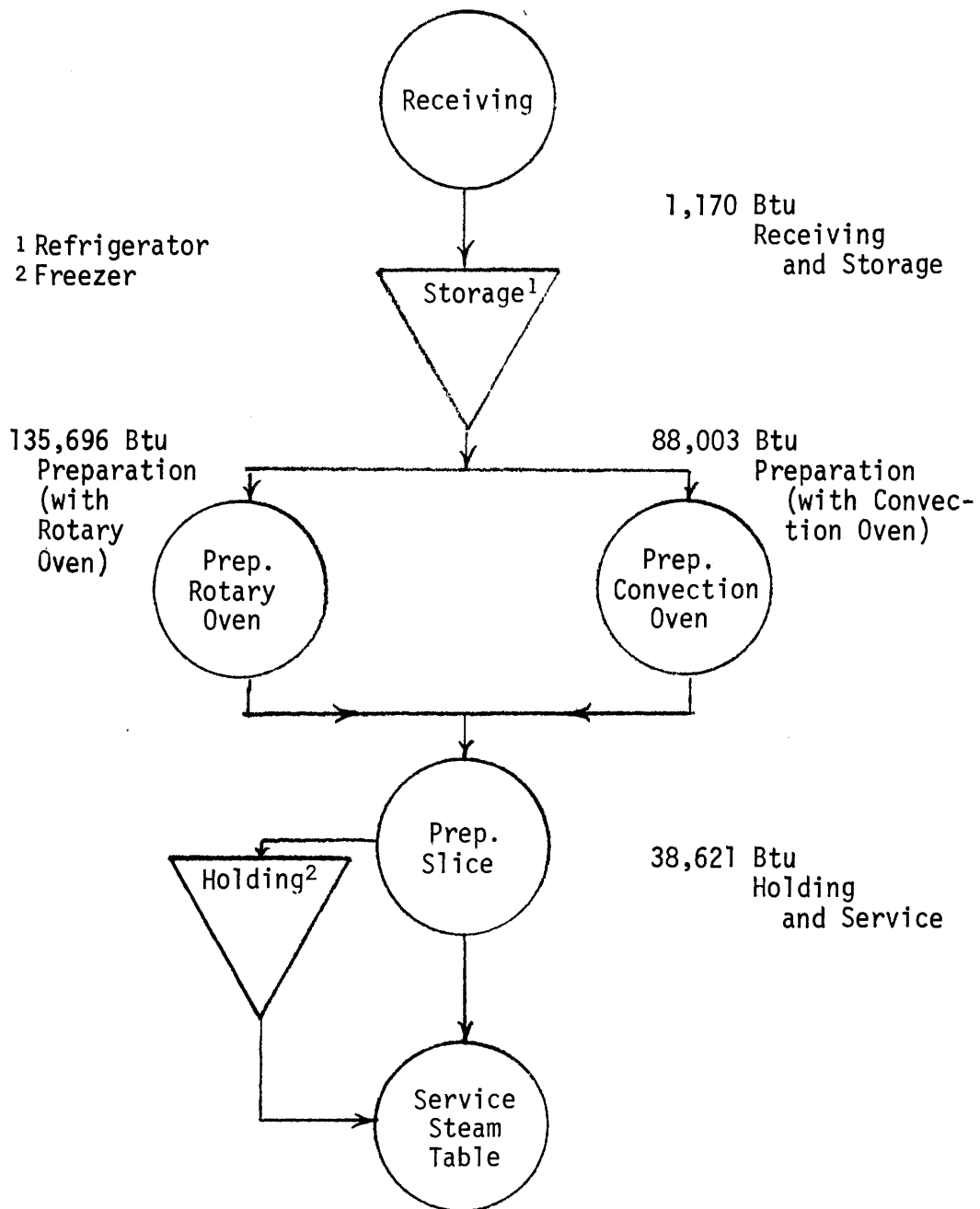
APPENDIX D

SCHEMATIC ENERGY FLOW DECISION MODELS



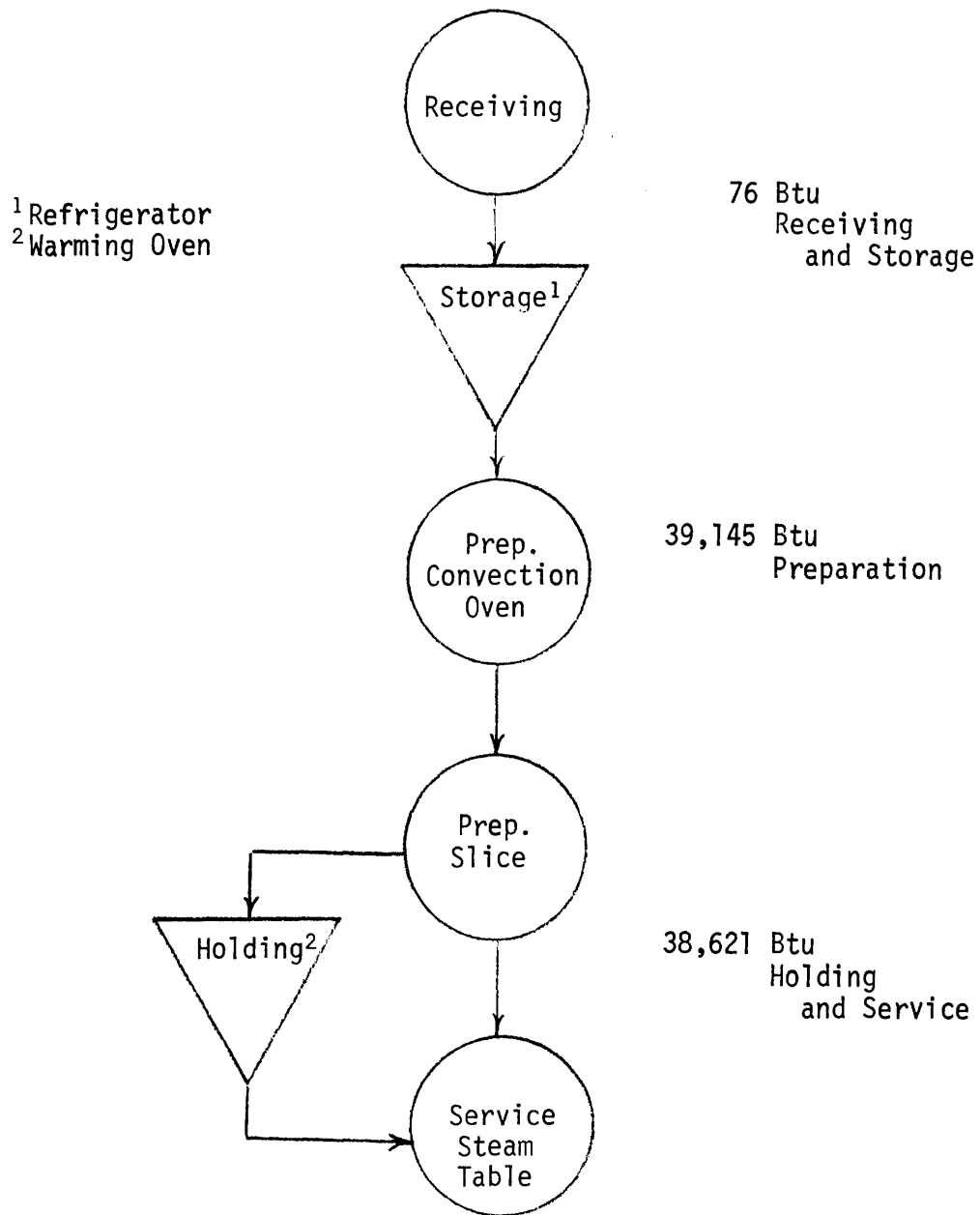
186,652 Mean Total Btu: 2,356 Btu/Kg. Roast Beef

Figure 9. Sequential Energy Consumption through the Food Product Flow for Roast Beef (800 Servings) (76 kilograms)



175,487 Mean Total Btu: 2,031 Btu/Kg. Meatloaf (Rotary Oven)
 127,794 Mean Total Btu: 1,479 Btu/Kg. Meatloaf (Convection Oven)

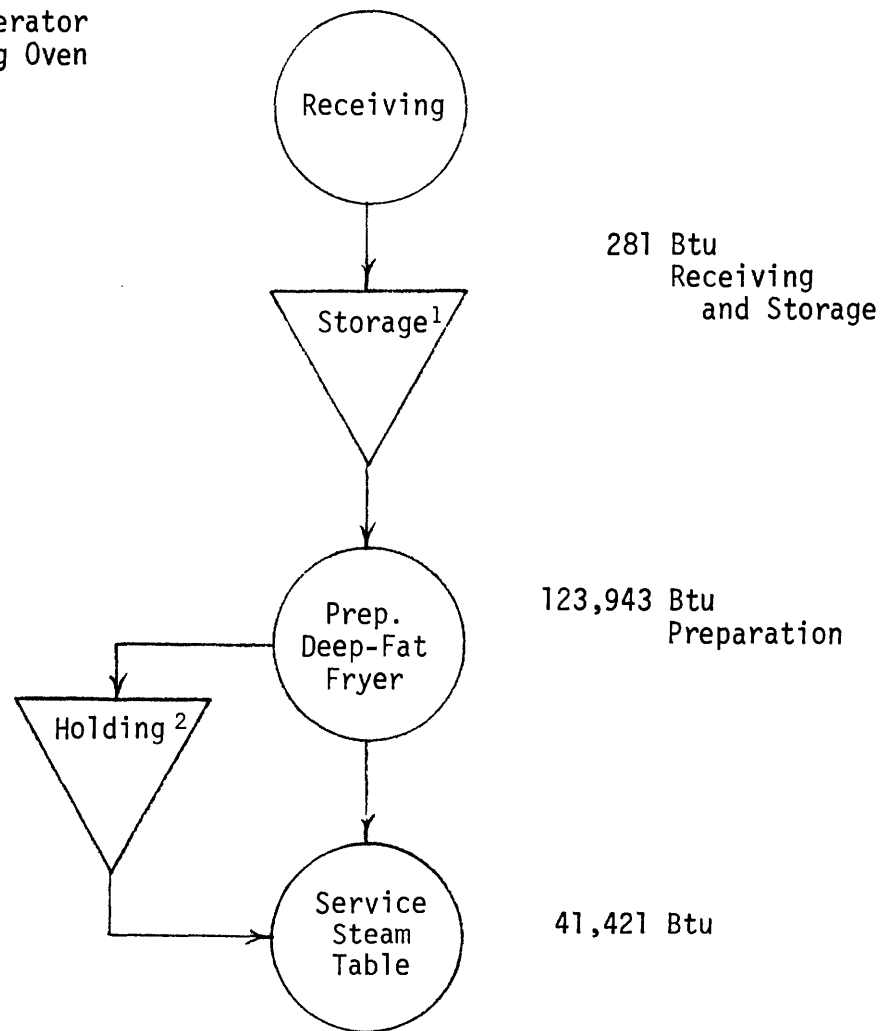
Figure 10. Sequential Energy Consumption through the Food Product Flow for Meatloaf (720 Servings) (86.4 kilograms)



77,842 Mean Total Btu: 6,769 Btu/Kg. Baked Ham

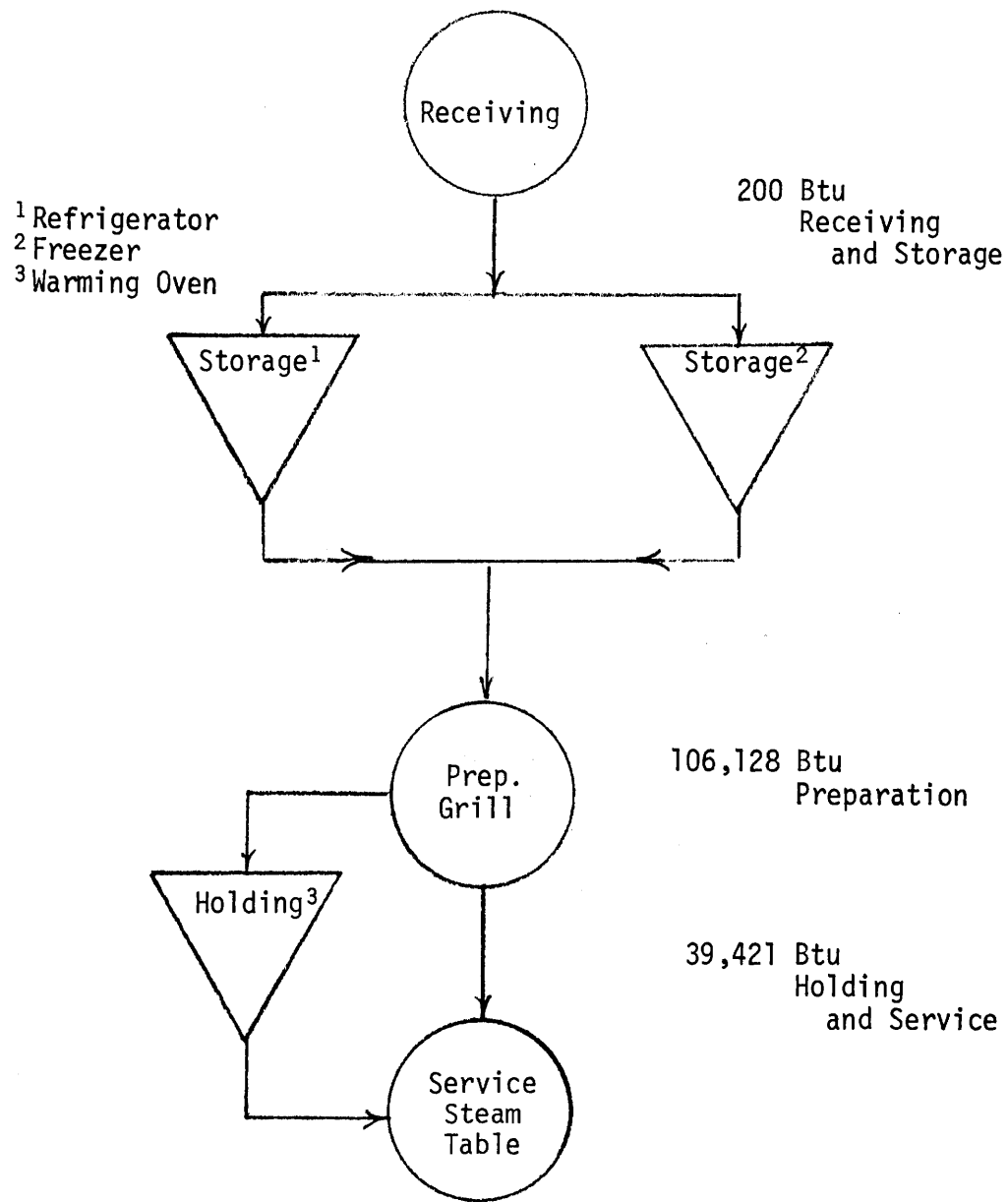
Figure 11. Sequential Energy Consumption through the Food Product Flow for Baked Ham (480 Servings) (11.5 kilograms)

¹ Refrigerator
² Warming Oven



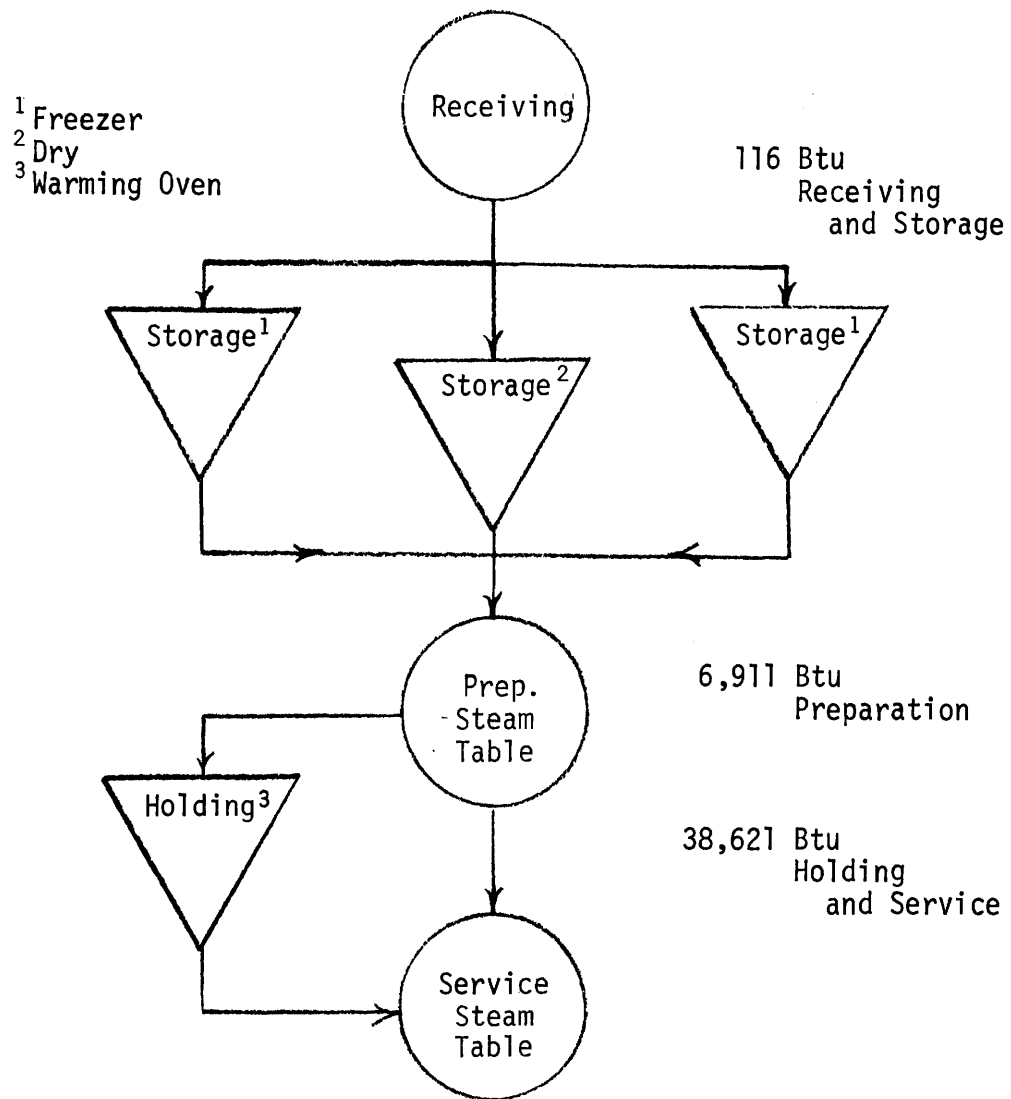
165,645 Mean Total Btu: 1,684 Btu/Kg. Fried Chicken

Figure 12. Sequential Energy Consumption through the Food Product Flow for Fried Chicken (720 Servings) (98.4 kilograms)



145,749 Mean Total Btu: 1,388 Btu/Kg. Egg Product

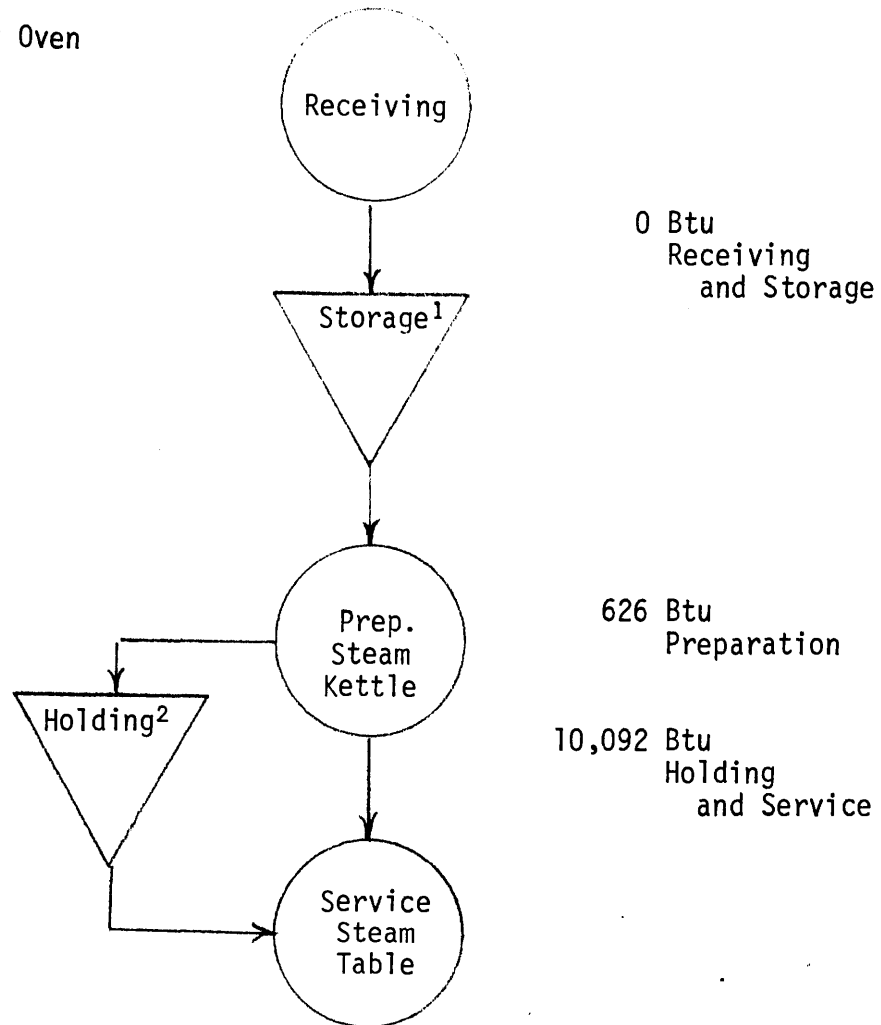
Figure 13. Sequential Energy Consumption through the Food Product Flow for Egg Products (1,100 Servings) (105 kilograms)



45,648 Mean Total Btu: 1,122 Btu/Kg. Corn-on-the-Cob

Figure 14. Sequential Energy Consumption through the Food Product Flow for Corn-on-the-Cob (600 Servings) (40.7 kilograms)

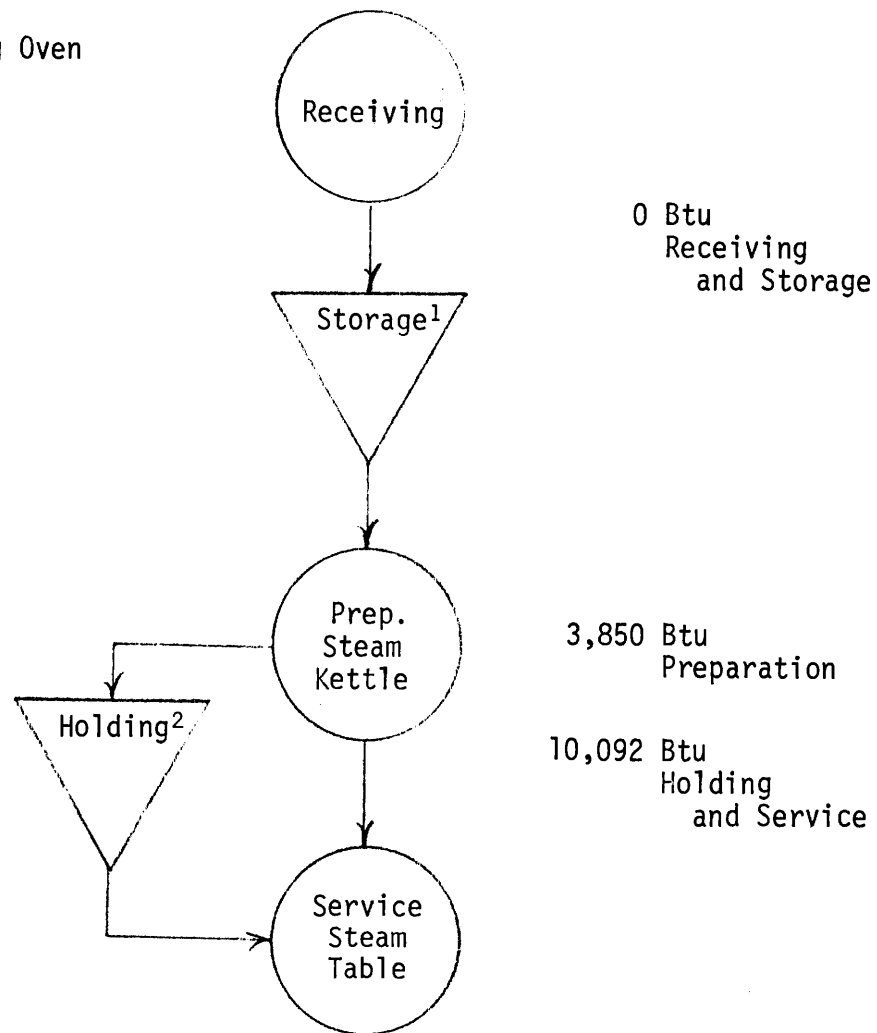
¹Dry
²Warming Oven



10,718 Mean Total Btu: 1,340 Btu/Kg. Oatmeal

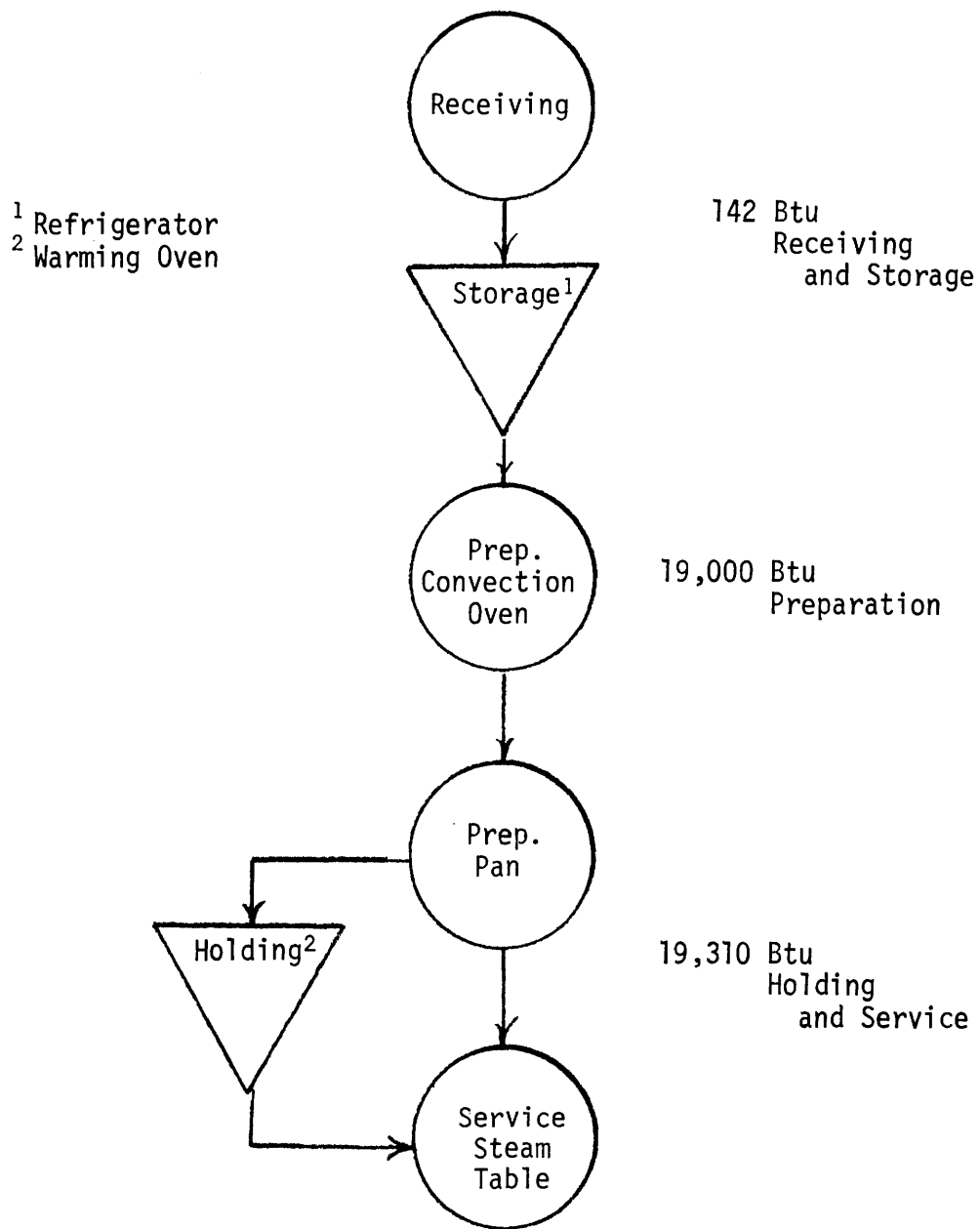
Figure 15. Sequential Energy Consumption through the Food Product Flow for Oatmeal (70 Servings) (8 kilograms)

¹Dry
²Warming Oven



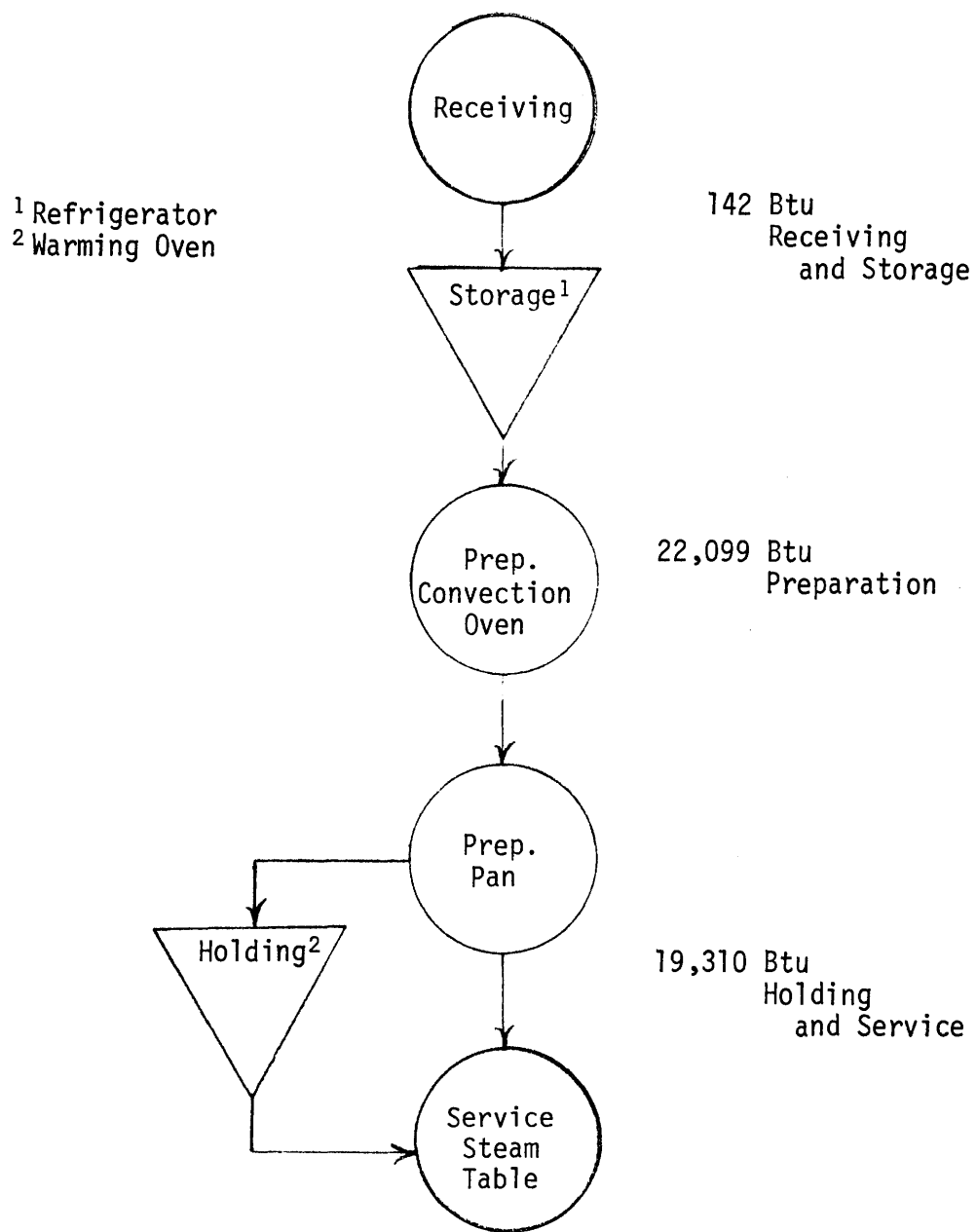
13,939 Mean Total Btu: 528 Btu/Kg. Vegetable Soup

Figure 16. Sequential Energy Consumption through the Food Product Flow for Vegetable Soup (110 Servings) (26.4 kilograms)



38,452 Mean Total Btu: 4,005 Btu/Kg. Bacon

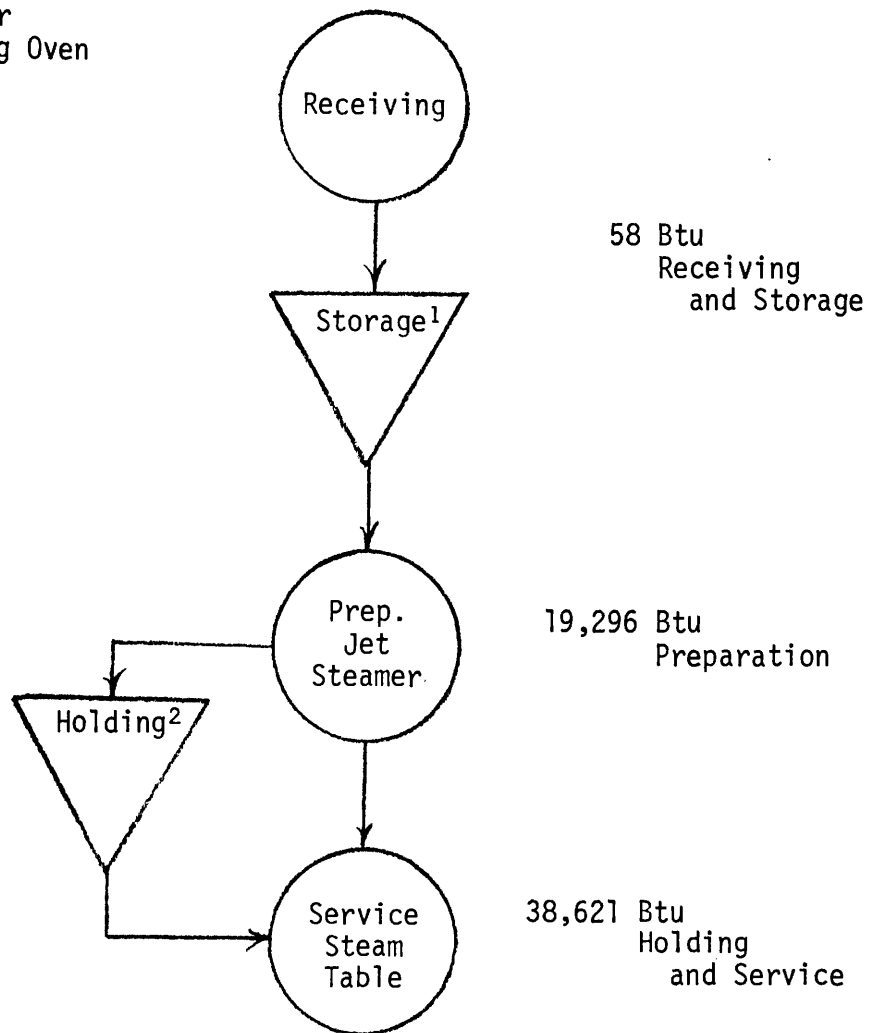
Figure 17. Sequential Energy Consumption through the Food Product Flow for Bacon (975 Servings) (9.6 kilograms)



41,551 Mean Total Btu: 4,328 Btu/Kg. Sausage

Figure 18. Sequential Energy Consumption through the Food Product Flow for Sausage (125 Servings) (9.6 kilograms)

¹Freezer
²Warming Oven



57,975 Mean Total Btu: 1,611 Btu/Kg. Peas

Figure 19. Sequential Energy Consumption through the Food Product Flow for Green Peas (300 Servings) (36 kilograms)

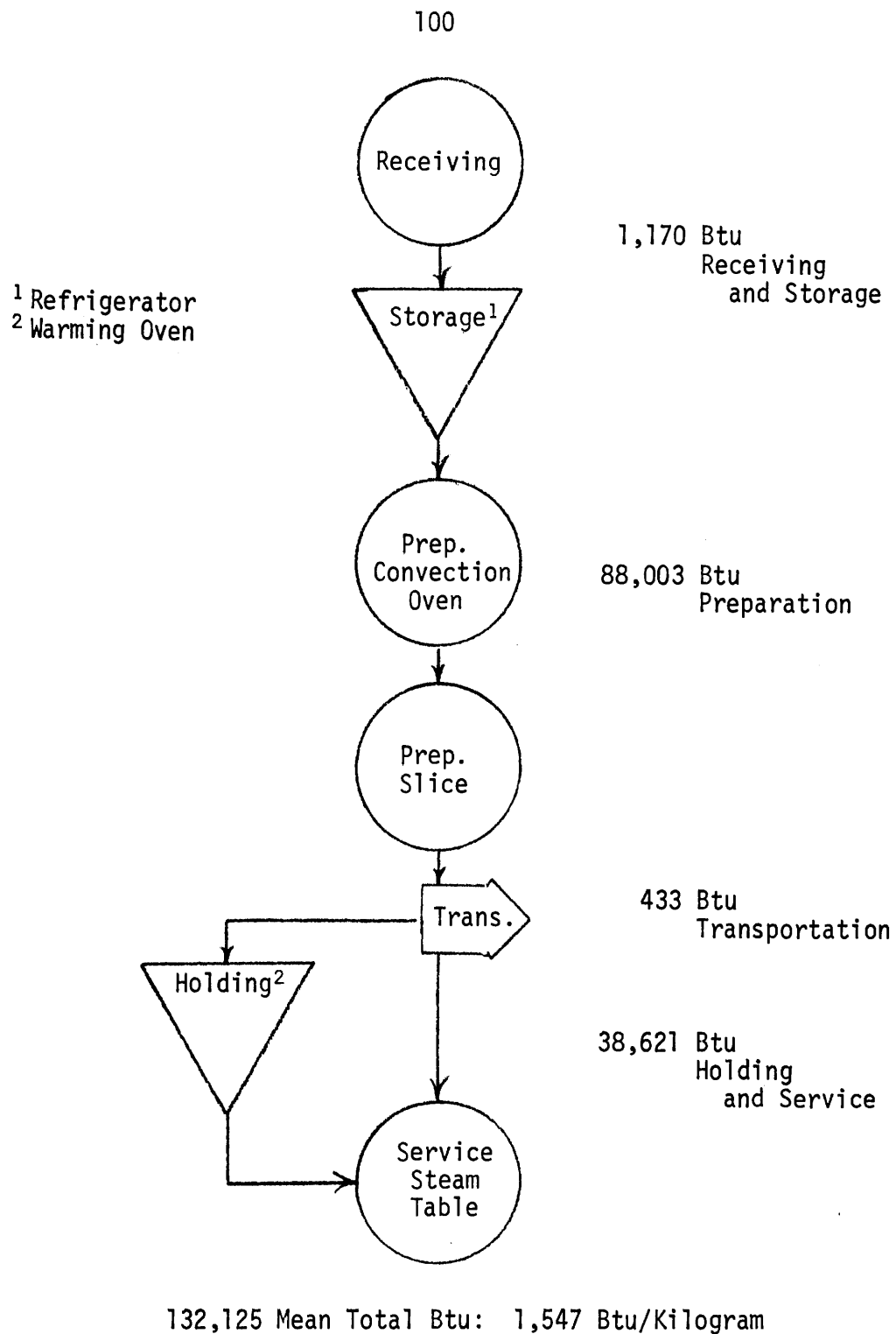


Figure 20. Sequential Energy Consumption through the Food Product Flow for Meatloaf in the Commissary System (720 Servings) (86.4 kilograms)

¹Freezer
²Warming Oven

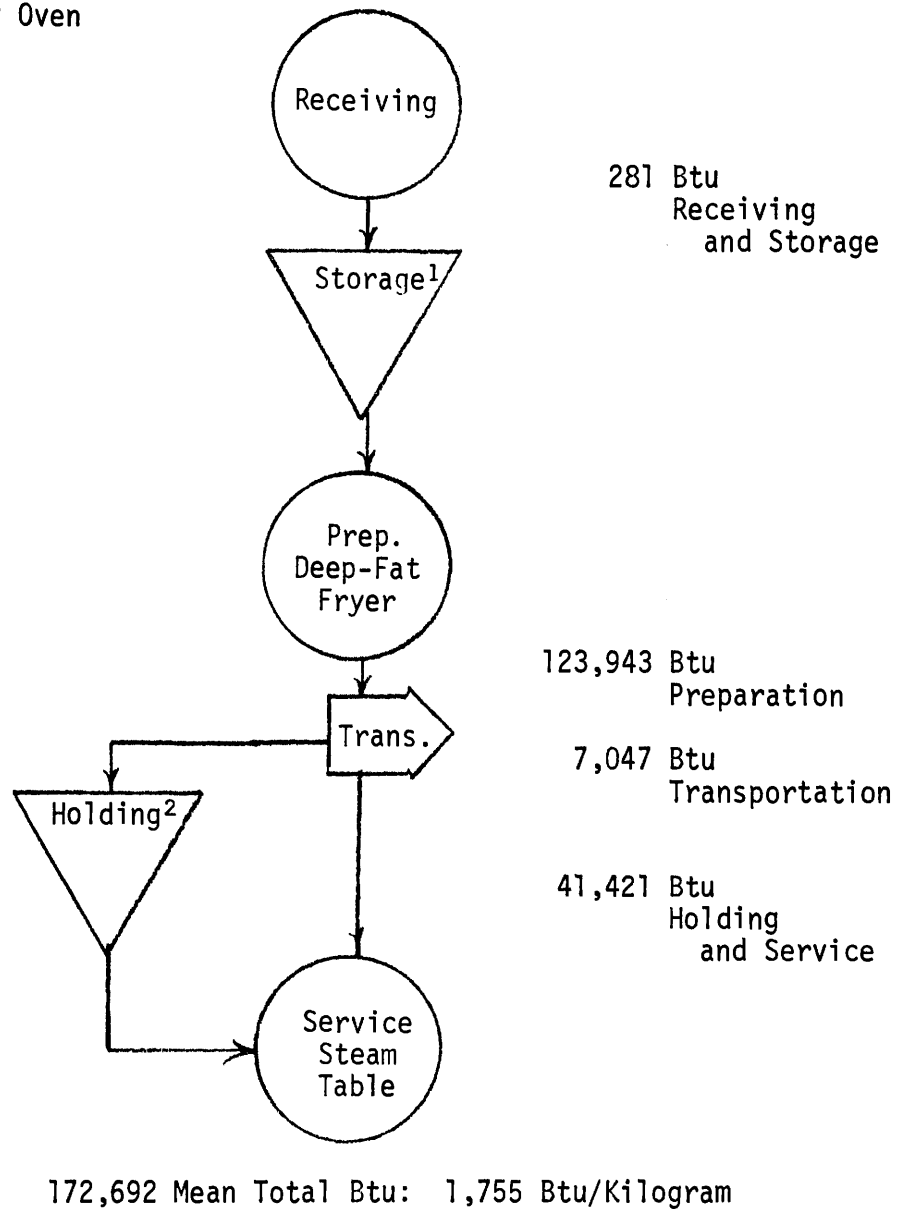
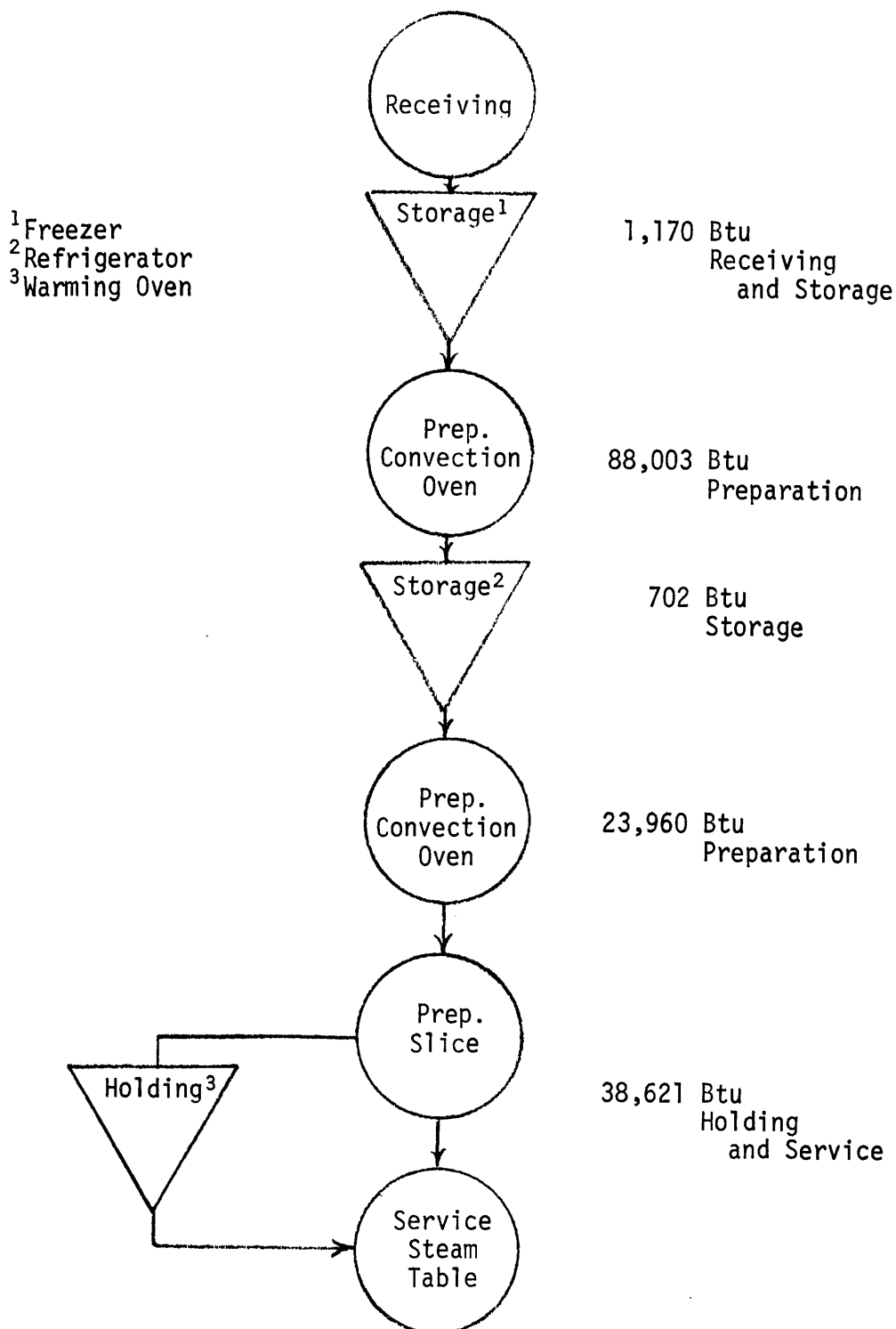
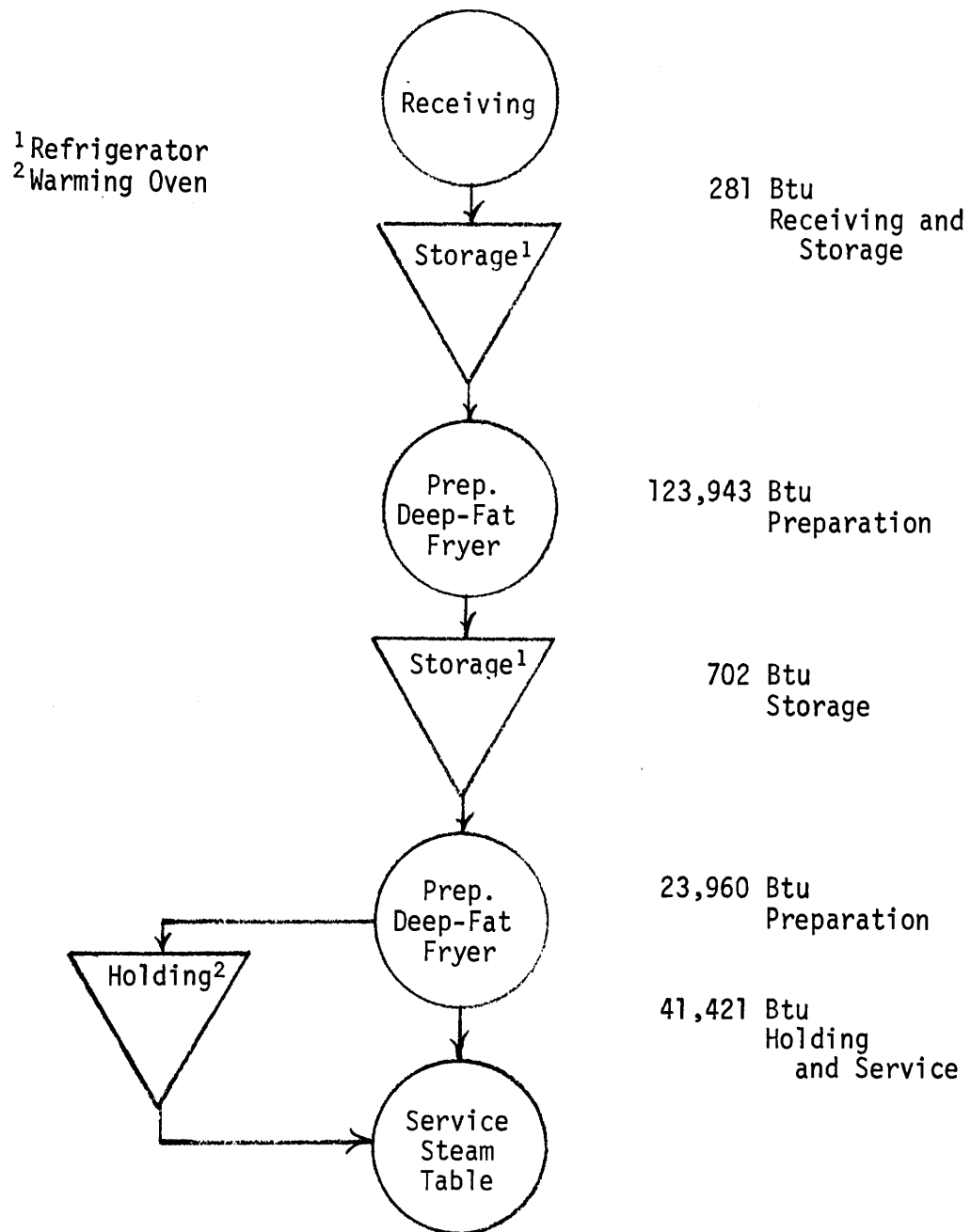


Figure 21. Sequential Energy Consumption through the Food Product Flow for Fried Chicken in the Commissary System (720 Servings) (98.4 kilograms)



190,307 Mean Total Btu: 1,743 Btu/Kilogram

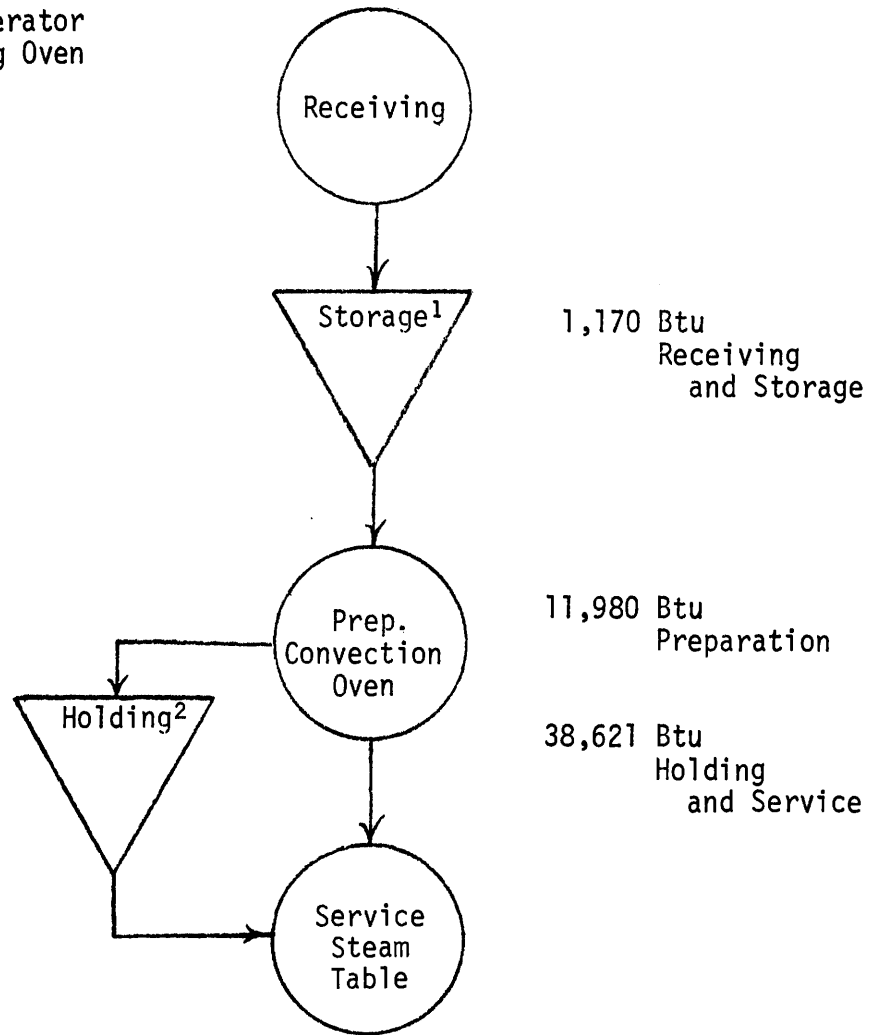
Figure 22. Sequential Energy Consumption through the Food Product Flow for Fried Chicken in a Ready-Prepared (Cook/Chill) System (720 Servings) (98.4 kilograms)



150,584 Mean Total Btu: 1,934 Btu/Kilogram

Figure 23. Sequential Energy Consumption through the Food Product Flow for Meatloaf in a Ready-Prepared (Cook/Chill) System (720 Servings) (86.4 kilograms)

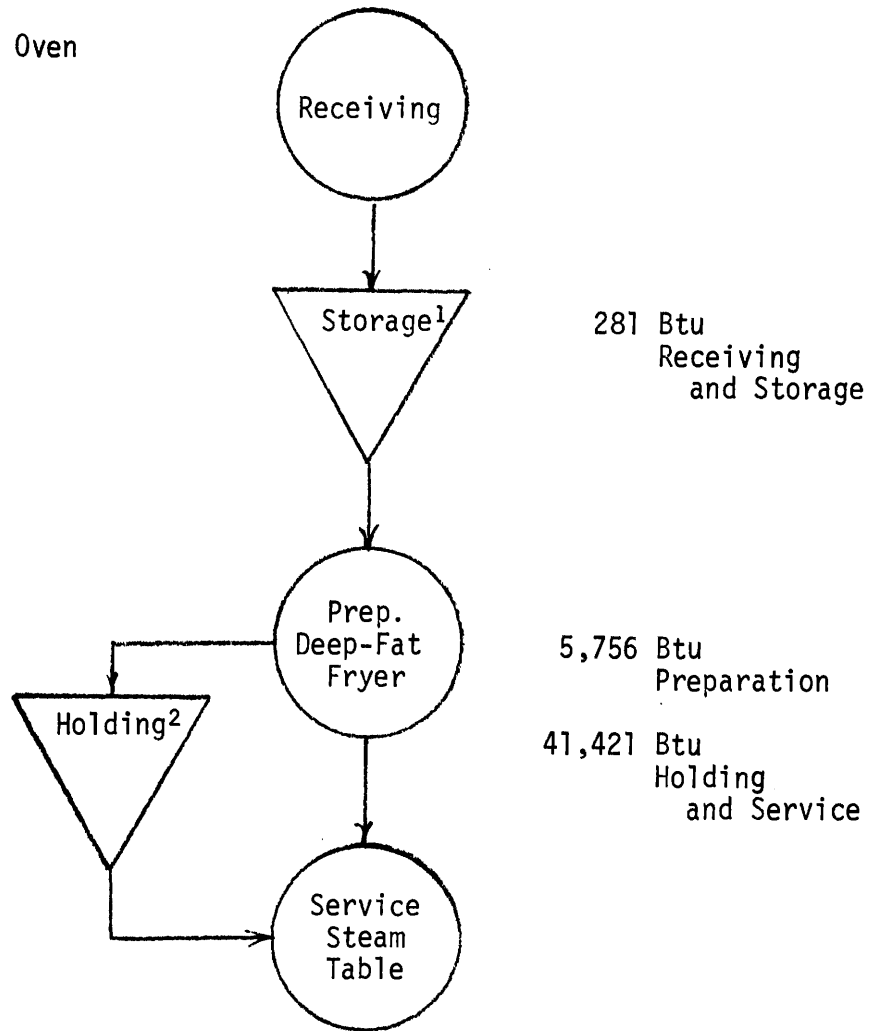
¹ Refrigerator
² Warming Oven



51,771 Mean Total Btu: 599 Btu/Kilogram

Figure 24. Sequential Energy Consumption through the Food Product Flow for Meatloaf in an Assembly-Serve System (720 Servings) (86.4 kilograms)

¹Freezer
²Warming Oven



47,458 Mean Total Btu: 482 Btu/Kilogram

Figure 25. Sequential Energy Consumption through the Food Product Flow for Fried Chicken in an Assembly-Serve System (720 Servings) (98.4 kilograms)

APPENDIX E

DURATION OF EQUIPMENT UTILIZATION

Table 10. Foodservice Areas, Associated Equipment and Time of Equipment Usage per Menu Item in the Conventional Foodservice System

Product	Foodservice Area	Equipment	Hours of Equipment Usage
Roast Beef	Receiving and Storage Preparation	- Refrigerator	7.0
		- Refrigerator	14.0
		Rotary Oven	2.1
		Slicer	0.8
	Holding and Service	- Warming Oven Steam Table	3.5 3.7
Baked Ham	Receiving and Storage Preparation	- Refrigerator	19.7
		- Refrigerator	52.0
		Convection Oven	1.7
		Slicer	0.8
	Holding and Service	- Warming Oven Steam Table	3.5 3.7
Meatloaf	Receiving and Storage Preparation	- Refrigerator	40.0
		- Refrigerator	6.0
		Convection Oven	2.0
		(or Rotary Oven)	1.4
		Slicer	0.5
	Holding and Service	- Warming Oven Steam Table	3.5 3.7
Fried Chicken	Receiving and Storage Preparation	- Freezer	7.0
		- Freezer	22.0
		Deep-Fat Fryer	4.2
Egg Products	Receiving and Storage	- Warming Oven	4.0
		Steam Table	3.7
	Preparation	- Refrigerator	7.0
		Freezer	7.0
	Holding and Service	- Refrigerator	14.0
		Grill	5.5
Corn-on-the-Cob	Receiving and Storage Preparation	- Warming Oven	4.5
		Steam Table	4.0
		- Freezer	7.0
		- Freezer	18.0
		Steam Jacketed Kettle	0.5

TABLE 10 (continued)

Product	Foodservice Area		Hours of Equipment Usage
Corn-on-the-Cob	Holding and Service	- Warming Oven	3.5
		Steam Table	3.7
Cereals	Receiving and Storage Preparation	- Dry Storage	-
		- Dry Storage	-
		Steam Jacketed Kettle	0.3
	Holding and Service	- Warming Oven Steam Table	4.0 4.0
Bacon	Receiving and Storage Preparation	- Refrigerator	9.0
		- Refrigerator	33.0
		Convection Oven	0.5
	Holding and Service	- Warming Oven Steam Table	3.5 3.0
Sausage	Receiving and Storage Preparation	- Refrigerator	9.0
		- Refrigerator	33.0
		Convection Oven	0.8
	Holding and Service	- Warming Oven Steam Table	1.8 3.0
Green Peas	Receiving and Storage Preparation	- Freezer	7.0
		- Freezer	18.0
		Jet Steamer	0.2
	Holding and Service	- Warming Oven Steam Table	1.8 3.0

VITA

Martha Jane Ault Barclay was born in Warren County, Illinois, on July 5, 1948. She graduated from Roseville High School in May, 1966. She earned a Bachelor of Science degree, majoring in foods and nutrition, from the University of Illinois in June, 1970. She completed a dietetic internship at the Indiana University Medical Center in Indianapolis, Indiana, in December, 1970. She was granted a Master of Science degree in Education (Nutrition) from Indiana University in May, 1972.

She has been employed as a registered dietitian for over five years in various hospitals in administrative and clinical positions. The hospitals include Indiana University Medical Center, Barnes Hospital in St. Louis, Memorial Hospital in Belleville, Illinois; and St. Francis Medical Center in Peoria, Illinois. In 1976, she joined the faculty of Western Illinois University as an instructor. She taught at Western Illinois University for one year before returning to complete her Ph.D. She has been employed six months as a graduate teaching assistant in the University of Tennessee-Knoxville Food Science, Nutrition, and Food Systems Administration Department in the College of Home Economics. She is currently a research associate at the University of Tennessee Energy, Environment, and Resources Center.

Martha is married to Lawson Barclay of Macomb, Illinois. Her parents are Mr. and Mrs. George L. Ault of Roseville, Illinois.