ENERGY AUDITS IN MEAT PROCESSING OPERATIONS

by

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Nearly everyone at this meeting would be classified as an expert. Generally that would be considered good. However, the difficulty comes when you talk to experts in the *energy* field. If you pick a dozen experts in energy and ask about the level of the current energy crisis, you will get twelve different answers. Despite this uncertainty, *you* would probably all agree that the energy situation is important to your group. In dealing with food production, energy is a significant factor, and will become more so.

With the rising energy costs, the experts will generally agree on two facts: 1. energy costs are going to go up and 2. spot problems will be in certain areas where energy sources will be in short supply.

Plant Sizes Vary

The meat packing industry should be very concerned about any potential energy shortage. Approximately 90 trillion Btu's are used annually in this country in meat processing, in order to produce 31 billion pounds of meat product. One difficulty in evaluating these data is the great diversity of plant sizes and types. For instance, 2/3 of the plants have less than 20 employees and produce about 4% of the total U.S. meat products. Only 6% of the plants employ over 250 people each, but the output of these plants make up 60% of the total production.

Type of Products Vary

In addition to a great variety of plant sizes, considerable variance in the type of products are found. Estimates of energy usage run from 750 Btu's per pound for fresh cuts of meat to as much as 12,000 Btu's for sausage. This great diversity still adds up to a high energy use for meat packing. This in turn means much expense, and much difficulty if the needed energy cannot be obtained.

"Typical Plants" Studied

Typical plants use an average of 1,000 to 5,000 Btu's per pound. The term "typical plant" illustrates one of the problems that currently exist. Much of the work in the past has had to deal with overall averages for plants, or with overall industry averages. A limited amount of energy data has been available on specific products or on specific unit operations. This situation led to Purdue's interest in energy usage in meat packing. The Agricultural Engineering department is conducting a project for the Department of Energy, involving monitoring of two typical meat plants on a unit by unit basis. From these data can be compiled energy usage on a product by product basis also. This will be desirable basic information, and relatively easy to adjust for specific plant types and sizes.

The procedure used for this project was to gather all data directly from in-plant measurements. The initial step was to review the actual plant operation steps to estimate energy flow rates. Energy balances were calculated from these data to check the estimates. From these estimates, the types and sizes of metering and monitoring equipment were selected.

Problems developed when the initial metering installations were made. Actual measurements showed the original estimates to be in error by as much as 300%. Unfortunately, this variance indicates that standard engineering techniques cannot be safely used for accurate estimates of energy flows in meat plants. Too many variables and too many unknowns are present. These estimates are adequate for equipment selection, however.

Significant problems were encountered with the original metering equipment. If individual plants or individual researchers start a metering program, this will likely be a difficult area.

The original turbine meters selected were advertized and sold for use with steam. However, typical operating life in the plants was on the order of one hour. Condensate in the steam lines would destroy the turbines almost immediately. Vortex shedding meters were selected to replace the turbine meters.

The measurement equipment found to be satisfactory for the Purdue study included Neptune/Eastech vortex shedding flow meters for gas and for steam. For water, Mead turbine flow meters were selected where continuous monitoring was required. In many

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cases, Rockwell totalizing meters were satisfactory where daily total water flow would suffice. These meters were also used on glycol measurement for refrigeration streams. Temperatures were measured with RTD's (resistance temperature devices). All of the information was transmitted by wire to a central multiplexer. The multiplexer converted the data from analog to digital form, and fed the data to a small computer.

The data collection required an exceptional amount of cooperation from the individual plants. The extensive wiring installation caused interference with maintenance and production schedules. In addition, the installation had to fit meat plant sanitation requirements.

About 40% of the vortex shedding meters were inoperative as received. This was unfortunately typical of much of the instrumentation purchased for this project. Four of the five multiplex units did not function properly when first delivered. Generally the microcomputers functioned well.

The use of microcomputers was not necessary to the data collection, but greatly extended the amount of data that could be obtained.

Once the full instrumentation was available, students from Purdue spent the summer in the plants supervising the installation of the equipment and calibrating the system.

Also during this time the electrical data were collected. Electrical measurements were made with portable Amprobe recorders. Many more points could be measured this way than with fixed installations. Many typical motors in the plant were selected and monitored through full operating cycles.

All of the other data, which was fed to the microcomputer, were collected over a several month period. The microcomputer operated unattended, recording processed data onto a floppy disc. The data could then be picked up on a weekly basis.

The various problems encountered with the measurement equipment did not prevent obtaining high quality data, but they did make obtaining these data relatively difficult.

The data for the individual unit operations were used to calculate the energy usage totals for process steps. For example, Table 1 shows the information for the kill floor.

The data in Table 1 have been grouped into sections of "stun" through "chill." Note that the steam usage is divided into two categories: process and sanitation. In some cases, sanitation covers more than one processing activity. This is because these activities take place in the same general area, and the sanitation usage covers that whole physical area. Steam is a major energy factor on the kill floor, primarily due to use of steam to heat the scald tank. The large gas use shown is for the direct flame singeing used. As expected, refrigeration usage is high due to the carcass chilling.

Figure 1 is the flow chart for bacon processing by the batch method.

This flow chart is typical of these drawn for each process. Each step in the process is laid out. Then for each step the steam, electricity, gas, water and refrigeration flow in and out were totaled. These totals were then used to generate the summary tables shown in this paper. Table 2 is the energy use summary table for batch processing of bacon.

Note the large amount of gas used for smoking and refrigeration used for chilling. A considerable amount of steam is used for sanitation in this process.

Frankfurters involved a more extensive evaluation than bacon. The flow chart in Figure 2 demonstrates this fact. In a smoke house there are many energy

TABLE 1

OPERATION	ELECTRICITY BTU	STEAM PROCESS BTU	STEAM SANITATION BTU	REFRIGERATION BTU	GAS BTU
STUN, BLEED, SCALD	0.70	50	8.2		
DEHAIR	2.6	120	13.0		76
EVISCERATE	0.20	0.50			
SPLIT BACKS AND PULL LARD	0.32	0.19	15.0 (Split backs and pull lard, head table, shower)		
HEAD TABLE	0.34				
SHOWER	0.04				
CHILL CARCASS	23			76	

KILL FLOOR
BASIS: 1.0 POUND CHILLED CARCASS

TABLE 2

OPERATION	ELECTRICITY BTU	STEAM SANITATION BTU	REFRIGERATION BTU	GAS BTU
CURE	18	106 (Cure through package)	239	
SMOKE	48			274
SKIN	0.4			
CHILL AND TEMPER	11		87	
PACKAGE	72		81	

BACON
BASIS: 1.0 POUND BACON PACKED

BACON PROCESSING

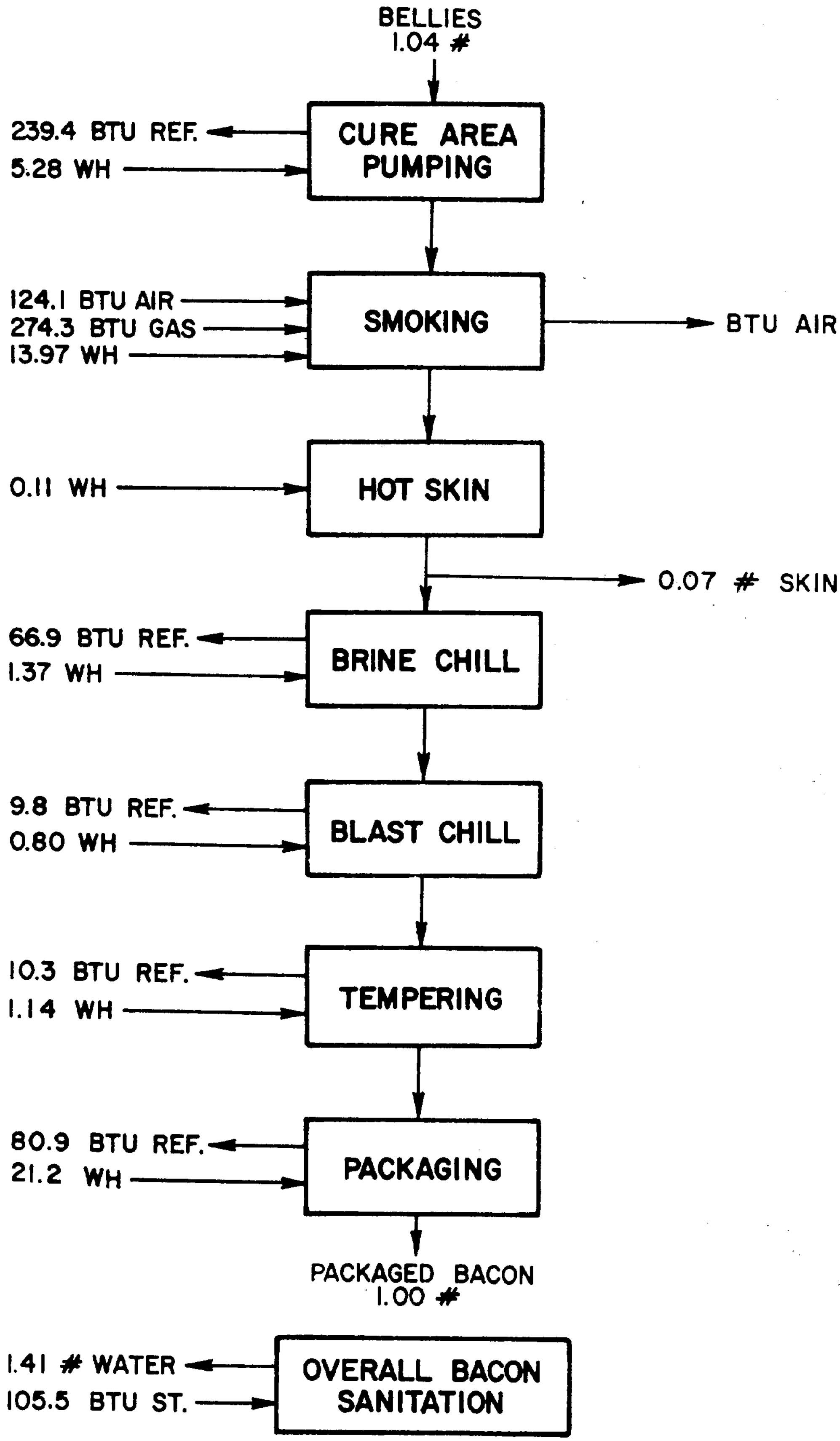

FIGURE 1

flows to measure. Table 3 shows the results of these measurements.

Approximately 25 percent more energy is used per pound of frankfurters as compared to bacon. Frankfurters require more steam for sanitation and more refrigeration, but slightly less gas. It is relatively expensive to produce frankfurters in terms of energy consumption.

At the second plant, the frankfurter production was done in a continuous process. Data from this operation gave a comparison to the batch process. Table 4 shows the data.

The major difference noted in the comparison between batch and continuous frankfurter production was that much more energy was used for continuous production. The increased energy usage was the trade-off for reduced labor usage. This type of trade-off must be carefully evaluated, especially in consideration of a new plant. Research is needed on methods of operating labor-efficient processes without greatly increasing energy consumption.

Various rendering processes were examined. It was found that rendering was a very high consumer of energy. Table 5 shows data for edible rendering.

As shown in Table 5, very large quantities of steam are used in the lard processing in edible rendering. This is the major energy usage in the process. Other forms of energy are used at considerably lower levels.

TABLE 3

OPERATION	ELECTRICITY BTU	STEAM PROCESS BTU	STEAM SANITATION BTU	REFRIGERATION BTU	GAS BTU
GRIND AND BLEND	16	77			
EMULSIFY AND STUFF	61				
SAUSAGE KITCHEN	25		205	324	
SMOKE	22	4.6			184
COOL AND CHILL	16			54	
PEEL AND PACK	23	3.0		155	

FRANKFURTER PROCESSING
BASIS: 1.0 POUND FRANKS PACKED

TABLE 4

METHOD	ELECTRICITY BTU	STEAM PROCESS BTU	STEAM SANITATION BTU	REFRIGERATION BTU	GAS BTU
BATCH	163	85	205	533	184
CONTINUOUS	134	205	205	501	421

CONTINUOUS VS. BATCH FRANKFURTER PRODUCTION
BASIS: 1.0 POUND FRANKS PACKED

Table 6 gives comparable data for inedible trim rendering. Huge amounts of energy are used in this process. The cooking step uses very large amounts of steam. In this process, the sanitation needs are high also. Steam is used at high levels for wash-down hot water.

Because preliminary estimates indicated that sanitation energy needs would be significant, particular attention was given to this area. Plant personnel gave guidance as to which wash-down stations were typical. The wash-down stations were of the steam-water mix type. Both steam and water on the selected stations were metered, generally with totalizing meters. This information enabled calculating the average wash-down energy usage. The students in the plant during the summer verified that the selected stations were representative.

Hair hydrolyzing also uses large quantities of energy, as shown in Table 7. This is not surprising, since hair is a very low density product. Energy figures on the basis of Btu's per pound of dry hair are leveraged by the low density.

The next table deals with process efficiencies. A problem arises when efficiency is discussed. Several

TABLE 5

OPERATION	ELECTRICITY BTU	STEAM PROCESS BTU	STEAM SANITATION BTU	WATER POUNDS
GRIND AND LOAD	12.6			
COOK		1300		
LOAD AND COOK SANITATION			48	0.64
CENTRIFUGE	2.7			
SEPARATE AND STORAGE SANITATION			16	0.22

EDIBLE RENDERING
BASIS: 1.0 POUND OF LARD

TABLE 6

OPERATION	ELECTRICITY BTU	STEAM PROCESS BTU	STEAM SANITATION BTU	WATER POUNDS
PREBREAK	48			
COOK	96	8100		
PERCOLATION	13			
EXPELLER (CRAX)	44			
MILL (CRAX)	32			
WASH (GREASE)		82		0.47
SANITATION			590	7.9

INEDIBLE RENDERING (INEDIBLE TRIM)
BASIS: 1.0 POUND GREASE (1.43 POUNDS CRAX)

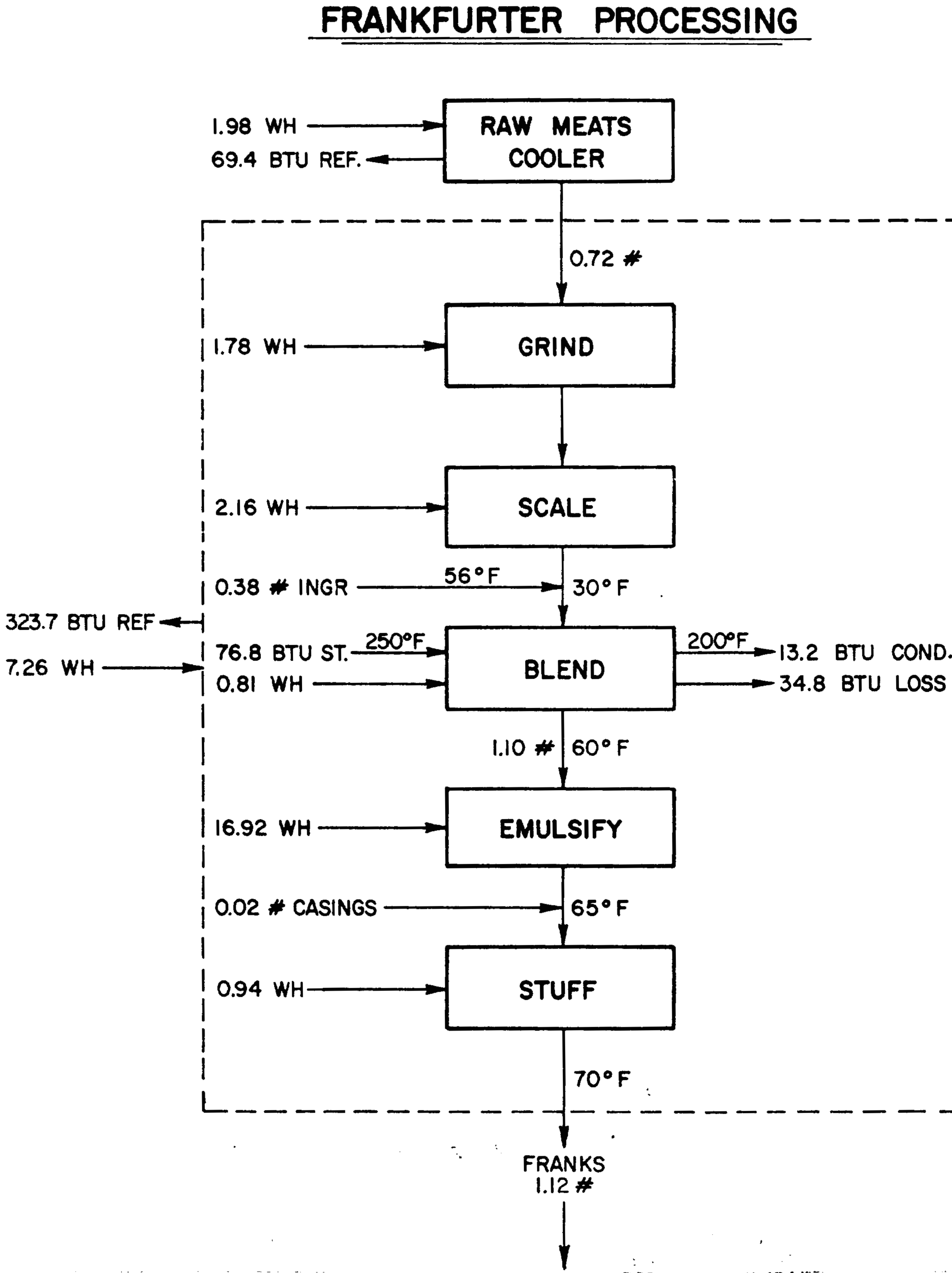
FRANKFURTER PROCESSING
1.98 WH
69.4 BTU REF.
RAW MEATS COOLER
0.72 #
1.78 WH
GRIND
2.16 WH
SCALE
0.38 # INGR
56°F
30°F
323.7 BTU REF
7.26 WH
76.8 BTU ST.
250°F
0.81 WH
BLEND
200°F
13.2 BTU COND.
34.8 BTU LOSS
1.10 #
60°F
16.92 WH
EMULSIFY
0.02 # CASINGS
65°F
0.94 WH
STUFF
70°F
FRANKS 1.12 #

FIGURE 2

FRANKFURTER PROCESSING
(Cont.)

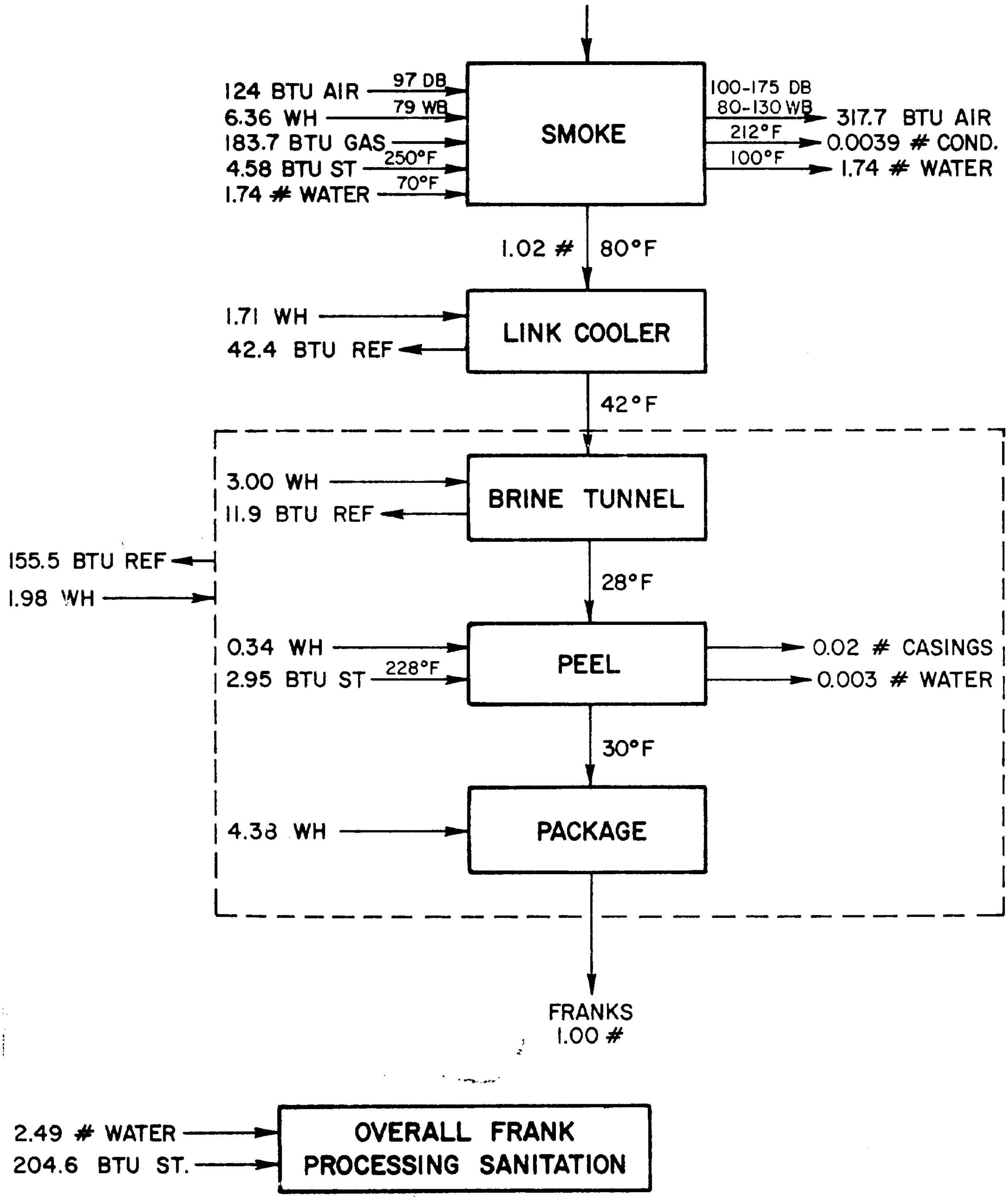

FIGURE 2 (continued)

definitions for efficiency can legitimately be used, and each may be useful for different purposes. Efficiency in this case is chosen to compare energy that actually goes into the product to the energy supplied to that processing operation. This definition is useful in evaluating plant efficiency, but will give low numbers. For example, most of the energy supplied to a smoke house is vented to the atmosphere. However, this venting is used as one means of controlling the humidity in the smoke house.

The definition of energy used here gives an insight into the fact that the potential for energy reduction is large. The numbers in Table 8 demonstrate this. However, these numbers are not representative of the actual degree of potential. In many cases, the best available technology will not give anywhere near 100% efficiency.

One important consideration in evaluating the data in Table 8 is that the efficiencies are based on energy delivered to the process. This does not take into account that steam generating efficiency is usually below 85%. Nor are the losses in a typical distribution system included.

The basic information collected described what energy is being used, and what potentials exist. The next step was then to evaluate various methods of energy conservation. Basically these fall into two categories: 1. Recovery of energy now being lost and 2. Process or equipment modification to reduce energy usage.

Hog singeing gives a good example of where energy recovery can be effective. Most of the waste heat goes out the vent stack. The quantity of heat and temperature of the exhaust are suitable for recovery using an air to water heat exchanger. The recovered heat can be used for several purposes. Hot water for clean up is an obvious choice. Another potential use is to supply hot water for the scald tank. The physical location of the scald tank is usually close to the singeing operation.

Recovery of heat from the smoke house exhaust is a similar opportunity. Nearly any process that discharges waste heat can be examined in terms of potential heat recovery.

A heat pump is one means of transferring heat from a waste stream to a process use. Three methods of producing hot water for sanitation were evaluated. Table 9 shows the results.

Refrigeration equipment in a meat processing plant usually discharges the heat to the atmosphere. Recovering this heat is an efficient means of providing hot sanitation water. A heat pump is efficient for 140°F, but its efficiency decreases rapidly as water temperature increases.

An example of alternate process equipment is modification of a smoke house. Table 10 shows the total energy used for a conventional batch house as measured by the Purdue project, energy calculated for a closed loop batch house, and energy calculated for an "ideal" continuous system. This last system would use warm water from the water shower to heat incoming frankfurters and a heat pump for additional heat recovery. This may not be a feasible system, but demonstrates the potential that should exist.

TABLE 7

OPERATION	ELECTRICITY BTU	STEAM PROCESS BTU	STEAM SANITATION BTU	WATER POUNDS
LOAD	13			
HYDROLYZE	48	4400		
DRY	72	2100		
MILL	8.2			
SANITATION			160	2.1

INEDIBLE RENDERING (HAIR)
BASIS: 1.0 POUND DRIED HYDROLYZED HAIR

TABLE 8

OPERATION	ENERGY SUPPLIED BTU/LB	ENERGY USED BTU/LB	EFFICIENCY
KILL FLOOR	370	63	20%
FRANKFURTERS	1,180	67	6%
BACON	590	132	22%
LARD	1,380	162	12%
HYDROLYZED HAIR	6,800	660	10%
DRY BLOOD	11,700	670	6%
WHITE GREASE	9,000	1,288	14%

PROCESSING ENERGY EFFICIENCIES

TABLE 9

METHOD	COST per 1000 gallons
REFRIGERATION HEAT RECOVERY	$2.81
HEAT PUMP (75°F source)	$3.14
STEAM BOILER	$5.00

HOT WATER COSTS
(140°F Water)

TABLE 10

TYPE	BTU PER POUND OF FINAL PRODUCT
CONVENTIONAL	342
CLOSED LOOP	194
IDEAL	131

SMOKE HOUSE COMPARISONS

Another example of a modified process is skinning versus scalding of pork. The Purdue Animal Science Department has estimated a 98% reduction in energy for this step by changing from scalding and singeing to skinning. Many more variables must of course be considered.

A major result of the Purdue study is a determination of those process areas where the most potential exists for energy conservation and reduction. Much of the basic data are applicable to various sized and type plants. These data then will reduce the amount of actual measurement that must be done at an individual plant. In addition, these data will significantly reduce the potential for error in selecting and sizing measuring equipment.

Each plant will have better tools to evaluate their own savings potential.