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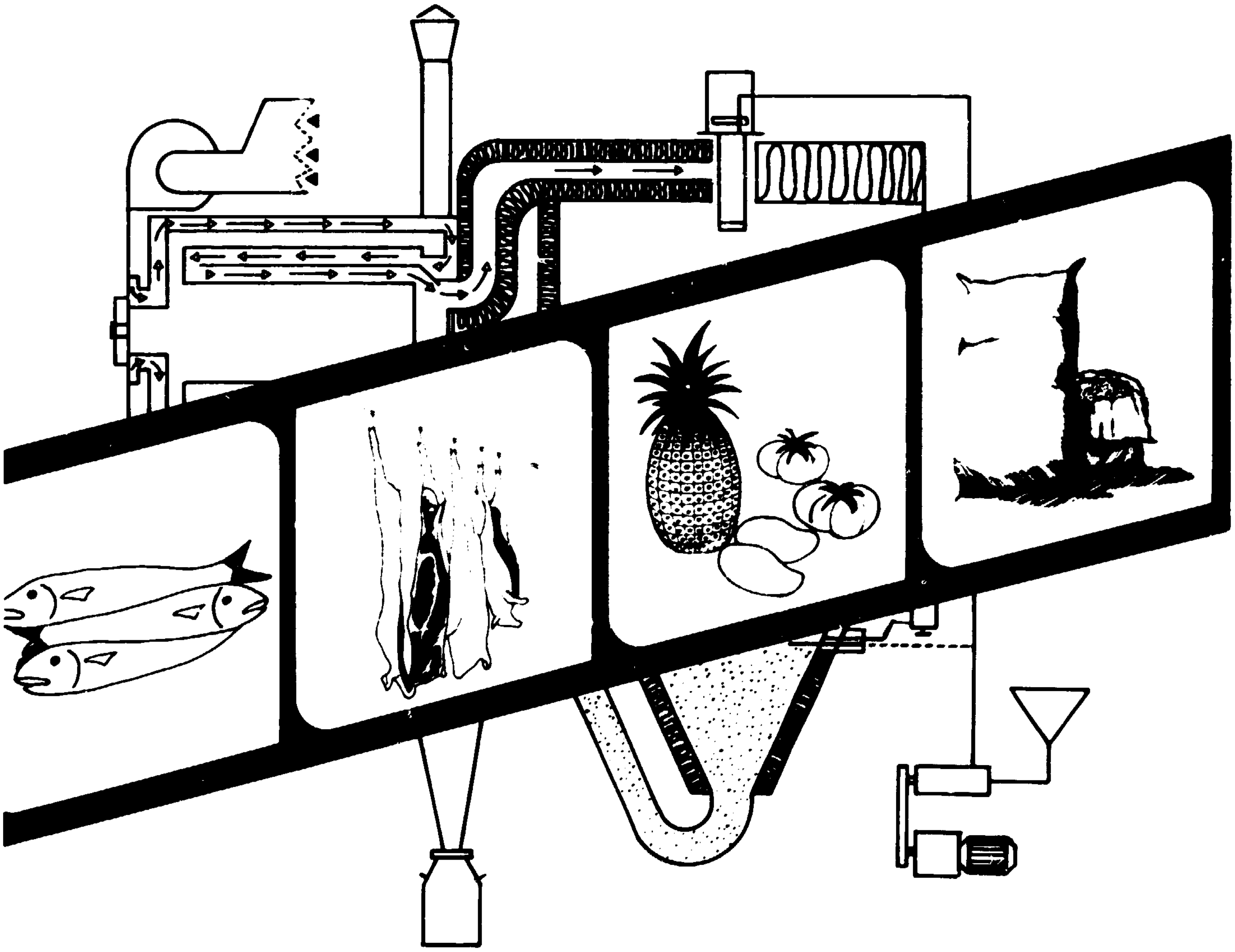
GUIDES TO ENERGY CONSERVATION IN THE FOOD PROCESSING INDUSTRY

1986



GUIDE SERIES ON EFFICIENT ENERGY USE

GUIDES TO ENERGY CONSERVATION IN THE FOOD PROCESSING INDUSTRY

Bureau of Energy Utilization
Ministry of Energy

National Engineering Center
University of the Philippines

U.P. Engineering Research and Development Foundation, Inc.

United Nations Industrial Development Organization

June 1986
Quezon City, Philippines

GUIDE SERIES ON EFFICENT ENERGY USE

1. Guides to Quick Estimates of Energy Costs for Industrial Use (May, 1985)
2. Guides to Retrofitting Oil-Fired Boilers, Kilns and Other Furnaces to Use Alternative Fuels (July, 1985)
3. Guides to Industrial Preventive Maintenance for Energy Conservation (April, 1986)
4. Guides to Energy Conservation in the Food Processing Industry (June, 1986)

This Guide Series is dedicated to providing industry handy references for the efficient and wise use of energy.

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MESSAGE

It is with pleasure that I convey my congratulations to the U.P. National Engineering Center, the U.P. Engineering Research and Development Foundation, Inc., the Bureau of Energy Utilization and the United Nations Industrial Development Organization as well as the private companies and individuals who participated in the development and publication of this handbook, "Guides to Energy Conservation in the Food Processing Industry", the fourth in the Guides Series on Efficient Energy Use.

I am heartened that the University is a part of this meaningful work, where the academe takes an active role in a collaborative effort with industry and the government for the ultimate benefit of the country.

The success of this project provides another strong argument in favor of expanding such cooperation in other areas of endeavor.

EDGARDO J. ANGARA

30 May 1986

FOREWORD

This book is intended to serve as a practical guide for plant engineers, supervisors and energy managers in the food processing industry for carrying out actions which would generate savings in electric bills and fuel costs.

The ultimate aim is to increase productivity and minimize wastage through the efficient and wise use of energy.

Chapter 1 gives a brief profile of energy consumption in the food processing industry and summarizes the energy conservation measures for thirteen types of equipment and systems covered in the manual.

Chapters 2 to 5 describe ways of conserving energy in the processing of fish, meat, fruits and vegetables, and grains. Each chapter starts with the identification of final food products derived from the commodity. This is followed by an analysis of energy use in the processes and equipment involved. Energy conservation potentials and measures are then listed down, accompanied by illustrative diagrams as necessary. A documentation of a successful case of energy conservation in a food plant rounds off the chapter.

Chapter 6 covers equipment commonly used in food processing plants, namely: boilers, steam systems, electric motors, compressed air systems, lighting systems and canning equipment. Specific procedures and techniques are given, as well as descriptions of needed capital improvements.

The appendices include some nomographs which can be used in estimating expected savings in energy costs, typical energy efficiencies of common equipments, energy engineering data, financial evaluation methods, tables on the SI system of units, guides and forms for conducting an energy audit and a directory of technical assistance centers which can provide energy conservation services.

It is hoped that this book will effectively serve its purpose as a practical guide for users in the food processing industry.

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CHAPTER 1

Introduction

1.1 ENERGY USE IN THE FOOD PROCESSING INDUSTRY

The food processing industry consists of all establishments engaged in the application of any physical, chemical or biological treatment to food from its raw materials to various consumer forms. The industry is the largest of all the manufacturing sectors in the Philippines accounting for at least 30% of the total gross output from 1956 to 1974. Due to its heterogeneity, the industry has been classified into various subsectors depending on the types of products manufactured.

Among the major industrial sectors, the industry ranks fourth in the consumption of petroleum products. In 1983 alone, the industry used 1.18 million barrels of fuel oil equivalent, accounting for 8.9% of the total industrial energy consumption.

Based on the National Census and Statistics Office's *1980 Annual Survey of Establishments*, (Reference 2), the industry has been categorized into:

1. Sugar Milling
2. Coconut and Vegetable Oil
3. Grain Products
4. Dairy Products
5. Coffee, Chocolate and Confectionery
6. Animal Feeds
7. Processed Fruits and Vegetables
8. Bakery Products
9. Meat Products
10. Fish Products

This manual focuses attention on the processing of fish, meat, fruits and vegetables, and grains. According to the survey mentioned above, a total of 19,739 establishments are engaged in the processing of these commodities. They compose 67% of the food manufacturing plants in the Philippines.

A useful index of performance in the use of energy is the specific energy consumption, in kWh or barrels of oil equivalent (BOE) per unit of product. If monitored periodically, it will indicate whether or not energy use is becoming more efficient. An example is the specific energy consumption for flour in 1984 which is 0.147 BOE/MT.

The steam requirements for various food products are individually estimated or known empirically to operators but little information has been published. The findings of a study to measure the consumption of steam in the packing of corn and tomatoes are shown in Table 1.1.

1.2 SUMMARY OF PROCESS EQUIPMENT AND ENERGY CONSERVATION MEASURES

The development of energy conservation measures and efficiency improvement targets for the food processing industry requires the evaluation of numerous operations and equipment in each industry subsector. Theoretically, many measures would conserve energy; the savings would be limited only by the laws of thermodynamics. However, only those determined to be technically feasible at the present are discussed here.

Table 1.1 Steam Required in Various Unit Operations
Source: Reference 3

Unit Operation	Equipment	Operating Demand, kg/h	Peak Demand kg/h	Steam Used Per Case, kg
Blanching	Reel Blancher	454	1,360	2.3-2.7
Blanching	Tubular blancher	544	1,360	2.3-2.7
Cooking	Open kettle, 60 min., 100°C	45-90	907	0.9-2.3
Concentrating	Open kettle, tomato puree –1.045	2,268	2,722	22(6-10's)*
Brine Heating	15.5 to 93.3°C	–	–	1.4
Exhausting	Steam exhaust, 1.2 x 6.1 m	227	227	1.4(6-10's)*
Retorting	Non-agitating			
	25 mm steam inlet	45-68	1,134	2.9
	32 mm	45-68	1,588	2.9
	38 mm	45-68	2,041	2.9
	50 mm	45-68	2,722	2.9
	Continuous pressure cooker	45-68	2,722	1.6-1.8

*

There are energy conservation measures that can be carried out just by improving maintenance and operating procedures. Some additional devices or capital improvements may be found immediately adoptable. Other additional equipment or improvements may be justified only through a financial evaluation study. Such study would require an estimation of the expected as given in the appendix. *Guides to Quick Estimates of Energy Costs for Industrial Use (May, 1985),* which is the first in a series of books on energy use of which this book is the fourth, is a useful reference in cost studies.

The following list shows the equipment types and systems covered in this manual:

a. freezers and cold storage systems
b. scalding tanks
c. evaporators
d. bottle washers
e. blanchers
f. can washers
g. exhausters
h. retorts
i. boilers
j. steam systems
k. electric motors
l. compressed air systems
m. lighting systems

A summary of actions for conserving energy is given below.

1.2.1 Freezers and Cold Storage Systems

a. Improving maintenance and operating procedures
   1. Reduce refrigeration load by deboning or removing unnecessary parts.
   2. Do not overcrowd the cold storage space as this would reduce convection heat transfer.
   3. Do not set temperature controls lower than necessary.
   4. Run large compressors at their rated capacity.

5. Cycle small freezer motors.
6. Adjust freezer motor capacity utilization.
7. Keep freezer doors closed most of the time.
8. For air blast freezers, place fans before the cooler to promote uniform air flow.
9. Limit the clearance between the fan and the casing to a few millimeters to prevent air recirculation.

b. Adding capital improvements to conserve energy

1. Improve insulation on doors and walls.
2. Use correct motors size to fit requirements.
3. Provide baffles around corners or where direction of air flow changes, to ensure uniform air distribution.

1.2.2 Scalding Tanks

1. Use direct heating of water for scalding, if possible, rather than steam-heating.
2. If steam must be utilized, use closed or indirect steam heating instead of direct mixing to enable condensate recovery.
3. Insulate the sides and bottom of the tank.
4. Minimize steam loss to the atmosphere.

1.2.3 Evaporators

1. Preheat the feed to improve the efficiency of the plant.
2. Use mechanical processes to minimize the moisture which has to be removed by evaporation.
3. Where applicable use multiple effect evaporators instead of single effect evaporators.
4. Investigate the use of a mechanical vapor recompression (MVR) evaporator to realize greater energy savings.
5. For plate evaporators, thermo-compression reduces the steam consumption significantly.

1.2.4 Bottle Washers

1. Recover the water from different stages of bottle washing, particularly the final rinse.
2. If possible, install a heat pump for heat recovery.

1.2.5 Blanchers

a. Improving maintenance and operating procedures

1. Control the residence time for blanching.
2. Minimize steam loss by using correct steam pressure which does not cause bubbling through the blancher water.
3. When applicable, use hot water instead of steam for blanching.

b. Adding capital improvements to conserve energy

1. Install and properly maintain thermostatic controllers.
2. Use proper size steam nozzles to ensure efficient heat transfer.
3. Insulate the blancher to prevent heat loss.
4. Provide strainer for inlet steam to avoid frequent purging.

1.2.6 Can Washers

1. Re-use hot water or steam generated from other processes.
2. Monitor and limit the use of hot water. Use flowmeters.
3. Recover waste heat.

1.2.7 Exhausters

1. Reduce the amount of steam escaping from the ends by decreasing the area of the openings.
2. Recover the condensate for hot water production.
3. Insulate hot external surfaces and steam lines.
4. If possible, use hot water for exhausting.

5. Where practicable, hot filling with sauces, oil, or brine should be done to reduce the heat requirement for exhausting.

1.2.8 Retorts

1. Insulate the retort.
2. Investigate the possibility of using drainings or condensate, venting steam and water from pressure cooling to produce re-usable hot water.
3. In aseptic canning operations, use product-to-product heat exchange.
4. Instead of steam venting, consider using vacuum pumps for removing air before retorting.
5. In continuous retorts, avoid preheating or venting too soon.
6. If compressed air for pressure cooling is used, check and eliminate air leaks.

1.2.9 Boilers

a. Improving maintenance and operating procedures
   1. Adjust burners for proper flame patterns.
   2. Monitor flue gas composition and temperature as often as necessary.
   3. Optimize combustion air requirements by adjusting dampers.
   4. Arrange for periodic soot blowing of convection tubes.
   5. Clean burner nozzles periodically.
   6. Seal all cracks and holes around the furnace to prevent air infiltration.
   7. Carry out proper water treatment.
   8. Reduce blowdown.
   9. Keep insulation in good condition.
   10. Make a daily plot of furnace efficiency.

b. Adding capital improvements to conserve energy
   1. Install low excess air burners to increase furnace efficiency.
   2. Install an air preheater.
   3. Install an economizer.
   4. Install a heat exchanger to recover heat from blowdown.
   5. Install additional process heating coils in convection section.

1.2.10 Steam Systems

a. Improving maintenance and operating procedures
   1. Operate boilers at their designed pressures and set pressure-reducing valves to provide a pressure no higher than necessary.
   2. Use correct size steam traps and carry out regular check up of all units.
   3. Simplify all heat distribution systems and remove or seal off sections no longer in use.
   4. Repair all steam leaks.
   5. Develop regular inspection and maintenance schedules for all heat distribution facilities.
   6. Control steam consumption of process equipment in accordance with optimum required temperature, pressure and time. A steam meter is necessary.
   7. Load process equipment to capacity but do not overload.
   8. Improve heat transfer rates by agitating or stirring the materials being heated.
   9. Preheat incoming materials by using heat recovered from the processes.
   10. Cut down waste and overprocessing.

b. Adding capital improvements to conserve energy
   1. Consider installing a system for returning condensate to the boiler when this does not exist.
   2. Where large amounts of high-pressure steam are used for low pressure applications, install equipment (e.g, turbine) to generate useful work in pressure reduction.
   3. Insulate all hot pipes and repair faulty insulation.
   4. When direct steam injection is used for heated tanks and vats, consider other possible methods like indirect steam heating with thermostatic control or direct-fired immersion tubes.

5. Where a widely fluctuating steam load exists, consider the use of an accumulator to enable operating the boiler more steadily and hence more efficiently.

1.2.11 Electrical Systems and Motors

a. Improving maintenance and operating procedures
   1. De-energize excess transformer capacity.
   2. Limit demand peaks.
   3. Optimize plant power factors.
   4. Switch off operating equipment without load.

b. Adding capital improvements to conserve energy
   1. Replace underloaded motors.
   2. Replace less efficient motors with high-efficiency motors.
   3. Consider variable speed motor for variable pump, blower and compressor loads.
   4. Add capacitors to improve power factor.
   5. Install demand control systems and time switches.

1.2.12 Compressed Air Systems

a. Improving maintenance and operating procedures
   1. Operate system at minimum air pressure required.
   2. Keep air distribution lines clean, dry and warm.
   3. Repair leaks in air lines.
   4. Minimize air venting from the system.
   5. Clean or replace inlet air filters regularly.

b. Adding capital improvements to conserve energy
   1. Relocate air inlet to cool location.
   2. Improve pipe layout to reduce flow resistance.
   3. Match compressed air system to pressure and volume requirements to avoid oversizing.

1.2.13 Lighting Systems

1. Use the most efficient light source practicable.
2. Use lamp light output efficiently with proper luminaires.
3. Maintain lighting equipment in good order.
4. Use well-designed energy-effective lighting schemes.
5. Control the switching operation and usage of the lighting installation.
6. Consider the effect of the surrounding decor.
7. Install skylights in production areas and warehouses.

REFERENCES

1. *Industry Energy Profiles*, Volume IV, Ministry of Energy, Republic of the Philippines.
2. *1980 Annual Survey of Establishments*, National Census and Statistics Office, National Economic and Development Authority.
3. Joslyn, Maynard A. and Heid, J.L., *Food Processing Operations*, The AVI Publishing Company, Inc., Westport, Connecticut, U.S.A., 1976.
4. *Guides to Quick Estimates of Energy Costs for Industrial Use*, published by the U.P. National Engineering Center, U.P. Engineering Research and Development Foundation, Inc., Bureau of Energy Utilization and the United Nations Industrial Development Organization, Quezon City, 1985.

CHAPTER 2

Energy Conservation in Fish Processing

2.1 FISH PRODUCTS

Fish, in the fresh or processed state, is a major ingredient of the Filipino diet. Fish is preserved by freezing and processed by drying, salting, smoking and canning.

Sun drying, with or without salting, is practised in areas close to the source of the raw product. Small fish such as *dilis* are not salted before drying. These fish are washed with seawater and laid on bamboo mats to dry under the sun for two to three days. Medium and large fish are salted before sun drying. Before salting, the fish are eviscerated, cleaned and washed in seawater. Large fish are split and salted to make *daing*. After splitting, the fish are soaked in brine, rubbed with salt and packed in salt inside barrels or clay pots. After several days the fish are taken out, cleaned, washed and sun dried on poles or bamboo mats.

Smoked fish, like the *tinapa*, are washed in seawater, and cooked in medium brine. The fish are exposed to the sun and wind to remove the surface moisture. Smoking is done in round bamboo baskets stacked one above the other over a smoking hardwood fire. The length of smoking is determined by the desired storage life of the finished product.

Thermal processing, or canning, involves subjecting the fish inside a container to high temperatures to kill bacteria and inactivate enzymes. The heat treatment is done with the fish inside hermetically sealed bottles or tin cans to guard against contamination after the product is sterilized. Water is required for washing, cooking, processing, cooling and steam generation. Steam generation requires considerable quantities of fuel. Fishes canned locally are *bangus*, sardines, salmon and tuna.

Bacteria and enzyme activity is reduced, if not totally stopped, by lowering the temperature of the fish. Kept at a temperature of $-30^\circ C$, the frozen fish will remain edible for several weeks or months. Freezing plants consume electricity for the operation of blowers and compressors.

2.2 PROCESSES AND ENERGY USE

Freezing and thermal processing use up immense quantities of electricity, fuel and water. Sun drying, relies on the sun and wind, which cost nothing, for their energy source. This chapter will offer energy conservation measures applicable to freezing and canning.

2.2.1 Freezing

Approximately 80 per cent of the composition of fish flesh is water. To illustrate how much energy must be extracted from the fish during freezing, it will be assumed that fish flesh has the same specific and latent heat constants as water.

Above $0^\circ C$, 4.187 J of heat must be removed from 1 g of water to lower its temperature by $1^\circ C$. At $0^\circ C$, approximately 335 J must be extracted to change water into ice. To lower the temperature of 1 g of ice by $1^\circ C$, 2.09 J of heat must be removed. However, the presence of salts and chemicals in the fish flesh lower the freezing temperature of the water. As water is locked away as ice, the concentration of these salts and chemicals in the water increases, further lowering the freezing temperature. At –30°C, only 90 per cent at the water in the flesh is frozen. (This temperature is sufficient to arrest most bacterial and enzyme activity and is used in commercial freezers). The heat that must be extracted from a 1 kg fish at 25°C to freeze it at –30°C would be 505 kJ.

The three methods of freezing fish are by blowing a stream of chilled air over the product, by direct contact of the fish with the refrigerated metal plates and by immersing the fish in a low temperature liquid. The first method is practised in the Philippines to preserve trawler catches and will be discussed in more detail.

Because of the fans required to circulate the chilled air, air blast freezers require more energy and are more expensive to operate than the plate freezer. They require more space than other types of freezers but are able to handle different sizes and shapes of product.

Blast freezing is either of the continuous process, where the fish move through the freezer, or of the batch process, where fish are stationary.

In the batch process, the product is loaded into the freezer on trolleys, pallets or shelves. (See Fig. 2.1.) After freezing is completed, the freezer is emptied and the next batch of fish is loaded. To freeze a whole batch of warm fish requires a very high refrigeration load. This can be overcome by running the batch freezer on a batch-continuous basis. Several trolleys of fish are loaded into the freezer and the first one is taken out when it is fully frozen to be replaced by a new trolley. Warm fish should not be loaded upstream of frozen or poorly frozen fish to avoid accidental thawing of already frozen product.

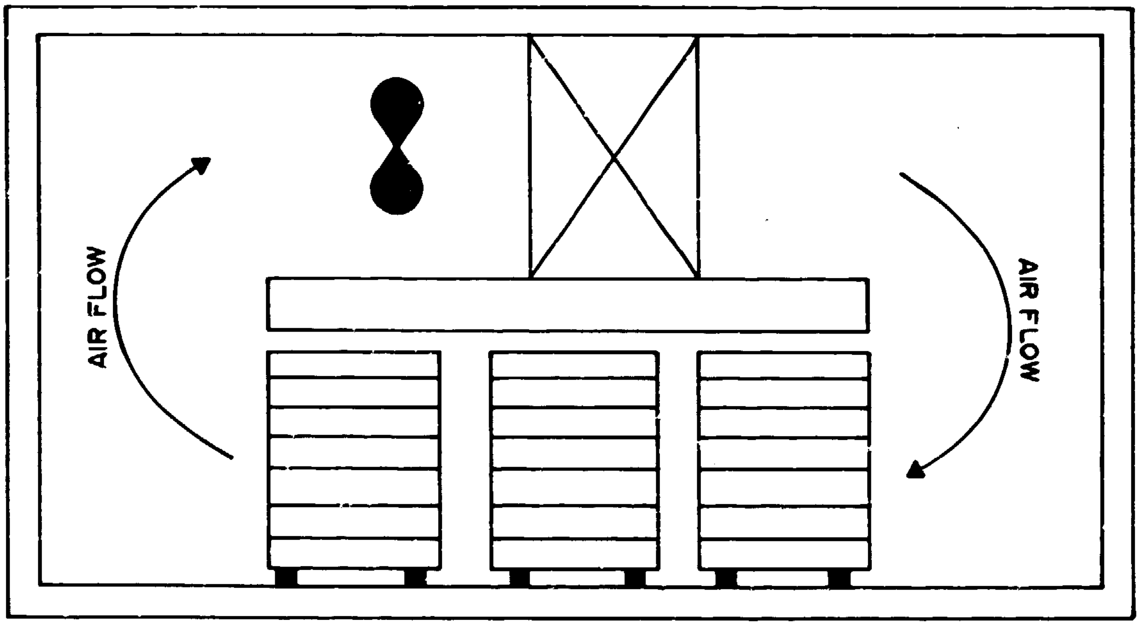


Figure 2.1 Batch Air Blast Freezer With Side Loading and Unloading

2.2.2 Thermal Processing

Thermal processing involves packing the prepared fish, usually in oil or light brine within a metal can or bottle, sealing the container completely and heating the contents to kill most microorganisms in the products. Cooling follows immediately to avoid over-cooking the product and to prevent the growth of thermophilic organisms and corrosion of metal cans. The high temperature operations, washing and cooling require considerable amounts of steam or directly fired fuel, electricity and water.

Figure 2.2 shows the major steps in the sardine-style processing of round scad (*galunggong*). The fresh fish is headed, eviscerated, cleaned, washed and cut to size. Soaking in brine draws out blood and gives the flesh a firm texture. (In other processes, the fish may be prepared by salting, smoking, or pre-cooking). The prepared product is packed in the container with the sardine sauce which was previously prepared in a steam kettle or a direct-fired cooker. Air is removed from the contents by steam-exhausting or by sealing the can under vacuum. The canned product is subjected to high temperature and pressure in a retort or pressure cooker. The fish product is subjected to a time-temperature treatment sufficient to kill bacteria of public health significance such as *Cl. botulinum*, as well as spoilage-causing microorganisms. If cooling is done in the retort, compressed air is injected into the retort to prevent straining the container.

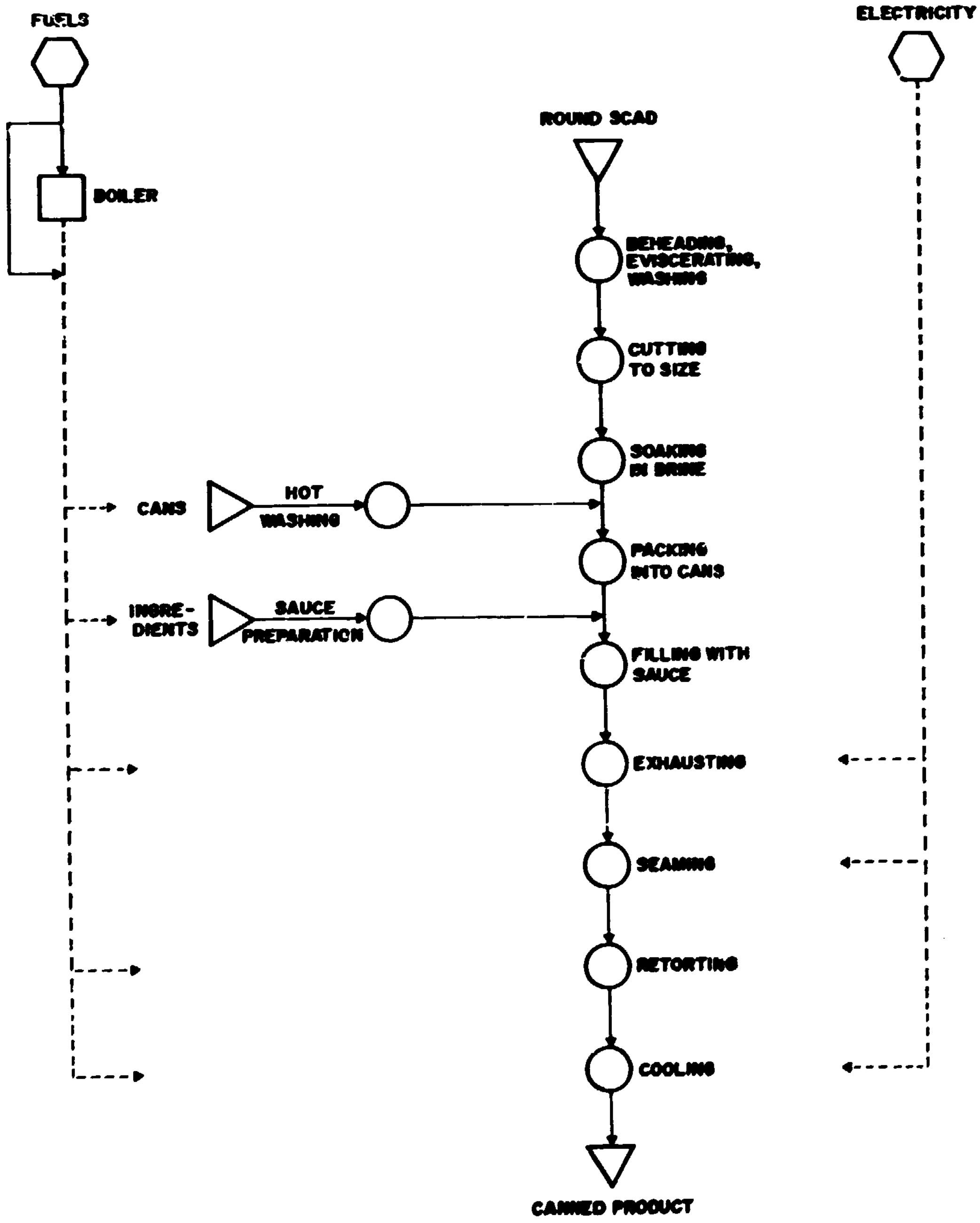


Figure 2.2 Materials and Energy Flow For Round Scad *(Galunggong)* Processed Sardine Style

2.3 ENERGY CONSERVATION POTENTIALS AND MEASURES

2.3.1 Air Blast Freezing

(a) *The Refrigeration System*

The freezer manager must pay attention to changes in the freezing process. A slower freezing rate or an incompletely frozen product means that something is wrong with the refrigeration system. Instruments to check the pressure and temperature in the evaporator and condenser and the refrigerant level in the reservoir will help in monitoring the refrigeration system.

The system requires maintenance. Air and non-condensable gases within the system will reduce the system's capacity to extract heat. The piping system requires frequent checks as a protection against refrigerant leaks. Leaks not only waste refrigerant and energy but can threaten plant equipment, the product and plant personnel.

Dirt on the fins of an air-cooled condenser or fouling of the fins of a water-cooled condenser, will lead to inefficient condensation and a high refrigerant temperature. This will be manifested in the increase in temperature of the condenser cooling medium or in the decrease of the water flow rate for the water-cooled system.

The evaporator must absorb the heat from the air as it passes through the cooling coils. Ice or frost on the coil surface hampers the heat transfer. The evaporator coil requires regular defrosting to prevent it from becoming fully covered with ice.

Other methods of reducing power consumption are:

(1) Sizing motors to fit requirements (Motors operate more efficiently at or near their rated loads.);
(2) Running large compressors at their rated capacity;
(3) Cycling small freezers motors; and
(4) Adjusting freezer motor capacity utilization.

Items 2 to 4 require no capital outlay and imply good equipment use management. Aside from improvements in refrigeration equipment operating procedures, the use of heat recovery devices can also save on electrical energy use. Heat extracted by the refrigeration plant can be used on plant operations requiring warm water (40-50°C).

(b) *Fans*

Blast freezers depend on the circulating chilled air to cool the product. The velocity of the air over the product determines the rate of freezing. Although a faster air speed will increase the freezing rate, a larger fan requires more power, generates more heat and therefore, is more expensive to run. An air speed of 5 m/s is a compromise between high costs and slow freezing rates. The chilled air temperature rises an average of 1 to 3°C as it passes over the products resulting in slower freezing rates over the products located downstream. Increasing the air speed of 5 m/s is necessary to protect the fish from the hazards of slow freezing.

The following suggestions promote uniform air flow and freezing:

(1) Place fans before the cooler to even out the air flow as it passes through the cooling coils.
(2) Limit the clearance between the fan and the outer casing to a few millimetres to prevent air recirculation.
(3) Provide baffles around corners or when the direction of flow changes to assure even air flow over the products. Baffles with adjustable pitch can operate under different conditions.

(c) *Trays*

Since the fish have to be packed in trays, the latter must be able to transfer heat efficiently. They should be able to withstand the strain caused by the swelling of the fish as they freeze. The edges that lie across the airstream should be lowered to allow close contact between the air and the fish. Freezing in the shortest time is attained when the fish is packed in open trays without wrapping and the tray filled to the top to eliminate any pockets of dead air above the product.

Designing the tray for easy unloading of the product prolongs the life of the tray by requiring less force to unload the product. A tray with a taper of one in eight can be easily emptied by pouring cold water on the bottom for a short time and gently tapping the ends. Constructing the sides that lie along the airstream higher than the two other sides will also facilitate unloading.

For maximum and uniform chilling, the distance between the surface of the product in one tray and the underside of the tray on the shelf above must be about 1/2 to 2/3 the depth of the product. It is also advisable to position the trays evenly across the blast freezer to have a direct and uniform air flow over all the products (See Fig. 2.3.). Air will bypass the trays if they are concentrated in one area.

(d) *General Considerations*

Because of the versatility of the blast freezer, it is often misused. Overloading and underloading result in a poorly frozen product and less efficient freezer operation. There is a maximum heat load the freezer can handle which when exceeded will raise the refrigerant temperature and lengthen the freezing time. Loading product at a temperature higher than normal, opening the freezer doors more often than necessary and providing doors with ineffective seals will overload the refrigeration system. Opening freezer doors while the freezer is in operation not only increases the load but also hastens the build-up of ice on the evaporator coils. Leaks in the freezer doors will cause the formation of ice in these areas, "locking" the door in place. In some instances, a forklift will have to force the doors open, causing undue damage to the door and the door mountings.

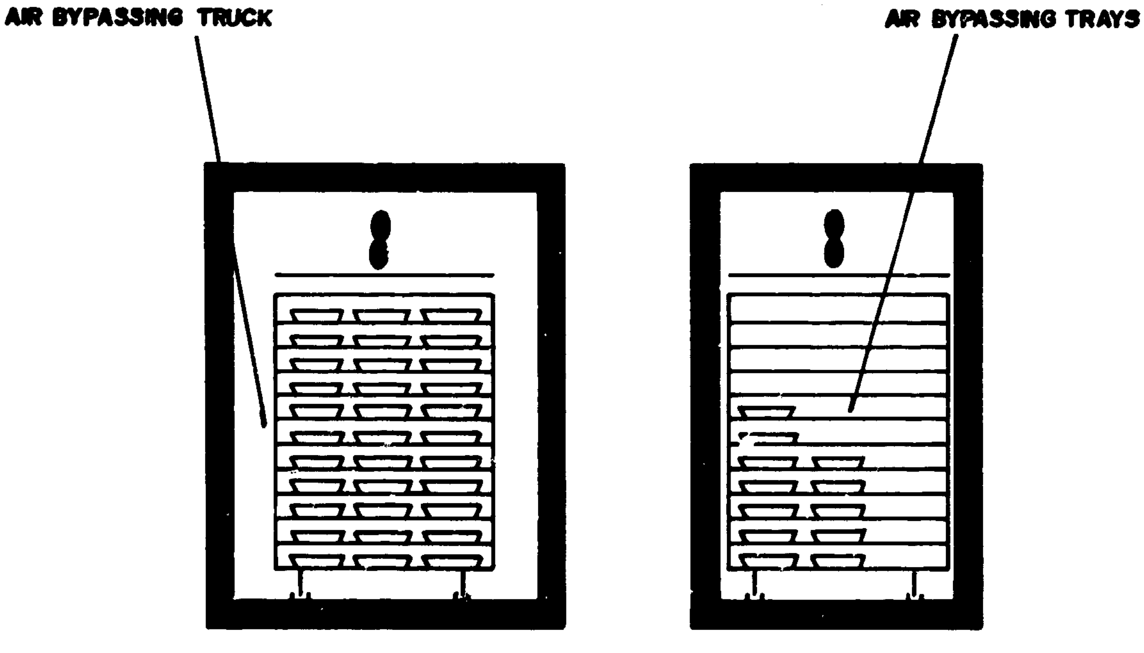


Figure 2.3 Uneven Distribution of Trays Across the Air Blast Freezer

Conversely, better use of freezer doors will conserve energy. This means:

(1) Keeping freezer doors more tightly closed and keeping them closed most of the time and

(2) Improving insulation on freezer doors.

Severe underloading of the freezer will lead to valves and controllers "hunting", resulting in excessive wear and intermittent operation of compressors.

Regular defrosting is necessary to keep the freezer operating at its peak efficiency. The accumulation of frost reduces the heat transfer and hinders the air flow. It is better to defrost the freezer by heating with the doors closed than turning off the refrigerant flow and opening the doors. The latter method is slow and messy; the heavy condensation can ruin the freezer housing and insulation.

2.3.2 Thermal Processing

The major heat energy consuming steps in fish canning are pre-cooking, exhausting, retorting and hot can washing.

Considerable savings can be generated by increasing the boiler efficiency through the following:

(a) Better combustion control,
(b) Reduction of blowdown procedures,
(c) Repair of leaks in lines and valves,
(d) Maintenance of insulation, and
(e) Reduction of energy loss in distribution.

Chapter 6 provides a more detailed discussion of energy-saving techniques for boilers.

Water for cooling the product after retorting can be ran through a cooling tower to save on water use. Condensate from the exhauster, steam kettle, etc., can be collected and used for operations requiring hot water.

Insulating pressure cookers and steam kettles will stop the escape of heat to the atmosphere, eliminating unnecessary waste of energy. This is illustrated in an application case found at the end of this chapter.

The section on canning in Chapter 6 contains more suggestions for efficient energy use in canning.

2.4 APPLICATION CASE

Reduced Heat Losses from Cooker Plant

A steam-heated pressure cooker used for cooking canned products had very large heat losses from its exposed metal surfaces. The temperature of this exposed surface was measured and found to be 100°C. The cooker was insulated with rigid foam insulation which reduced measured surface temperatures to 35°C.

Surface temperature measurements were taken to ascertain the energy loss from the outside surfaces.

Average surface temperature	:	100°C
Approximate surface area per cooker	:	9.5 m^2
Process chamber temperature	:	110°C

From Tables 2.1 and 2.2:

(a) **Without Insulation:**

Heat loss due to radiation:	585 W/m^2
Heat loss due to radiation-free connection	436 W/m^2
Total	1021 W/m^2

(b) **With Insulation:**

Heat loss due to radiation:	29.5 W/m^2
Heat loss due to connection:	24 W/m^2
Total	53.5 W/m^2

(c) **Savings:**

Heat Saved: = (9.5 m^2) (1021 – 53.5) W/m^2
= 9191 W

Table 2.1 Heat Emission Due to Radiation
(Based on a surrouding air temperature of 25°C)

Surface Temp. °C	Heat Emission (W/m^2) Bright/Polished	Normal	Dull/Oxidized
5	–33	–65	–98
10	–25	–60	–75
15	–17	–34	–51
20	–9	–18	–26
30	9	18	28
40	29	58	87
50	50	102	153
60	75	150	225
70	101	200	304
80	130	260	390
90	160	320	484
100	195	390	585
120	270	540	815
140	360	720	1080
160	460	928	1390
180	580	1160	1750
200	720	1430	2150
220	870	1740	2610
240	1040	2090	3130
260	1240	2480	3720
280	1460	2910	4370
300	1700	3400	5100
320	1970	3940	5910
340	2270	4540	6800
360	2600	5190	7790
380	2960	5920	8800
400	3360	6710	10100

Table 2.2 Heat Emission Due to Free Convection
(Based on a surrounding air temperature of 25°C)

	Heat Emission (W/m^2)		
Surface Temp. °C	**Horizontal Looking Down**	**Vertical**	**Horizontal Looking Up**
5	–91	–75	–27
10	–62	–51	–19
15	–36	–30	–11
20	–14	–12	–5
30	5	12	14
40	19	51	62
50	36	101	123
60	54	158	192
70	75	221	269
80	96	289	351
90	118	361	438
100	141	436	530
120	190	598	726
140	241	771	936
160	295	954	1160
180	350	1150	1390
200	407	1350	1640
220	466	1560	1890
240	527	1770	2150
260	589	1990	2420
280	652	2220	2700
300	717	2460	2980
320	782	2700	3280
340	849	2940	3570
360	917	3190	3880
380	986	3450	4190
400	1060	3710	4510

REFERENCES:

1. Burgess, G.H.O., C.L. Cutting, J.A. Lovern, J.J. Waterman eds., *Fish Handling and Processing*, Chemical Publishing Co., Inc., New York, 1967

2. Clucas, I.J. ed., *Fish Handling, Preservation and Processing in the Tropics:* Part I and Part II, Tropical Products Institute, London, 1981.

3. Borgstrom, George ed., *Fish as Food*, Vol. III, Academic Press Inc., New York, 1965.

4. *Philippine Handbook on Canned Low Acid Foods*, National Institute of Science and Technology, Manila, 1982.

5. Small-scale processing of fish, International Labour Office, Geneva, 1982.

CHAPTER 3

Energy Conservation in Meat Processing

3.1 MEAT AND POULTRY PRODUCTS

Meat as defined by the Food and Drug Administration is the properly dressed flesh of cattle, swine, sheep or goats of sufficient maturity and in good health at the time of slaughter but is restricted to the striated muscles attached to the tongue, diaphragm, heart, esophagus, and not the ears, lips, mouth, etc. The major kinds of meat include: beef (cow or cattle), pork (hog), veal (calf), and mutton (sheep). In the Philippines, the common sources of meat include cattle, hogs and poultry.

Meat products refer to the meats which have been subjected to one or a combination of the following procedures: curing, smoking, canning, freezing, dehydration, production of intermediate-moisture products and the use of certain additives such as chemicals and enzymes.

The manufactured meat products can be grouped as follows:

a. *Fresh* – meat which has been cut, cleaned, sorted and graded; sold without any curing or cooking.
    1. Pork – pork chop, spare ribs, loin lean, etc.
    2. Beef – bucket, round, loin, ribs, etc.
    3. Poultry – i. classified according to age – broiler, freezer, etc.
        ii. classified according to cuts – white meat, dark meat, giblets

b. *Corned* – usually beef or pork which has been treated with salt solution containing sodium nitrate, sugar and spices and may or may not be canned.

c. *Cured* – meat preserved by the application of curing ingredients, with or without smoking. Typical examples are ham, bacon, and native sausage.

d. *Sausage* – usually consisting of chopped or comminuted meat containing not more than 3.5% binder by weight, seasoned and placed in pork or beef casings. Binders commonly used are cereals, vegetable starch flour and non-fat milk solids. Examples of sausages are frankfurters or hotdogs, breakfast sausage, bologna, salami and liverwurst. Sausages may be fresh, dried or smoked.

e. *Canned* – meat placed in hermetically sealed containers followed by an adequate sterilization process to destroy spoilage organisms as well as enzymes.

f. *Dehydrated/dried/salted* – meat, usually thinly sliced, which has been pretreated with common salt and then dried to remove moisture until a minimal amount of liquid is left.

g. *Potted or devilled* – product obtained by comminuting and cooling meat with or without spice added and is usually packed in hermetically sealed containers.

h. *Prepared* – the clean, sound product obtained by subjecting meat to processes which include comminuting, drying, curing, cooking, seasoning.

3.2 PROCESSES AND ENERGY USE

3.2.1 Beef and Pork

Figure 3.1 shows the common preliminary step in the processing of meat. The sources of energy are purchased electricity and fossil fuel. The latter is almost always used in the production of steam in boilers.

(a) *Slaughtering.*

The general flowcharts for the slaughtering and butchering of cattle and swine are shown in Figures 3.2 and 3.3, respectively. In cattle slaughtering, the major form of energy used is electricity, which is used to power the conveyor system, cutting tools, and stunner. Heat energy is used only in the boiling of cattle entrails. This is usually done by direct injection of steam into hot water (90-100°C) in large open-top containers. In pork processing, large amounts of steam are consumed in scalding. Hot water is kept at around 60°C by direct steam injection. In many hog processing plants, singeing is done with LPG burners or in singeing ovens. However, some hog processors eliminate this step to conserve energy. Other steam consuming stages for pork slaughtering are the boiling of entrails and leg scalding. Both processes also use direct steam injection.

(b) *Production of Ham, Bacon, and Picnics*

Figure 3.4 illustrates the flow of energy and meat in the production of ham, bacon, and picnics. Heat in the form of steam or hot water is used primarily in thawing or tempering and cooking. Direct heat is used in process ovens, ham glazing, and smoking. Power for cutting equipment, conveyors, and refrigeration is provided by electricity. However, in plants where skinning, trimming, cutting, and slicing are done manually, electrical consumption is much lower. In such plants, lighting is a major electricity consumer.

(c) *Production of Sausage and Comminuted Meat*

Figure 3.5 is a typical energy and materials flowchart for sausage and comminuted meat production. The energy requirement for this sector is very much higher than in other meat processing industries. Some sources report that the amount of energy required per unit weight of meat processed in the manufacture of sausages and comminuted meat products is more than double of that for canned meat products. The major energy categories are cooking, smoking, cooling, and boiler inefficiencies. In addition, mechanical operations such as grinding and mixing, cutting and trimming, breaking, and automatic conveying require considerable amounts of electricity. However, in plants utilizing manual labor in some of these operations, the electric power requirements are lower. Refrigeration is required in cooling, aging, and storage.

(d) *Production of Canned Meats*

A general materials and energy flowchart for the canning of meat products is shown in Figure 3.6. Mechanized meat cutting and processing equipment account for the electricity input in meat preparation. As mentioned before, factories which use manual labor for cutting, trimming, etc. obviously have lower energy requirements. Other equipment which use electricity are conveyors, automatic batching equipment, pumps, and air compressors. Major steam or hot water consumers are the retort, cookers, exhauster, and hot can washer. For solid packs such as luncheon meat, corned beef, etc., mechanical exhausters, which use electricity, are commonly used. For a more in-depth discussion of the canning process and applicable energy conservation measures please refer to Section 6.7.

(e) *Frozen or Raw Meat Processing and Storage*

Figure 3.7 shows a typical frozen meat processing flowchart. Obviously, the largest requirements for electric power are the fans and compressors for blast freezing and refrigerated storage. In many cold storage plants which use fluorescent lighting, the bulbs are on 24

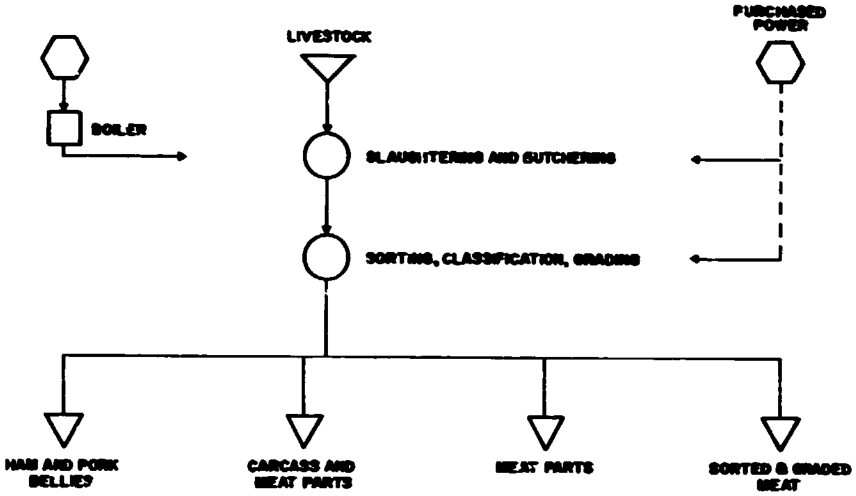


Figure 3.1 Preliminary Meat Processing Steps

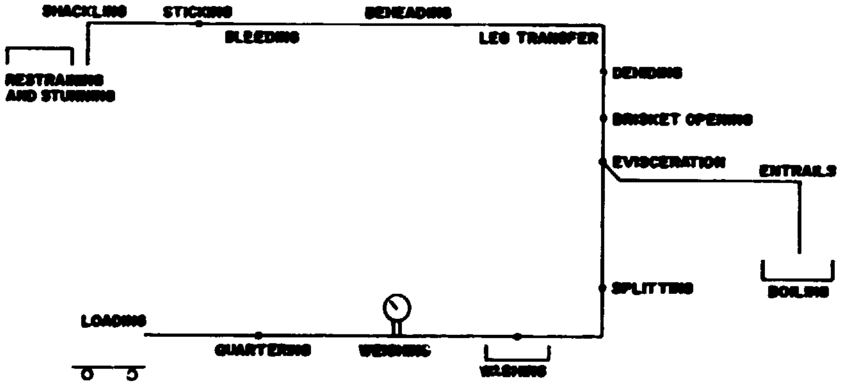


Figure 3.2 Cattle Slaughtering Line

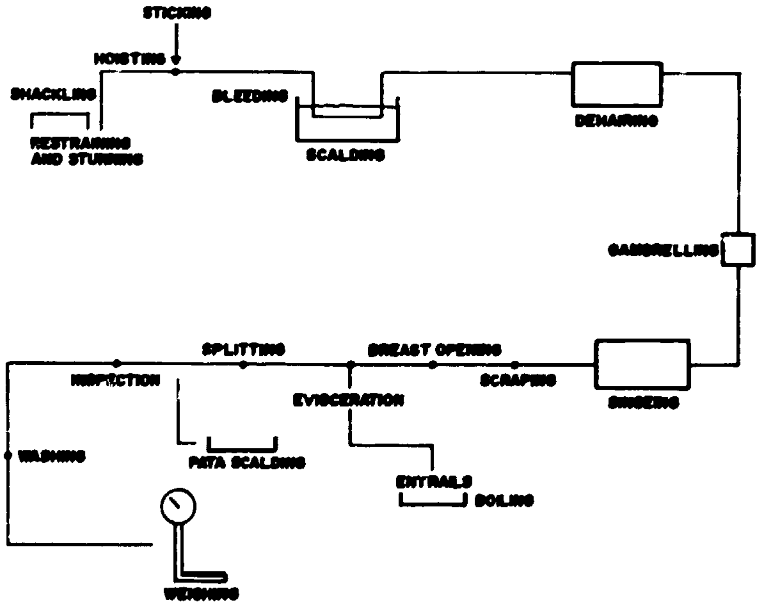


Figure 3.3 Hog Slaughtering Line

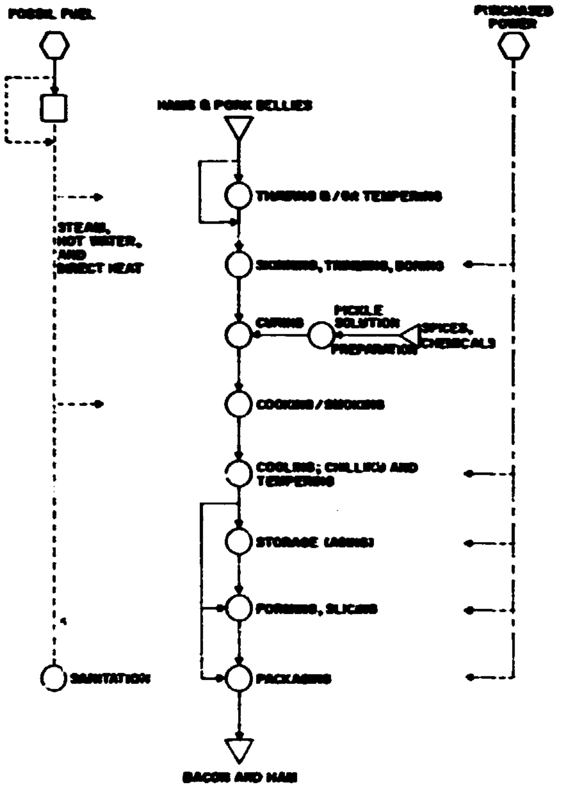


Figure 3.4 Material and Energy Flow for Processing Ham, Bacon and Picnics
Source: Reference 1

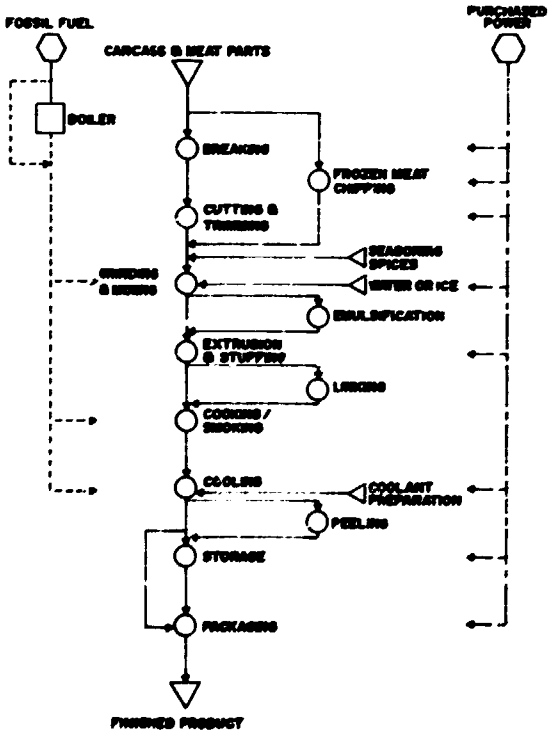


Figure 3.5 Material and Energy Flow for Sausage and Comminuted Meat Products
Source: reference 1

hours a day, even if there is no one inside. The reason for this is that it has been found from experience that turning the fluorescent bulbs off in the cold space for considerable periods of time will drastically reduce bulb life. This could be due to condensation of water in the bulb. Other equipment which require electricity are conveyors and automatic packing equipment.

Materials handling equipment such as forklifts or trucks may require diesel, gasoline, or LPG fuel. Some forklifts are battery operated.

3.2.2 Poultry Dressing and Freezing

Poultry processing in the Philippines consists mostly of dressing, packaging, and freezing. Both heat and electricity are used.

A typical chicken dressing flowchart is shown in Figure 3.8. Live chickens are hung by both feet on the conveyor. Sometimes chickens are electrically stunned or punctured through the brain. Aside from immobilizing the chickens, this reportedly relaxes the feather muscles and makes the quills easier to remove. The next step is sticking and bleeding. While the chickens pass through the bleeding tunnel, they are sprayed with water. Then, they are immersed in hot water (58-60°C for soft scald, 62°C for hard scald) in the scalding tank to facilitate the removal of the feathers. The scalding tank is usually direct steam-injected and open at the top. The sides and bottom are made of stainless steel sheets and are seldom, if at all insulated. Defeathering and finishing are done by roller-mounted rubber "fingers". The rotating rollers are powered by electric motors. Tail slitting and evisceration are done manually. After evisceration, the feet are cut off, causing the chickens to drop into a container. Next, the dressed birds are washed then soaked in a chilling tank which is at a temperature of about 4°C. After that, the chilled chickens are packaged and sealed in plastic containers and quickly taken to the freezer for blast freezing. The freezing process is similar to that in Figure 3.7. Then the chickens are kept in cold storage. The poultry production industry is not stable and in times of over-production millions of kilograms of frozen chicken are kept in cold storage for months. This of course results in tremendous electric power requirements for refrigeration.

3.3 ENERGY CONSERVATION POTENTIALS AND MEASURES

The food processing industry has large potentials for conservation of heat because many processes require only hot water (60-90°) which can readily be generated using waste heat. The boiler is a major fuel-consuming equipment; it is found in almost all meat processing plants. Energy conservation in boilers and steam systems is discussed in Section 6.2. In low-temperature (90°C or less) heating applications using water, the possibility of using direct heating in place of steam injection should be considered. Electricity is used in meat processing for motors to power such equipment as conveyors, refrigerant or air compressors, pumps, fans, etc. Energy conservation in electric motors is discussed in Section 6.4.

3.3.1 Scalding Tanks

Practically all of the steam requirements in hog slaughtering and chicken dressing are for scalding tanks or other similar open-top, hot water equipment. The majority, if not all, of these equipment utilize direct steam injection. Scalding tanks for chicken dressing are usually made of stainless steel sheet and have no insulation for the sides and bottom. In many cases steam injected into the water does not condense completely and merely escapes to the atmosphere. The following are some suggestions for conserving energy in scalding tanks:

(a) *Use direct combustion of fuel, instead of steam, for heating if possible.* Hot water in scalding tanks is only about 60-70°C. This temperature can easily be attained by direct heating although provisions must be made for good temperature control. Since no steam is used, direct heating will greatly reduce the boiler load. In some processes like chicken dressing,

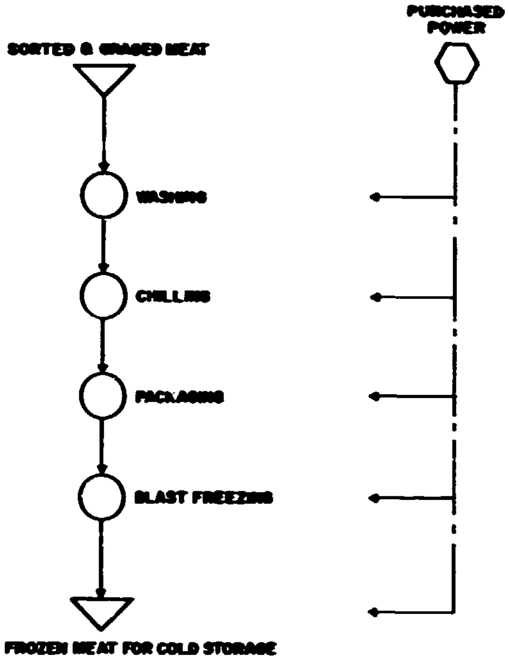


Figure 3.6 Material and Energy Flow for Canned Meat Products
Source: Reference 1

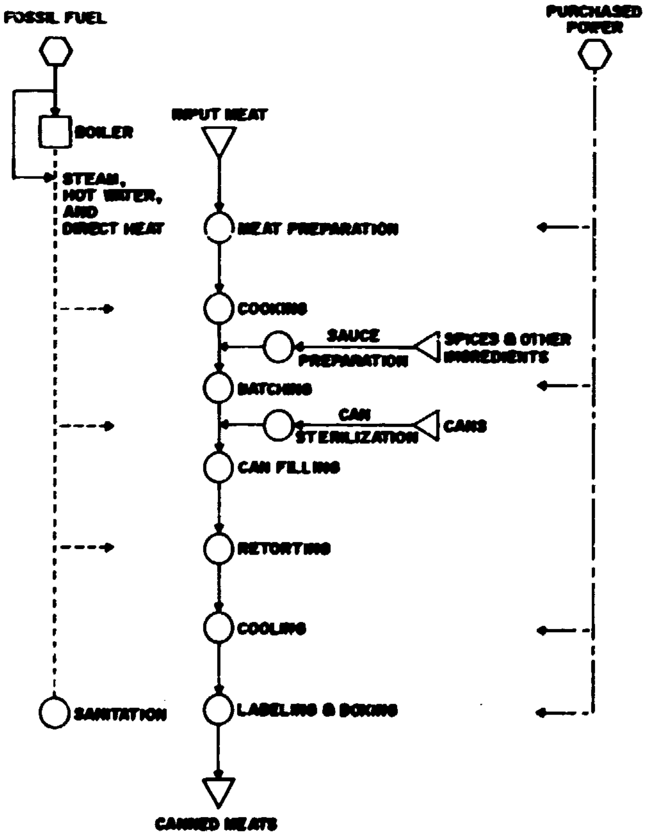


Figure 3.7 Materials and Energy Flow for Frozen Meat or Poultry

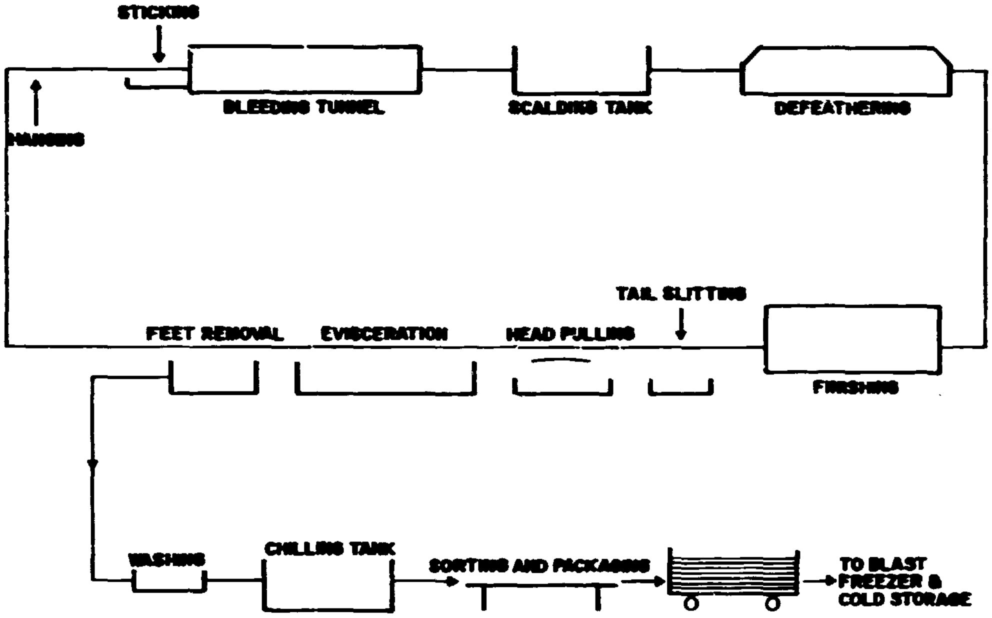


Figure 3.8 Typical Flowchart for Poultry Dressing

direct heating will eliminate the high cost of operating and maintaining a steam boiler system. However, there may be some limitations as will be pointed out in (b) below.

(b) *Use closed or indirect steam heating instead of direct mixing.* This will enable the condensate to be recovered for returning to the boiler or for hot water generation. This will also eliminate steam loss to the atmosphere and reduce feedwater treatment. It must be noted, however, that the water in the scalding tanks must be periodically replaced, thus necessitating quick heating so that operations will not be delayed. This can be done by continuous draining and replacement of the scald water, or by simultaneous preheating of replacement water. Cleaning and maintenance must also be considered in the installation of heat exchange tubes, etc.

(c) *Insulate the sides and bottom of the tank.* In many applications, the sides and bottom, or at least the sides, of scalding tanks are not insulated. This is especially true for scalders used in chicken dressing. Proper insulation will greatly reduce radiation and conduction losses and the exposure of employees to heat.

(d) *Minimize steam loss to the atmosphere.* As noted earlier, a lot of the steam injected into the water does not condense in the water but instead bubbles through it and escapes to the atmosphere. This can be prevented by first having steam give up its heat to the water through an indirect heat exchanger and later mixing the condensate with the hot water. This is discussed further in Section 4.3.1. Another method is to reduce the area above the tank exposed to the atmosphere. An example of this is floating styropor balls on the surface of the hot water.

3.3.2 Steam-jacketed Kettles

Steam-jacketed kettles and similar equipment must be purged of air at every start-up. Air in the steam cavity greatly reduces heat transfer. Many steam-jacketed kettles cannot be purged because they do not have vents. In most cases, the temperature of the food being cooked in the kettles does not rise fast enough no matter how much steam is admitted. A steam vent may be installed as in figure 3.9 to solve this. When steam is admitted into the chamber of the kettle, displaced air will escape through the open vent. After a few minutes, the vent is closed and the kettle is ready for use.

Energy may also be conserved in steam-jacketed kettles by proper insulation and by recovering the condensate.

3.3.3 Waste Heat Recovery

Waste heat can be recovered to preheat or produce hot water which is needed in so many processes. Waste heat can be recovered from spent or dirty hot water from cleaning or washing operations through indirect heat exchange. In operations involving heating and subsequent cooling of products, spent cooling water can be used for pre-heating or direct use in upstream or downstream processes. In large boilers, waste heat recovery from the stack gases is possible.

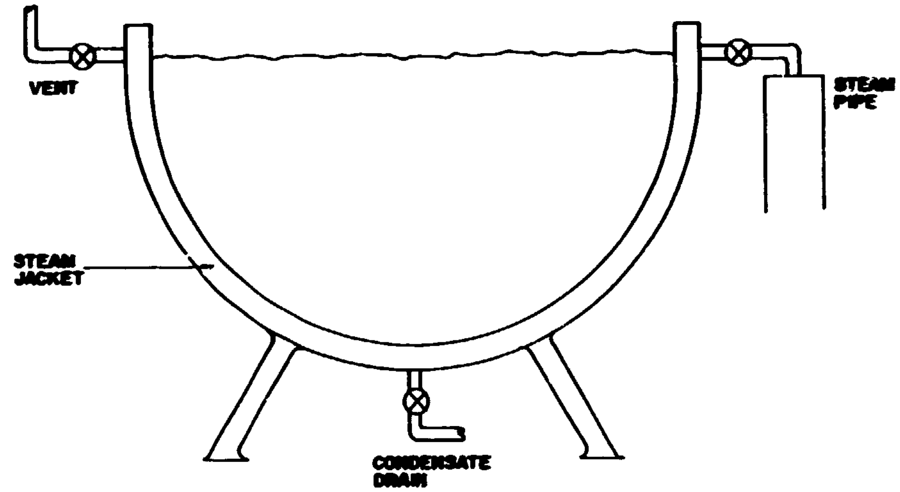


Figure 3.9 Steam-jacketed Kettle

In large installations where singeing ovens are used, it could be economically feasible to install waste heat recovery equipment to recover energy from the hot (usually around 500°C) gases.

3.3.4 Freezing and Cold Storage

Blast freezing is the method commonly used to freeze raw beef, veal, pork, or poultry. In poultry processing, open chilling tanks are used to cool the chickens before blast freezing. Some suggestions for reducing the consumption of electricity in refrigeration are:

(a) *Do not set temperature controls lower than necessary.* Although this may seem obvious, many plant engineers report that too often cold storage temperatures are lower than required.

(b) *Do not overload or overcrowd the cold storage or blast freezer space.* This will hamper air circulation and reduce convection heat transfer.

(c) *Institute processing at or near the point of slaughter.* Preserving meats by refrigeration so that they can be transported to the processing site requires a lot of energy. Of course, the ideal situation would be to have the slaughter house in the same site as the processing plant. This will eliminate freezing and cold storage for meat that will later be processed.

(d) *Reduce the refrigeration load by deboning or removing unnecessary parts before refrigeration.* The main argument against deboning before freezing is cold shortening. This can be prevented by a process known as hot boning. In hot boning, the meat is electrically stimulated for about one minute to artificially induce *rigor mortis*. This will prevent cold shortening.

(e) *Implement proper preventive maintenance.* Aside from reducing power costs by increasing the efficiency of the compressor, regular preventive maintenance will increase the reliability of the system. Regular cleaning of condensers will increase heat transfer. Minor repairs of insulation, prevention of air in-leakage, etc. will go a long way in reducing the refrigeration load.

Section 2.3.1 provides more discussions on blast freezing.

3.3.5 Condensate Recovery

Many food processing operations involve the generation of condensate from condensing steam. Examples of these are steam-jacketed kettles, cookers, steam boxes, etc. Usually this condensate is just thrown away. As already pointed out in preceding sections, this condensate can and should be recovered for return to the boiler for generation of hot water, and for pre-heating make-up water.

3.3.6 Lay-Outing

In many plants, energy flow was not considered in layouting. For example, the steam boiler may be far from the point of use. Expenses will be incurred for additional piping, steam traps, and insulation. Steam may lose much of its heat by the time it reaches a distant point of use. Another example is chilling and subsequent blast freezing for poultry products. If the chilling and packaging area is far from the blast freezer, chilled chickens may have absorbed considerable heat in transit, thus increasing the load on the blast freezer.

3.4 APPLICATION CASE

(The following case study was contributed by Engr. Esmeraldo Dautil, Assistant Plant Manager of Food Terminal, Inc.)

The Plant Maintenance Division of the Food Terminal, Inc. was commissioned to redesign and fabricate charcoal-fired heaters to replace the electric heaters of the smokehouse. The fan motor and materials for smoking (sawdust) were unchanged. Assuming 24 h/day operation, the payback period was less than one and a half (1.5) days.

3.4.1 Operating Cost

(a) Electric Heaters

(1)	(10 kalrods) (1.5 kW/kalrod) (₱2.18/kWh) (24 h) =	₱ 784.80
(2)	(20 kalrods) (2.1 kW/kalrod) (₱2.18/kWh) (24 h) =	₱ 2,198.44
	TOTAL	₱ 2,983.24

(b) Charcoal Heaters

(1 bag/h) (₱30/bag) (24 h) ₱ 720.00

NOTE: One bag of charcoal is approximately twenty kilograms.

Net Savings: ₱ 2,983.24 – ₱ 720 = ₱ 2,263.24

3.4.2 Fabrication Cost of Charcoal Fired Heaters:

(a) Materials and Supplies

(1)	Two (2) pcs discarded 210 litre steel drum	– ₱ 669.00
(2)	Two (2) pcs plain G.I. sheet 4' x 8', gage 24	– 770.00
(3)	Two (2) pcs. deformed steel bar 5/8" x 20 ft	– 720.00
(4)	One half kilogram (1/2 kg) filler rod 1/8" x 3 ft	– 78.00
(5)	Oxy-acetylene gas (approx. 1/4 cap. consumed)	– 90.00
(b)	Direct Labor	– 505.00
	TOTAL	₱ 2,832.00

3.4.3 Effects on Production:

The following improvements were reported:

(a) Come-up time (pre-heating) was shortened.

(b) The removal of the heating elements (kalrods) and supports inside the smoking chamber provided more elbow room for the operators.

(c) The arrangement of the products to be smoked inside the smoking chamber was improved and the capacity of the smokehouse was increased.

(d) Quality of the smoked products was enhanced due to the uniformity of hot air circulation.

(e) The production rate increased.

(f) Maintenance problems decreased.

REFERENCES:

1. Casper, M.E. *Energy Saving Techniques for the Food Industry,* Noyes Data Corporation, Park Ridge, New Jersey, 1977.

2. *Institutional Energy Conservation Workshop Proceedings,* sponsored by Wisconsin Public Service, Madison, Wisconsin, April 1984.

3. *Agriculture and Food Processes,* May, 1980.

CHAPTER 4

Energy Conservation in the Processing of Fruits and Vegetables

4.1 FRUIT AND VEGETABLE PRODUCTS

Since the majority of fruits and vegetables are available only when they are in season and owing to their perishability, a number of forms of processed fruits and vegetables have emerged to satisfy non-seasonal demands. Processed fruit products include the following: canned fruits (whole or sections), fruit preserves, jams, marmalades, jellies, juices, and purees. Vegetables can be similarly prepared and the processed forms are: canned vegetables, juices, purees, pickles and relishes. Fruits for export are preserved by freezing.

4.2 PROCESSES AND ENERGY USE

This section will discuss the typical operation processes employed in industry for the preservation of fruits and vegetables. When available, the energy input mix (electricity, fuel oil, etc.) will also be included.

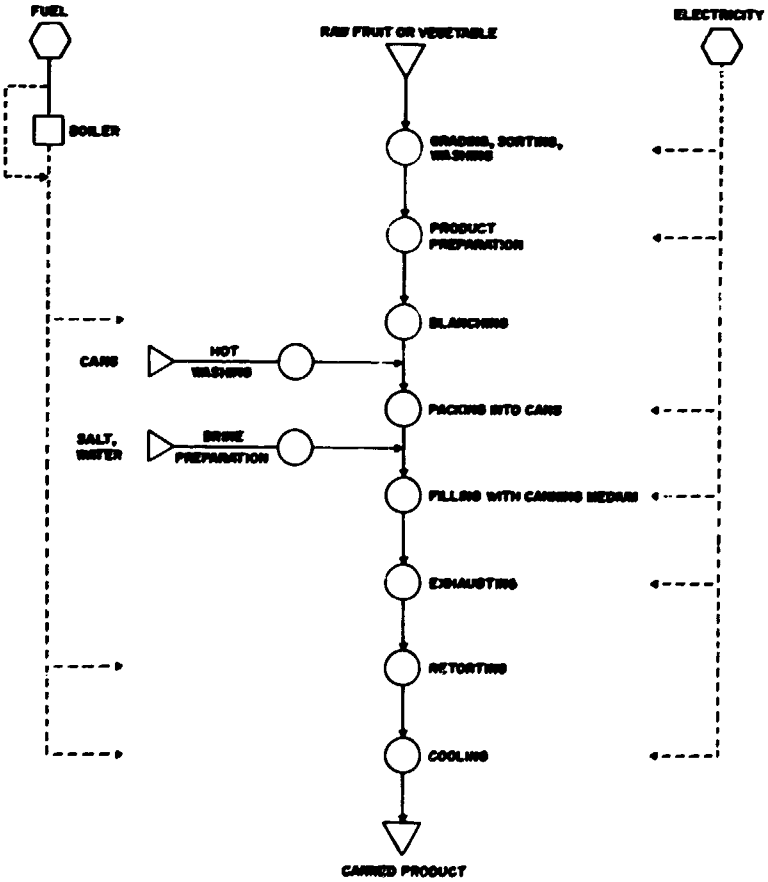


Figure 4.1 Materials and Energy Flow for Canned Fruits and Vegetables

4.2.1 Canned Fruits and Vegetables

The purpose of canning is to pack food in a container, usually of glass or tin, and to destroy all bacteria and enzymes in the product to prevent spoilage. A temperature in the range of 115.6 to 121.1°C is sufficient to sterilize vegetable products while a temperature of 93.3°C is adequate for prepared fruits. Figure 4.1 shows the energy flow in the canning of fruits and vegetables.

Only the best quality fruits or vegetables are selected for canning. The raw product is washed, sorted and prepared by peeling, trimming, coring, cutting or dicing. In certain processes, the product is cooked or blanched before canning while in others it is packed into the container without any heating. The container is sealed under vacuum, sterilized, cooled, packaged and stored.

As seen in the diagram, steam is extensively used in blanching, cooking, exhausting and sealing, and sterilization or retorting. Blanching is done by scalding the product in boiling water or exposing it to live steam for a brief period. Both rotary and pipe blanchers are used in industry, the latter having the advantage of allowing continuous operation.

Boiling pans or kettles are used to cook the product. The vessels of copper or stainless steel are jacketed for heating by steam and provided with agitators for stirring. Alternative methods of heating are by steam coils inside the kettle, an electric mantle or with direct-gas firing.

Cookers may be operated under atmospheric pressure, under a vacuum or under internal pressure.

Automatic filling machines fill a specified amount of product into the washed open cans. To prevent decay, a vacuum is created inside the can just before sealing by exhausting the air inside. This can be achieved with a mechanical exhauster or by exposing the filled can to steam or hot water before putting on the lid.

Another heat treatment process to sterilize the product is retorting. The retorts come as horizontal, vertical or rotary types, but all use steam or hot water to supply the heat. Rotary retorts allow agitation of the canned product for greater heat penetration.

4.2.2 Juices

Juices can be processed from fruits such as pineapples, mangoes, and *guayabano* while the more common vegetable juice is tomato. Figure 4.2 is a generalized process chart for the extraction and preservation of fruit and vegetable juices. The product is cleaned, sorted and trimmed before being pulped. The liquid may be filtered or screened to get a uniform consistency. Some fruit juices require clarification to improve their appearance while others are more appealing as extracted. Vegetable juices are usually canned afterwards. Fruit juices are preserved either by thermal processing, freezing or dehydration. Chemical additives such as sodium benzoate and sorbic acid are sometimes used as preservatives.

The product is cleaned by washing in a tank, pressure spraying or brush washing. Manual sorting is used by small scale producers but sorting can also be done mechanically with roller sorters, roller conveyors with gaps between rollers where debris can fall, or with screen separators. It is common to use several methods in the sorting operation to eliminate as much dirt and contaminants as possible.

Trimming by hand is done on a conveyor belt to remove the vegetable tops, any decayed portion, or skin. Machines are available for the stemming, pitting, peeling or coring or fruits or vegetables which require these operations.

Fruits are milled, pulped, or ground before pressing in a machine to extract their juices. Filter presses force the juice through a filter medium to separate the liquids from the solids. The force may be applied by a vacuum on one side of the filter or by external pressure on the product.

, The acidity of juices is not conducive to the growth of bacteria and pasteurization is enough to stabilize the product. Less thermal energy than for heat sterilization is sufficient to inactivate most microorganisms. In flash pasteurization the juice is held at 88°C for less than a minute for

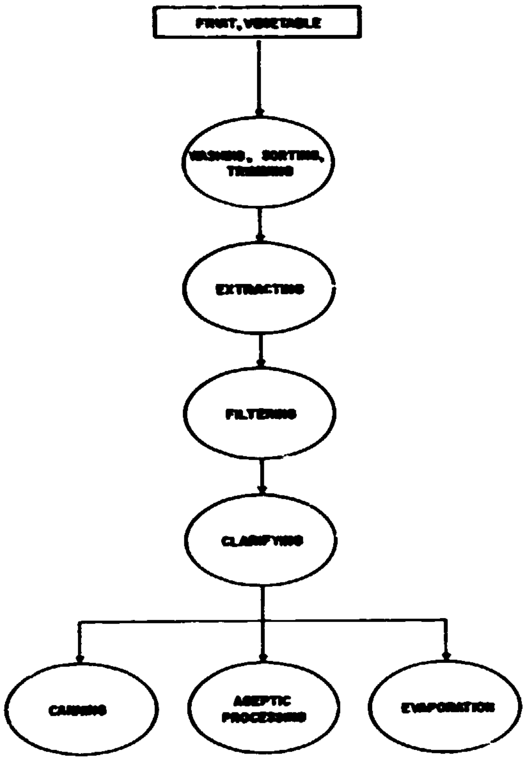


Figure 4.2 Process Flow Chart for the Production of Fruit and Vegetable Juice

microbial inactivation. After heating, the product should immediately be cooled to avoid the deterioration of the nutritional value and quality of the juice.

Aseptic Processing

Aside from retorting, fruit juice can be preserved using the aseptic process. The product is rapidly sterilized and cooled before it is aseptically filled into sterile containers. Containers used are either conventional metal cans or pouches made of laminated plastic and foil. An advantage of this process is that the juice does not undergo quality changes identified with slow heating in the retorting system. Aseptically processed products do not require refrigeration during storage.

In the Dole Aseptic Canning System the liquid product is pumped under pressure through the heating section of the sterilizer. It is brought to a temperature of 135 to 149°C and held there for the required length of time and passed to the cooling section. The process time is controlled by the flow rate of the product through the system, which is kept constant by the product pump. A controller-recorder type instrument automatically controls the process temperature and process time.

Evaporation

The juice is concentrated by evaporation in vacuum evaporators. Single or multiple effects as well as single or multiple stages may be used depending on the kind of juice and the desired end products. Steam is used for high temperature applications while a heat pump can provide low temperature heat. Most modern units are provided with instrumentation for savings on labor cost and effective control of the process.

Fruit juice, a highly heat-sensitive liquid, benefits from the low temperature and short contact time offered by plate evaporators, a compact arrangement of gasketed plates held together in a frame. Sufficient plates to suit the duty are built up into units, each comprising a rising film (inlet) section and a falling film (discharge) section, together with adjacent steam passages.

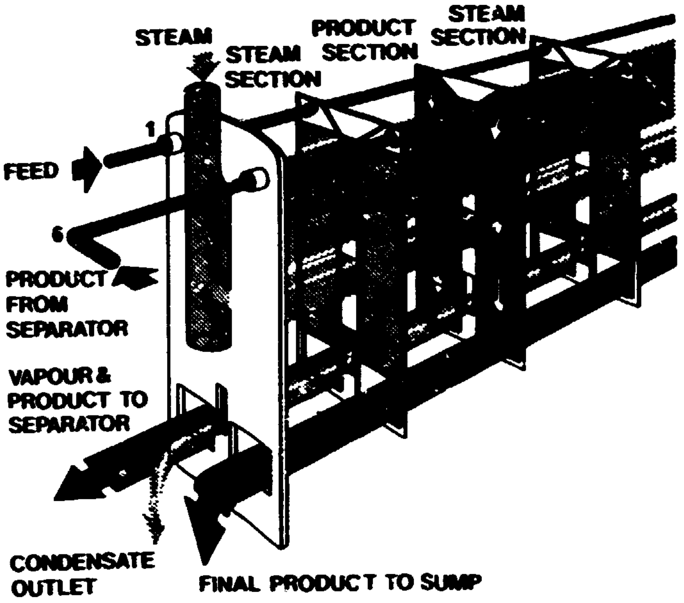


Figure 4.3 Operation of Two Stage Falling-Film Plate Evaporator

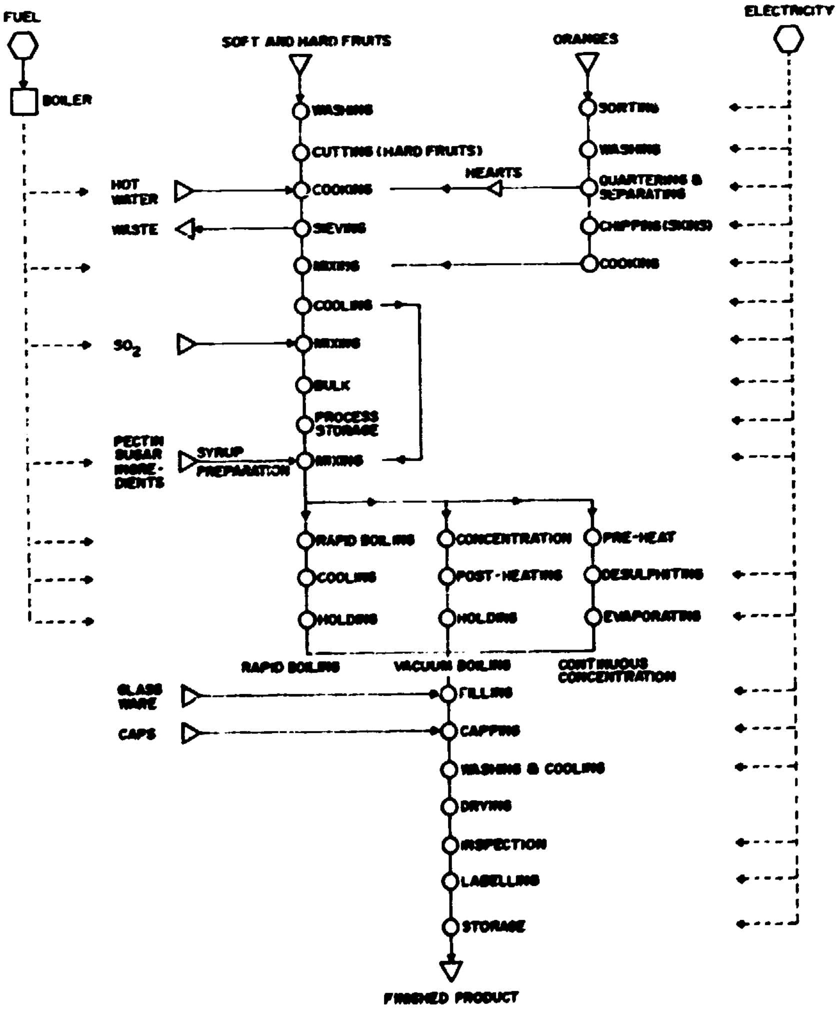


Figure 4.4 Operation Process Chart for Jam and Marmalade Making

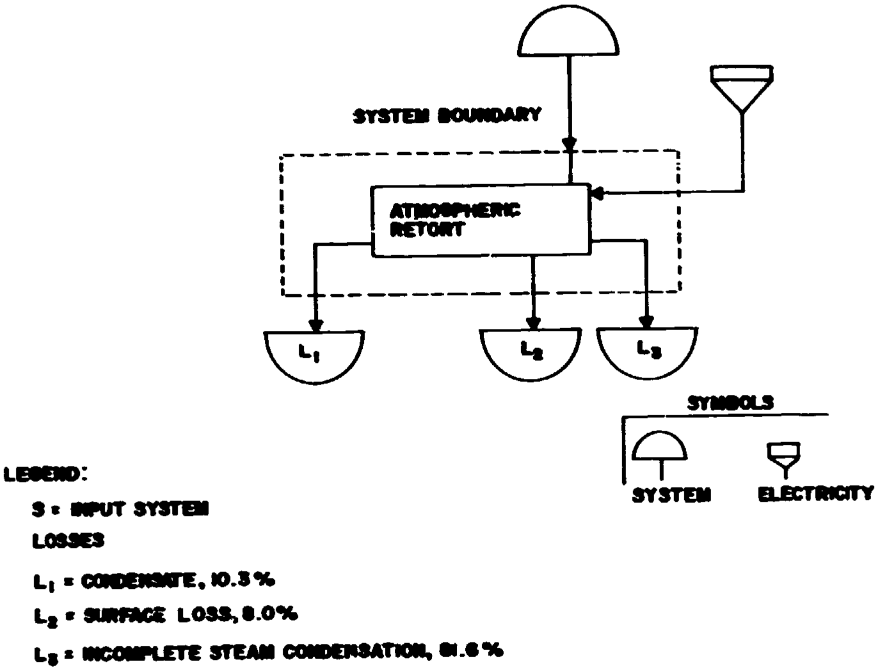


Figure 4.5 Energy Balance of Atmospheric Retort
Source: Reference 2

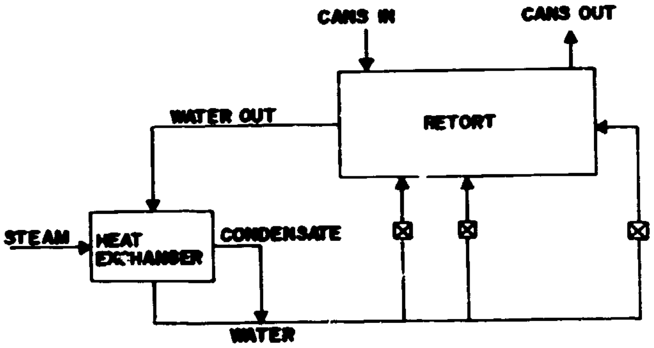


Figure 4.6 Atmospheric Retort with Externally Located Heat Exchanger
Source: Reference

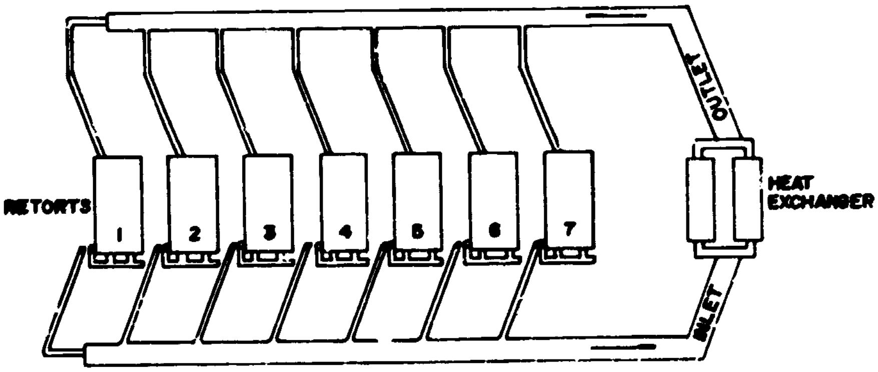


Figure 4.7 Multiple Retorts with Common Heat Exchanger
Source: Reference 2

Figure 4.3 shows the operation of one type of falling film plate evaporator. Fruit juice is distributed as a thin film over the left hand half of the heated plates, and boils at relatively low temperature as it falls. The partly concentrated product is separated from the vapor then returns to the right hand side of the plates for completion of the evaporation process. Alternatively both sides of the plates can be fed in parallel.

4.2.3 Jams, Marmalades and Jellies

Fruits which are not good for the market but of sound quality are made into jams, marmalades and jellies. These products are made by the addition of sugar to the fruit juice, the fruit, or both.

Jelly is made by boiling the fruit to extract the juice. Sugar is added to the filtered juice and the mixture is concentrated by evaporation. To get a jelly of good consistency, a gel must be formed by the right combination of acid, pectin and sugar.

Jams are made of the fruit portions, fruit juice and sugar. Marmalades are made from the skin of citrus fruits, the juice and sugar. Figure 4.4 shows the process chart for the manufacture of jam and marmalade. Rapid boiling and vacuum boiling are batch methods of production while the use of plate heat exchangers allows continuous processing.

In rapid boiling, water is evaporated from the mixture at atmospheric pressure in open-top steam heated pans. This method has the disadvantage of requiring large amounts of steam and labor.

Vacuum boiling allows for accurate control of the process and a lower operating temperature. Heat is provided by internal steam coils and cooling by water in vacuum vessels. A usual practice to save on water is to recirculate the water through a cooling tower or heat exchanger.

Plate type heat exchangers are used in the continuous concentration process. A high quality product is derived from accurate control of the process. It also has the advantages of requiring less labor, space, steam and maintenance.

4.3 ENERGY CONSERVATION POTENTIALS AND MEASURES

Energy for heating and cooling is used not only in the preparation of food products but also in the packaging of the product. Products mentioned in the previous sections such as juices, jams, marmalades and jellies are commonly packaged in glass bottles. Because of the large amount of water and steam used in bottle washing this process has been included as an area for energy conservation. Other energy saving measures discussed are in the use of multi-effect evaporation systems and modified atmospheric retorts for efficient energy use.

4.3.1 Heat Exchangers for Efficient Atmospheric Retorts

Atmospheric retorts are widely used for heat sterilization of processed fruits and vegetables. The energy balance across the boundary of a typical atmospheric retort, illustrated in Figure 4.5, shows that most of the energy of the incoming steam is lost by incomplete condensation of the steam in the water. Steam bubbles through the water without condensing and without releasing its energy to the water. Because of the absence of control, heat is further lost when the temperature of the water (just below 100°C) approaches the boiling point.

The use of a heat exchanger as shown in Figure 4.6 provides more efficient heat transfer from the steam to the kettle water. Water is pumped from the front end of the retort through the heat exchanger and distributed to different sections of the retort. More energy is available for heating the cans with the heat exchanger. A single heat exchanger can be used for several retorts as in Figure 4.7.

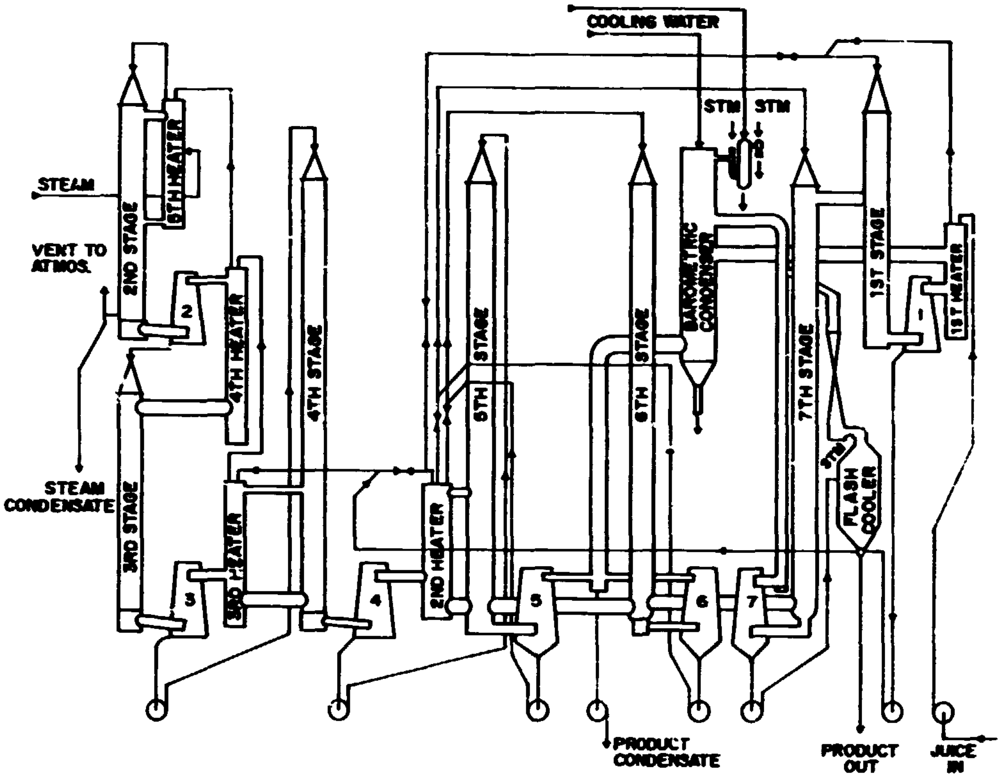


Figure 4.8 Four-Effect Citrus Juice Evaporator
Source: Reference 2

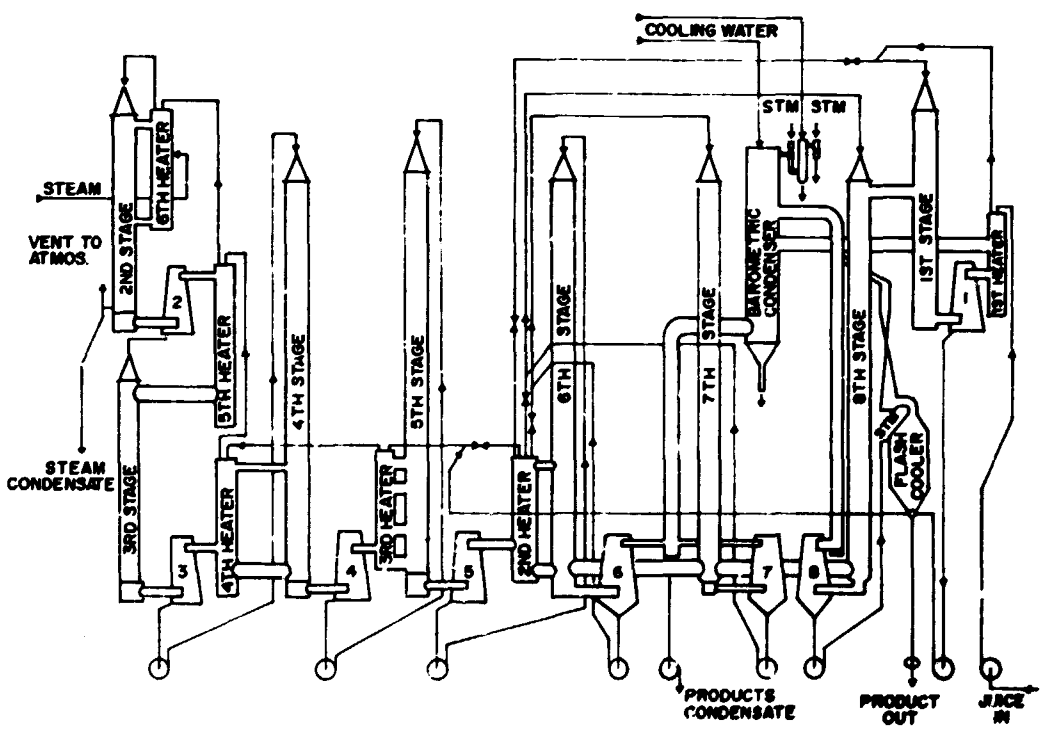


Figure 4.9 Five-Effect Citrus Juice Evaporator
Source: Reference 2

4.3.2 Evaporators

One method of concentration, namely, evaporation, uses considerable energy to remove moisture. The following measures offer ways to minimize this energy consumption:

(a) Use mechanical processes to minimize the moisture which has to be removed by evaporation. Screw and filter presses lower the moisture content with relatively less energy.

(b) Provide insulation to minimize the escape of heat to the environment.

(c) Maintain minimum possible vacuum needed; a vacuum higher than necessary is a waste of energy.

(d) Proper maintenance will ensure that the evaporator is working at its peak efficiency. Check for leaks, particularly at the steam jet ejectors. Constant descaling will make possible the maximum transfer of heat between the steam and the product.

(e) Mutliple effect evaporators remove more water with the same amount of steam than single effect evaporators. Water vapor evaporated from the first effects is used as steam to remove water in the next effect resulting in lower steam demand. As the number of effects increase, the energy requirements for the removal of a unit amount of moisture is decreased. In some cases, an existing evaporator may be modified to increase the number of effects.

Shown in Figure 4.8 is a 4-effect citrus juice evaporator converted to a system with 5 effects (Figure 4.9). In this case, approximately 20 per cent less energy will be required to evaporate a fixed amount of water.

(f) Another method which uses the water evaporated by steam is the mechanical vapor recompression (MVR) evaporator. Water vapor from the product, instead of going to the condenser, is sent to a mechanical compressor, where it is compressed to a pressure high enough for it to be used as a heating medium in the steam jacket of the evaporator. (See Figure 4.10B). The vapor condenses in the heating side of the evaporator, rejecting its heat to generate more vapor rather than being thrown to the cooling water. This "recycling" of heat increases the efficiency of the system.

Although energy is required to drive the mechanical compressor, this additional cost is very small compared to the savings acquired. An MVR-operated plant can be expected to have utilities cost of only 30 to 50 per cent of those of a steam-heated four effect evaporator. The absence of a condenser eliminates the need for cooling water, reducing the operating costs further.

(g) For plate evaporators, thermo-compression reduces the steam consumption significantly. In a double-effect set-up approximately 0.55 kg of steam is needed to evaporate 1 kg of water. With the addition of a first effect recompression the amount of steam needed to vaporize the same quantity of water becomes 0.39 kg.

A triple-effect plant requires only 0.25 kg of steam to evaporate 1 kg of water. Five effect plants operate with a steam demand as low as 0.25 kg/kg of water evaporated.

Preheating the feed can improve the efficiency of the plant. The feed temperature can be raised by using vapor from the final effect or a portion of the water discharged from a spray type condenser.

4.3.3 Heat and Water Recovery in Bottle Washers

A schematic diagram of a bottle washing machine is shown in Figure 4.11. The bottles are cleaned as they pass from different sections of the machine by soaking in or spray-jetting with hot water and detergent. Steam coils in the hot water tanks provide the heat to the detergent solutions. The temperature ranges from ambient in the first section, up to a high of 70 to 80°C, and back to a cool 10°C in the final rinse. Large quantities of heat in the order of 500 kg/h are required to heat the detergent solution. Water at a rate of 10000 litres per hour and a temperature of 20 to 30°C removes the dirt from the bottle and is usually thrown to waste. Considerable

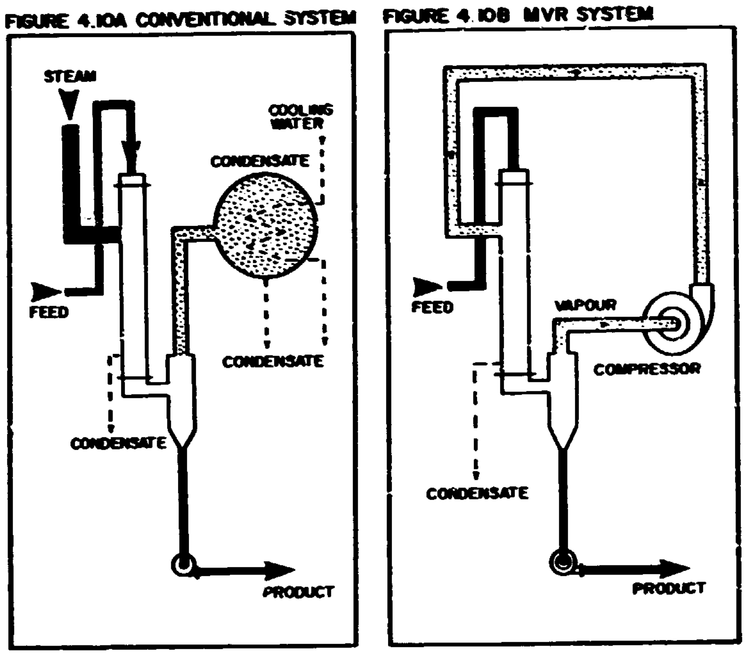


Figure 4.10 The Mechanical Vapor Recompression (MVR) Evaporator
Source: Reference 10

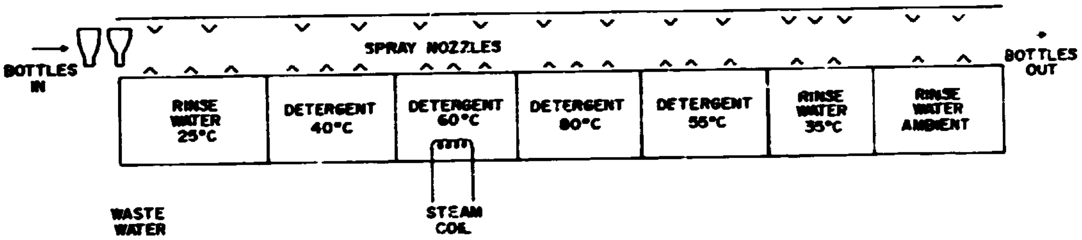


Figure 4.11 Schematic Diagram of a Bottle Washing Machine
Source: Reference 5

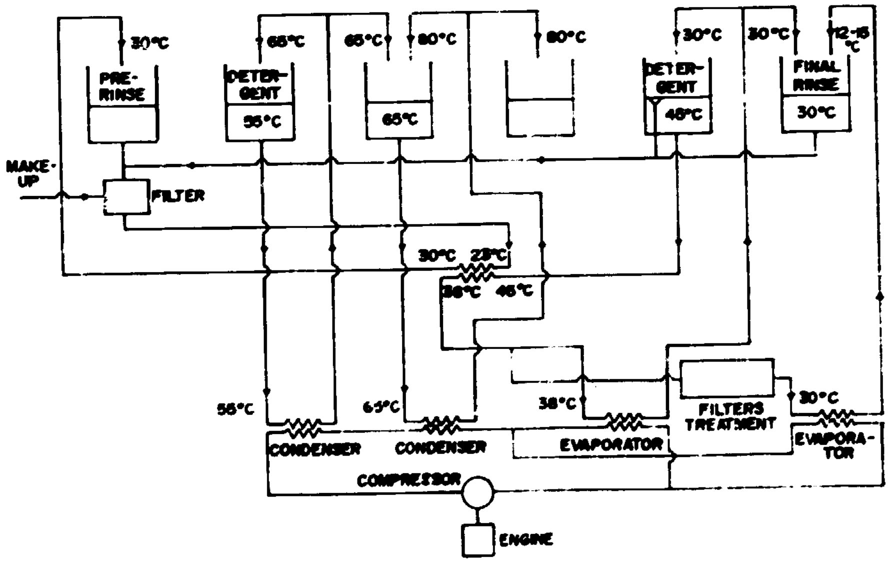


Figure 4.12 A Heat and Water Recovery System for Bottle Washing Machines
Source: Reference 5

amounts of heat move from one section of the machine to the next as the bottles are transported through the system.

Energy can be conserved with the use of a heat and water recovery system as shown in Figure 4.12. Because of the presence of high and low heat sinks, a heat pump is an ideal device for heat recovery. Low grade heat recovered through the two evaporators is absorbed by a refrigerant. Heat is added to the refrigerant by the compressor and is rejected to the high heat sink at the condensers.

Water at 45°C from the final detergent tank is passed through a heat exchanger to raise the temperature of the pre-rinse water. One stream of this water rejects heat to the first evaporator before returning at 30°C to the final detergent and final warm rinse tanks. The other stream is filtered, passes through the second evaporator and returns as the final cold rinse water at 12 to 15°C.

Water from the first detergent tank is raised from 55 to 65°C at the first condenser. The second condenser raises the high temperature section water from 65 to 80°C.

The pre-rinse spray water supply is replenished with water from the final rinse tank and with overflow from the final detergent tank. The water is cleaned in a filter together with any make-up water.

4.3.4 Blanchers

Proper blanching is the first heat treatment process in the production of canned fruits and vegetables. The use of control instrumentation and modifications as itemized below will minimize the heat requirement of this processing operation.

(a) *Thermostatic Controllers*

The maintenance of the correct operating temperatures throughout the blancher would be impossible without thermostatic controllers. The loading of cold product at the inlet causes the temperature in this section to vary considerably. Controlling only the inlet temperature would lead to a high outlet temperature, which can threaten the quality of the product. Providing both ends with temperature controls will result in a properly blanched product.

Upon entry of the product, the inlet cools faster and the inlet controller compensates by admitting heat at a rate proportional to the feed rate. At the middle section, the product is completely heated and the outlet controller limits the entry of heat for a correct temperature profile.

(b) *Hot Water Rather than Steam for Blanching*

When applicable, the use of hot water instead of steam for blanching will result in energy savings since the change of phase of water from liquid to vapor requires a significant quantity of heat.

(c) *Sizing of Nozzles*

Sizing nozzles according to the steam condition and process requirement will ensure the efficient transfer of heat to the product and cooking of the product in the quickest time. In some applications, only high pressure steam delivered through small steam injection jets can provide the required heat treatment.

(d) *Insulation*

Heat always moves from the high temperature body to the surroundings which are at a lower temperature. Insulating the blancher will prevent the escape of heat to the atmosphere, eliminating waste of energy.

(e) *Steam Loss*

A high steam pressure will cause the steam to bubble through the blancher water before it can transfer its heat to the water or product. Limiting the steam pressure will eliminate this waste. A pressure of 138 kPa will be sufficient in most applications.

(f) *Steam Inlet with Strainer*

Some operators purge the steam inlet line before every operation of the blancher. This wastes precious heat. The use of a strainer in this line will ensure that steam free from debris will enter the blancher even without regular purging. A 100-mesh stainless steel strainer will keep out most impurities. After installation, the frequency of purging should be determined by trial and error. Once this frequency is established, needless waste of steam can be avoided.

(g) *Residence Time*

Too short a residence time could result in ineffective bacteria elimination. On the other hand, over-blanching might be detrimental to the product and is certainly energy consuming.

REFERENCES:

1. Casper, M.E. ed., *Energy Saving Techniques for the Food Industry,* Noyes Data Corporation, Park Ridge, New Jersey, U.S.A., 1977.
2. Fazzolare, Rocco and Craig B. Smith, *International Conference on Energy Use Management* 2nd ed., Pergamon Press Inc., New York, U.S.A., 1979.
3. Lopez, Anthony, *A Complete Course in Canning,* Book I, Basic Information on Canning, 11th ed., The Canning Trade Inc., Maryland, U.S.A., 1981.
4. Pyke, Magnus, *Food Science and Technology,* John Murray, 50 Albemarle Street, London, 1964.
5. Reay, David A., *Industrial Energy Conservation,* Pergamon Press Ltd., Oxford, England, 1977.
6. *McGraw-Hill Encyclopaedia of Food, Agriculture and Nutrition,* Daniel N. Lapedes ed., 4th ed., McGraw-Hill Book Co., New York, 1977.
7. Considine, D.M. and S.D. Ross, eds., *Handbook of Applied Instrumentation,* McGraw-Hill, 1969.
8. *APV Plate Evaporator Climbing and Falling Film Type,* The A.P.V. Company Ltd., England, 1977.
9. *Stainless Steel Plant for Fruit Juice Processing,* The A.P.V. Company Ltd., England, 1981.
10. *Mechanical Vapour Recompression by APV,* The A.P.V. Company Ltd., England, 1978.

CHAPTER 5

Energy Conservation in the Processing of Grains

5.1 GRAIN PRODUCTS AND PROCESSES

The grain products involved in this chapter are flour and milled rice.

Processing of rice involves harvesting, threshing, drying, storing and milling. The flour milling industry not only produces flour from wheat but is also engaged in the blending and preparation of mixed flour for different purposes.

5.1.1 Rice Processing

(a) *Harvesting*

Harvesting of rice in the Philippines is mostly done by hand and constitutes about 22% of the total labor time for rice processing. It is usually done by either of three popular instruments or methods:

(1) a *yatab* that cuts the panicles without the leaves;

(2) a *lingkaw* that is efficient for lodged varieties because it lifts and twists the stems together and makes them easier to cut;

(3) a sickle or scythe that cuts a number of stems at the same time.

After the rice stalks are cut, they are bundled, piled and left in the rice field for a few days before they are threshed.

Mechanical harvesters are hardly used in the Philippines because of the high cost of the machines, fragmentation of the farms and difficult soil conditions.

(b) *Threshing*

There are at least three methods of threshing used in the country: the *hampasan*, trampling and mechanical threshers. In the *hampasan* system, panicles are threshed by impact against a slotted board, pavement block, or piece of wood. The trampling method utilizes rubbing action for separating the grain from the panicle. The mechanical method of threshing utilizes impact and some stripping action to separate the grains from the panicle. Large tractor-drawn mechanical threshers used to be popular but now locally fabricated smaller units powered by 16-hp engines are becoming more widely used.

(c) *Cleaning*

The manual method of grain cleaning is winnowing. Straw, chaff, weed seeds, and other foreign materials are removed by utilizing natural wind or manually operated blowers.

In the mechanical thresher, cleaning is usually integrated in the process using an open double-layer oscillating sieve.

(d) *Drying*

For satisfactory storage and subsequent milling, the moisture content of paddy must not exceed 14%. The most common grain drying method practiced in the Philippines is sun drying. Grains are spread on a flat dry surface, either on cement pavements or fiber mats, and occasionally stirred or raked so that the grain will dry uniformly.

There is, however, a great need for mechanical driers in the country today because of the introduction of high-yielding, early-maturing, and non-seasonal varieties. Existing mechanical driers are few and very much below capacity.

(e) *Storing*

The prevailing grain storage practice in the Philippines makes use of warehouses where the grain is stored in jute or plastic sacks. Two systems of piling stocks are utilized. One is the conventional stacking method in which the bags are piled side by side and one on top of the other. In this system of piling, there is no provision for ventilation space between the bags. The other system, called the Japanese style, provides ventilation between the bags. It allows for the circulation of convective air currents that provide a medium for heat dissipation.

On a commercial scale, but to a lesser extent, bulk or open storage is practised in the Philippines. In this storage practice, the grain is poured on the floor of the warehouse or into silos. The former method is readily susceptible to attacks by storage pests and the latter cannot handle different varieties of grains.

Small farmers use woven bamboo bins, cans, barrels, boxes, woven bags and earthenware for temporary or permanent storage.

As a result of these antiquated and inadequate storage facilities in the country, stored grain suffers from physical losses and deterioration.

(f) *Milling*

The rice milling equipment used in the Philippines can be classified loosely into: hand-pounding equipment; Engleberg mills (*kiskisan*); disc hullers (cono mills); and rubber-roller mills.

The most widely used are the Engleberg mills, which process about 40% of the annual paddy production. These mills are very wasteful, having a milling recovery of 59% or less, and the value of its by-products is low. However, only a small capital outlay is required for these mills and the milling fee is low, which makes them popular in the rural areas. The Engleberg mill suffers from the drawback that the required power is very high: a 4-hp motor gives an output of about 35 kg per hour, whereas the same power applied to a cono mill would provide about 1,350 kg per hour.

The mechanism for the disc huller or cono mill is shown in Figure 5.1. This mill produces an appreciably higher recovery rate (up to 68% by weight) than the Engleberg huller. In addition, head rice recovery is also higher and the degree of milling can be more closely controlled. It is more fully attuned to commercial markets. The capacity ranges from less than 100 to 1,000 cavans of paddy per 12-h day. Owners generally derive business

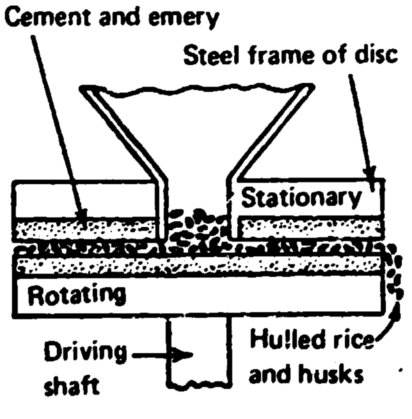
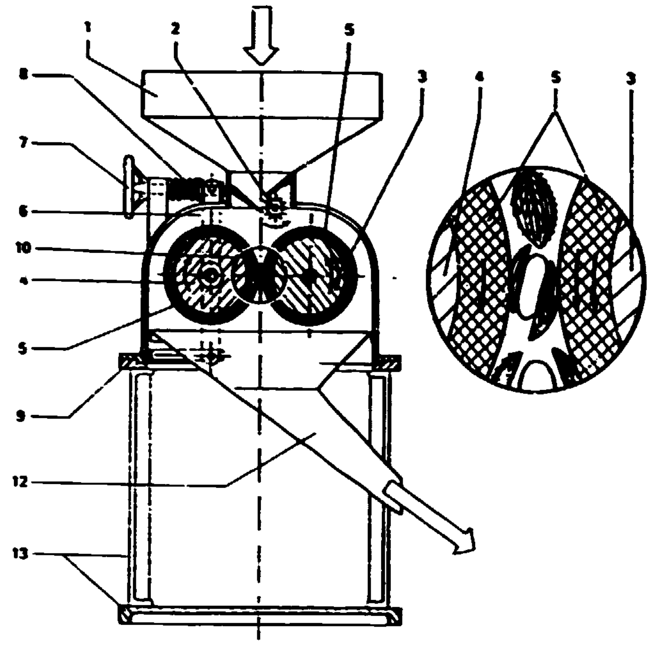


Figure 5.1 Section through a Disc Huller
Source: Reference 3



1. Feed hopper 2. Feed roller 3. Fast roll 4. Slow roll 5. Rubber surface
6. Roll shifting arm 7. Roll clearance adjustment handwheel 8. Roll tension spring
9. Husker housing 10. Drive pulley 11. Roll drive case 12. Husked rice and husk outlet
13. Machine base and frame

Figure 5.2 Rubber Roll Husker
Source: Reference 3

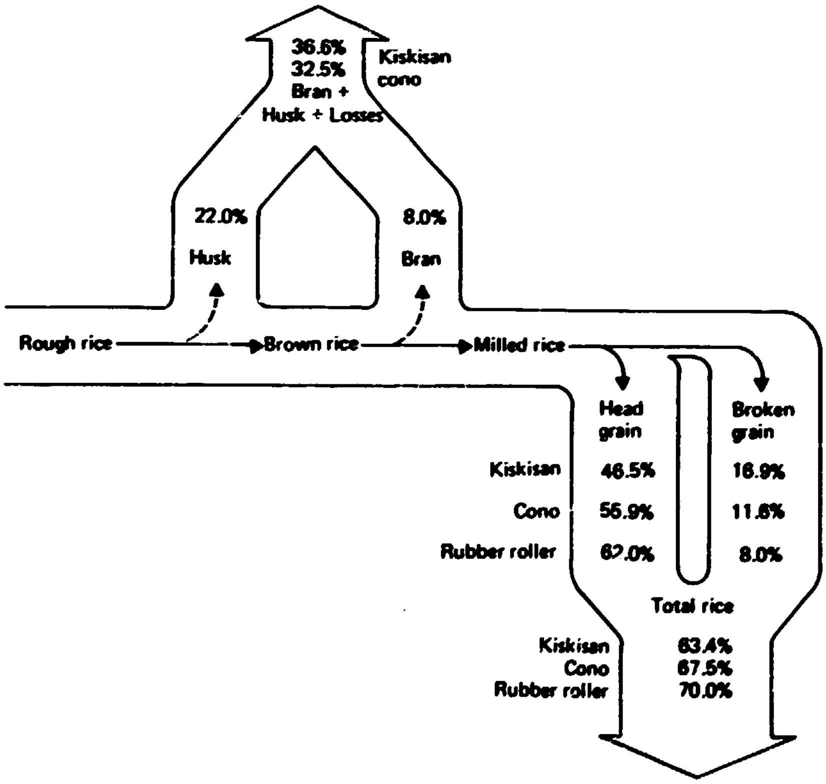


Figure 5.3 Recovery Efficiency Three Rice Milling Systems
Source: Reference 1

from buying, processing and selling milled rice unlike the *kiskisan*, which is largely a custom milling operation.

The rubber roller shown in Figure 5.2, was developed in Japan. It produces the highest total recovery when properly adjusted. It is available in sizes ranging from below 100 to over 5,000 cavans per 12-h operation. The rubber roller has the highest technical efficiency but its drawbacks are: high equipment cost, high milling fees and costly spare parts.

Figure 5.3 shows a comparison of recovery efficiencies for the three rice milling systems.

In a larger-scale modern rice hulling plant, the machines which perform the various operations are listed in Table 5.1. Cleaning can be performed by a variety of sieves, travelling screens, screens in series, or a cylinder with holes of different sizes. A common equipment in conjunction with those listed in Table 5.1 is an aspirator which sucks dust, dead grain and other impurities. A magnetic separator removes any metallic objects such as wires or nails which might damage any of the equipment in the succeeding operations. Hulling is performed either by a disc huller or a rubber roller. The mixture of hulls, broken rice, hulled rice and unhulled rice pass through a series of screens and winnowing fans to separate the hulled rice.

Pearling is done by a cone mill to remove the outer covering. The cuticle is removed as the rice passes through a narrow annular space between an inverted cone coated with emery and a steel wirecloth. For white rice, two or three pearling cones in series are used before the rice is polished.

To get rice with very fine appearance, rice is passed through a polisher. It is similar in construction and operation to the cone pearler except that instead of an abrasive, the cone is covered with leather. To improve the complexion of the rice, a second polisher may be used and a dry coloring agent added to increase the whiteness of the polished grain.

5.1.2 Flour Milling

The milling of wheat into flour is a continuous process, where three stages of operation are carried out, namely: cleaning, tempering and grinding. Figure 5.4 shows a diagram of flour milling operations.

In the first step, the stream of wheat grain passes through the separators, reciprocating screens where stones, sticks and other coarse and fine unwanted materials are removed. Lighter impurities (e.g., dust and loosened particles of bran coating) are carried off by air currents. Roughage and other impurities are scoured by beaters in screen cylinders while magnetic separators remove iron or other steel articles. The cleaning process is completed when the wheat undergoes washing in a washer-stoner that spins the wheat in a water bath. Stones drop to the bottom while lighter materials float off leaving only the clean wheat. It is also at this point where different varieties of wheat may be blended to form certain flour qualities.

In the tempering stage, the grains are moistened to toughen the bran preparatory to milling. From here, the wheat flows to a grinding bin or hopper where it is fed into the mill.

In the grinding stage, the wheat grains pass between several pairs of break rollers that gradually split the kernels into pieces and flatten out the bran. Then, the flour is removed by sifters and carried to purifiers. The purified wheat granules (free of bran as possible) are classified by size for treatment by the reduction rollers.

The process is repeated over and over again – sifters, purifiers, reduction rollers – until the maximum amount of flour is extracted. The various by-products are separated but flour is recovered first in each step in the reduction of the kernels.

As the flour proceeds to the packaging room, it undergoes bleaching, aging and color neutralization to suit the demands of the market. Flour is even enriched with thiamine, niacin, riboflavin and iron. For self-rising flour, salt and leavening agent (yeast) are also added.

Table 5.1 Operations and Machinery in a Modern Rice Hulling Plant

Operations	By-products recovered	Machines
Paddy scalping and cleaning (from rough to clean paddy)	Light foreign substances Heavy foreign substances Other seeds	Scalping machine Fan and screen separator Rotary sieve classifier Specific gravity apparatus Indented disc separator
Paddy awns (beards) cutting (from bearded to unbearded paddy)	Beards	Awners (beard-cutting machine) Fan and screen separator
Paddy grading (from paddy of non-uniform size to uniform-sized paddy)	Paddy of different length or thickness to be separately processed	Indented disc separator Grading cylinder Cellular or indented cylinder
Paddy husking (from paddy to husked rice)	Husks Bran (stone bran) Germ Brewers	Disk husker Rubber roll husker Rubber belt husker Fan and screen separator Rotary screen classifier Paddy or compartment separator
Grading of husked rice (from non-uniform to uniform product without dead grains)	Unripe rice Husked rice of different length or thickness to be processed separately	Grading cylinder Cellular or indented cylinder
Rice whitening or hulling (from husked to white or hulled rice)	Bran (bran and germ first and second break-white bran third break)	Pearling or whitening cone Tamping or hulling machine[1] Combined huller and polisher[2]
Rice polishing (from white or hulled rice to polished rice)	Polish	Polisher or brush Combined huller and polisher[2]
Rice grading (from a mixture of rice and brokens to head rice and different sized brokens)	Second head rice Half-grain White brewers Dead grains	Fan and screen separator Rotary sieve classifier Specific gravity separator Indented disc separator Grading cylinder Cellular or indented cylinder
Glazing or oiling of polished rice (from polished rice to coated or oiled rice)	Glucose and talcum lumps	Helix screw machine Glazing or oiling drum Fan and screw separator
Bran and polish shifting (from a mixture of cargo meal to pure bran and polish)	Pure bran Pure polish Germ Screenings	Rotary sieve classifier

1. This machine can also be used for husking and hulling in one operation.

2. This machine can also be used for husking, hulling and polishing in one operation.

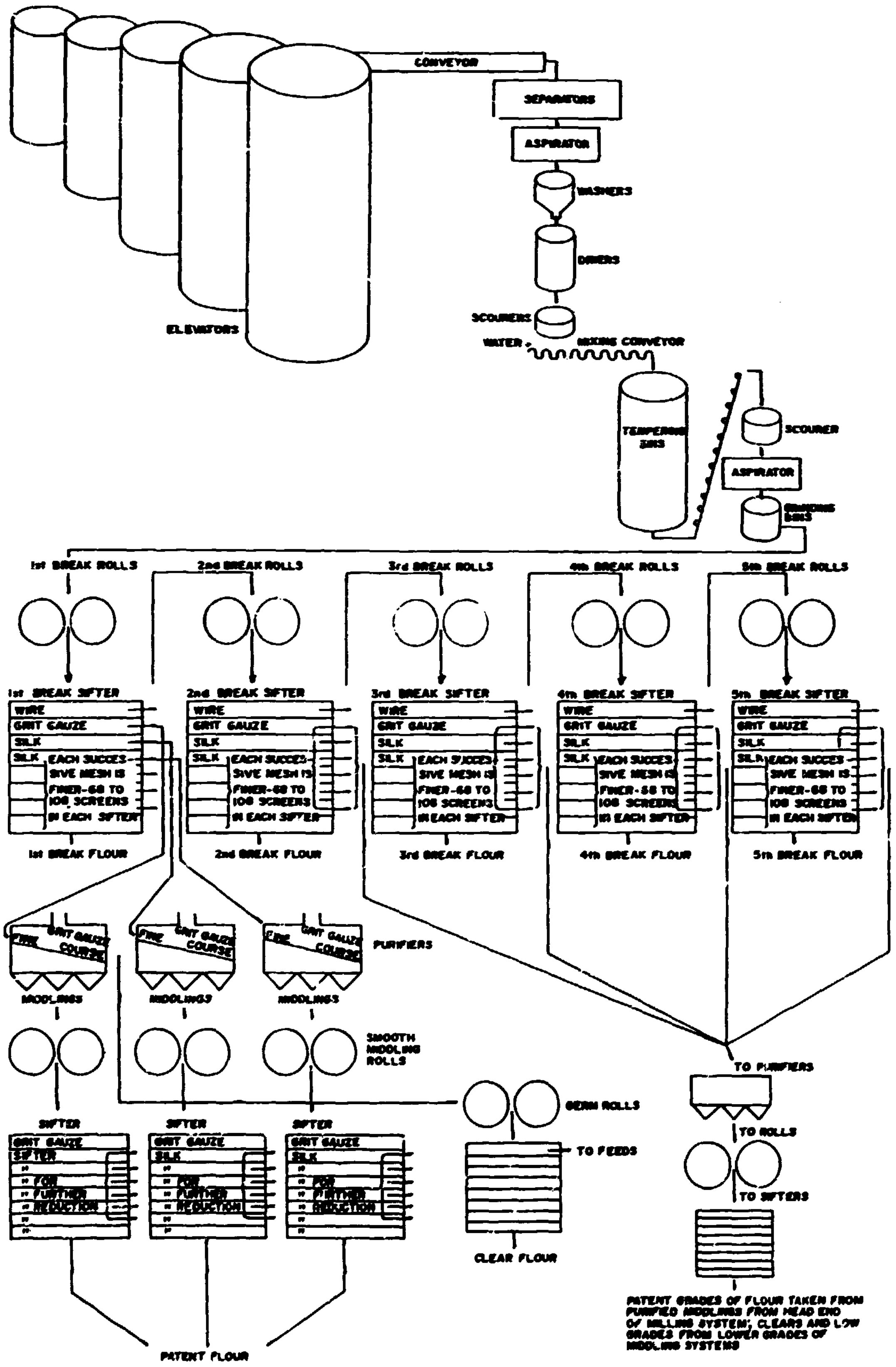


Figure 5.4 Diagrammatic Sketch Showing Flow of Wheat Milled into Flour
Source: Reference 2

5.2 ENERGY FLOWS IN GRAIN PROCESSING

5.2.1 Rice Processing

As earlier described, drying of rice in the Philippines is mostly done by exposure to the sun. Locally developed small-farm driers are ricehull-fired. Electricity is used in operating the blowers for these and larger mechanical dryers.

All other processes require mechanical energy. Mechanical threshers are engine driven. Rice mills are powered either by electricity or diesel engines.

Figure 5.5 shows the material and energy flow-diagram for rice milling.

5.2.2 Flour Milling

The only form of energy used in flour mills in the Philippines is electricity. Boilers are no longer in use since steam is no longer utilized in the tempering process. The following are the primary energy consuming operations in flour milling, arranged in decreasing order:

a. break rolls
b. pneumatic conveying system
c. receiving, blending, cleaning and tempering
d. packing
e. sifting
f. purifying
g. bagging

The break rolls and the pneumatic conveying system use a major portion of the electric consumption. The basic equipment used are motors and air compressors.

The material and energy flow-diagram for flour milling is shown in Figure 5.6.

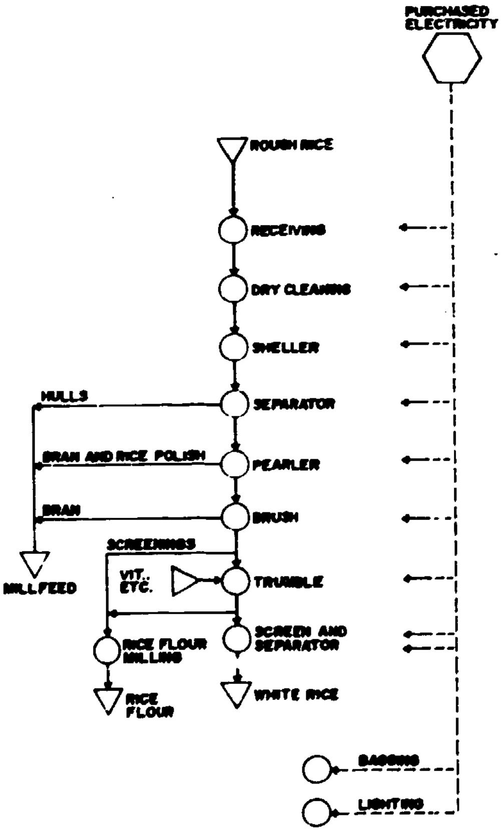


Figure 5.5 Material and Energy Flow-Diagram for Rice Milling
Source: Reference 2

5.3 ENERGY CONSERVATION MEASURES

a. *Increase the power factor.* Improvement of the power factor generates savings in the electric bill. The method commonly used is the installation of capacitors either at the central substation or at each section of the milling operations.

b. *Limit peak loads.* A sequence of actions for carrying out the leveling of demand in electricity is described in Chapter 6 (section 6.1.1). The start-up of large electric motors must be staggered to avoid the surge of power demand.

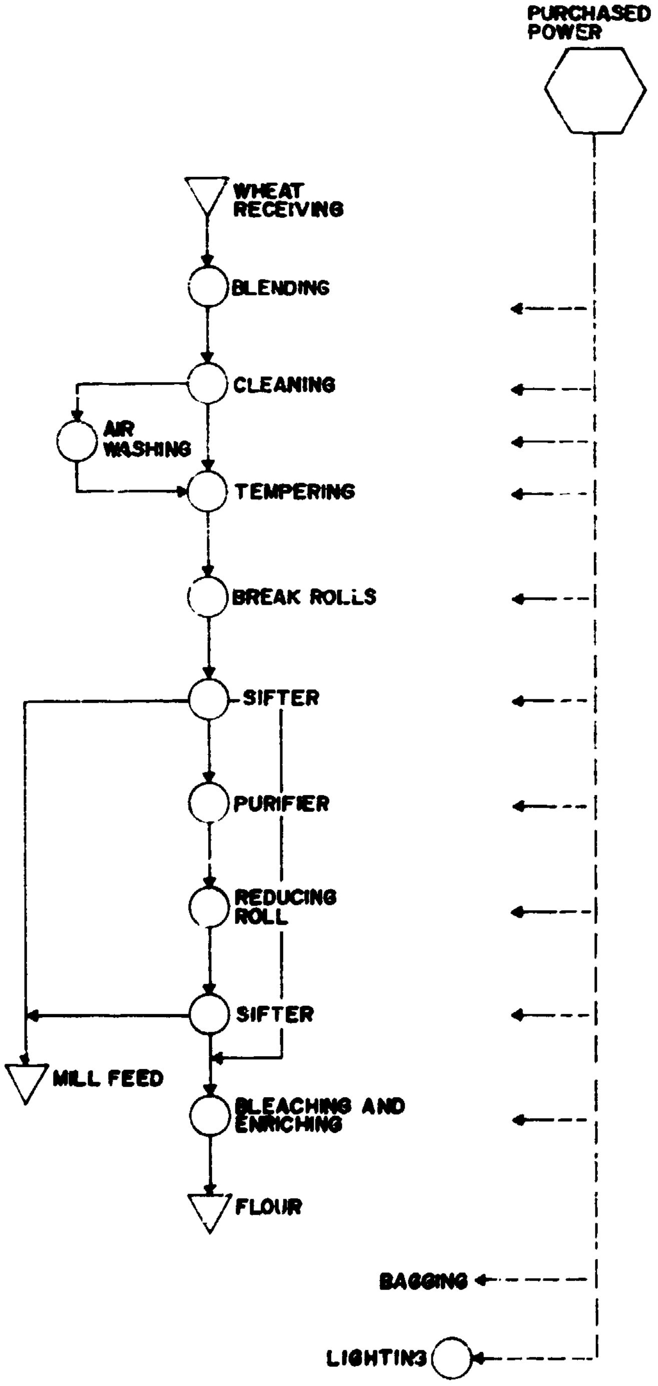


Figure 5.6 Material and Energy Flow Diagram for Flour and Other Grain Mill Products

c. *Check for grounding.* Make sure that no electric line is grounded since this would register a reading in the electric meter even when no equipment is switched on.

d. *Shut down equipment not in use.* While this is a common-sense procedure, equipment are left running without load. This should become a habit among personnel, which extends to the use of lights, air-conditioners and office equipment.

e. *Carry out an effective preventive maintenance program.* This not only results in energy savings but more importantly in the reduction of downtime.

f. *Use the proper motor size.* . Underloaded motors consume more electricity than needed and operate at low efficiency. Energy conservation in electric motors is discussed in Chapter 6 (section 6.4).

g. *Use high efficiency motors.* Table 6.5 can be used as a reference in motor selection.

h. *Conserve energy in lighting.* Substantial energy savings can be generated in lighting systems. Specific energy conservation measures are discussed in section 6.6.

i. *Use efficient rice mills.* . Rubber rollers and cone mills are much more efficient than Engleberg mills. However, the choice actually depends on which type would give the most profitable operation. Energy is just one of the cost items. As much as possible, mill only properly dried paddy grains.

j *Use rice hull as fuel for generating power.* Large rice mills are particularly suitable for the installation of rice hull-fired boiler turbo-generator sets.

k. *Check for leaks in the pneumatic conveying system.* A small leak downstream of an air compressor represents a significant power loss.

5.4 APPLICATION CASE

This section describes a successful case of using rice hull as fuel for a thermal plant which provides electricity to run a ricemill. The plant is in the Southern Philippines Grains Complex of the National Food Authority in Tacurong, Sultan Kudarat.

a. Equipment Specifications: Siller and Jamart
HRT Firetube 3-pass boiler
400 Bo. hp.
25 bars max. operating pressure

b. Plant Capacity : 13 tons of steam per hour

c. Fuel Consumption : 4 tonnes of rice hull per hour

d. Fuel Feeding : From the husk bin, fuel is fed by means of overhead screw conveyor equipped with an oscillating flap for even spreading of fuel on the furnace grate. Fuel is normally fed dry and/or as received.

e. Other Requirements : Labor requirement is 3 laborers per shift. Total power input is 97 kW. Pollution control devices installed are a water scrubber and settling tank.

f. Costs –

Total equipment cost : ₱8,755,436.50
Fuel price : ₱4.50/tonne, if from outside
Labor cost : ₱5.62 per hour

REFERENCES:

1. Araullo, E.V., De Padua, D.B. and Graham, M., eds., *Rice Post Harvest Technology,* IDRC-053e. International Development Research Centre, Ottawa, Canada, 1976.
2. Casper, M.E., ed., *Energy Saving Techniques for the Food Industry,* Noyes Data Corporation, Park Ridge, New Jersey, U.S.A., 1977
3. Grist, D.H., *Rice,* 5th ed. Tropical Agriculture Series, Longman Group, Ltd., Longman House, Burnt Mill, Harlow, Essex, England.
4. Parker, M.E., Harvey, E.H., and Stateler, E.S., *Elements of Food Engineering,* Vol. 1, Reinhold Publishing Corp., New York, U.S.A., 1952.
5. Pyke, Magnus, *Food Science and Technology,* John Murray 50 Albemarle Street, London, 1964.
6. "The Flour Milling Industry in the Philippines", *Journal of Philippine Statistics* Vol. 30 No. 2, National Census and Statistics Office, National Economic and Development Authority, 1979.

CHAPTER 6

Energy Conservation in Common Food Processing Equipment

6.1 COMMON EQUIPMENT

The common equipment in food processing plants for which energy conservation measures are described in this chapter are:

a. boilers
b. steam systems
c. motors
d. compressed air systems
e. lighting systems
f. canning equipment

Besides equipment-specific measures, two major actions may result in significant plant-wide savings in electric consumption. These are demand limiting and power factor correction.

6.1.1 Demand Limiting

Demand charges are imposed by utility companies for peaks in the use of electricity during a given billing period. Savings can be gained by leveling off the demand peaks. It is necessary to determine, first, when peak electrical requirements occur; second, the loads that are in use ; and third, the relative magnitude of the loads. Once a user has compiled this information, he can make his decision on operation/power requirement shifts. The following are specific recommended actions:

(a) Study the hourly variation in demand for the billing period. It may be necessary to install a demand recording meter. A wattmeter or a recording ammeter will be expedient.
(b) Determine the rating of each electrical load and the schedule of operation.
(c) Identify each electrical load as either primary or secondary. A primary load cannot be interrupted; a secondary load can be interrupted, rescheduled or difused without causing problems. Typical secondary loads are:
    (1) lighting
    (2) electric heating and/or cooling units
    (3) chillers
    (4) air handling units
    (5) exhaust fans
    (6) water heaters
    (7) pumps
    (8) electric boilers
    (9) furnaces and/or ovens
    (10) incinerators
    (11) air compressors
(d) After identifying secondary or sheddable loads, establish shedding priorities, giving essential secondary loads top priority, operating on a last-out first-in basis; lower priority loads should operate on a first-out last-in basis.

(e) Determine the potential impact of shedding on process comfort, productivity or environment. Effect on equipment should also be studied since frequent operation of controls may shorten life expectancy and increase maintenance.

(f) After identifying controllable loads and priorities, determine how much demand reduction can be obtained and the most cost-effective means for achieving this reduction. The measures include:

    (1) rescheduling the operation of certain equipment;
    (2) installation of time-switches; and
    (3) use of demand control meters which automatically shut down low priority equipment when a preset demand level has been reached.

6.1.2 Power Factor Correction

Power factor is the ratio of power producing current to total current in a circuit. Devices such as induction motors, transformers, fluorescent lights, induction heating furnaces, etc. require two kinds of current, reactive and power-producing current. The latter is the current converted by the equipment to useful work or heat. Reactive current is required to produce the flux necessary to produce induction. A plant with a low power factor consumes large reactive current. A device installed in a plant to improve the power factor actually generates most or all of the reactive power needed to set up the magnetic field of induction devices and thus reduces or eliminates the need to supply this power from the distribution system.

Several devices are available for power factor improvement: the two most popular are power factor correction capacitors and synchronous motors. There are two methods of installing capacitors. The first method is bank installations, in which a group of capacitors is connected at a central point such as the main switchgear or unit substation. The other method involves the installation of individual capacitors on each equipment which requires power factor improvement. The latter is more expensive but has more advantages in improved voltage regulation and reduced power losses. Capacitor installation is economically justified in many cases and requires practically no maintenance.

Synchronous motors are sometimes used in place of induction motors because of their ability to operate at a high leading power factor or even at a power factor of unity. They can do many jobs commonly done by induction motors, particularly when the load is steady and reasonably continuous.

A method of quick estimation of energy savings from power factor improvement is given in Reference 7.

6.2 BOILERS

Food processing plants use boilers to generate steam for cooking, heating, pasteurization, sterilization and other processes (See Table 6.1). Boilers are of two general types: firetube and watertube. These in turn may be obtained in several different styles. The type which is most commonly used in food processing plants is the firetube either in the horizontal return tubular (HRT) or Scotch marine styles. These are generally operated at pressures usually not exceeding 1034 kPa. A typical firetube boiler is shown in Figure 6.1. The watertube type is mostly used in larger installations involving year-round operations and where large amounts of steam are required and where very high boiler pressures are used.

6.2.2 Energy Conservation Measures

Energy conservation results in minimizing energy losses. Boiler losses are indicated in the diagram shown in Figure 6.2.

(a) *Combustion System*

(1) Seal all cracks and holes around burners to prevent air infiltration.

(2) Avoid using fuels with large amounts of free moisture. Drain water from oil storage tanks and coal bunkers.

(3) Keep all air and fuel supplies to the firing equipment as constant as possible. Avoid fluctuations in pressures and composition.

(4) Reduce losses from unburned fuel by improving firing conditions. Look for poor atomization, poor mixing and other causes of incomplete combustion. Table 6.2 gives visual indications of burner flame condition.

Table 6.1 Uses of Steam in Food Industries

Source: Reference 9

Operations	Factors Affecting Use	Desirable Type of Steam
Blanching		
Direct — Steam blanching	Pressure, moisture content, purity	Dry, saturated, low pressure
Indirect — Water heating	Pressure and purity	Dry, saturated, low pressure
Cooking		
Direct — Steam injection	Pressure, moisture content, purity	Dry, saturated, high pressure
Indirect — Jacketed kettles, etc.	Pressure, moisture content, purity	Dry, saturated, high pressure
Concentrating		
Direct — Steam injection	Pressure, moisture content, purity	Dry, saturated, high pressure
Indirect — Jacket, tube, etc.	Pressure, moisture content, purity	Dry, saturated, high pressure
Pre-Heating		
Direct — Steam injection	Pressure, moisture content, purity	Dry, saturated, high pressure
Indirect — Jacket, tube, etc.	Pressure, moisture content, purity	Dry, saturated, high pressure
Peeling		
Direct — Scalding, pressure peeling	Pressure, moisture content, purity	Saturated, high pressure
Indirect — Heating, lye solution, etc.	Pressure	Saturated, low pressure
Soaking		
Indirect — Heating water	Pressure and purity	Saturated, low pressure
Washing		
Indirect — Heating water	Pressure and purity	Saturated, low pressure
Deaeration, Evacuation and Processing		
Exhausting		
Direct — Steam exhaust boxes	Pressure, moisture content, purity	Saturated, low pressure
Indirect — Heating water	Pressure	Saturated, low pressure
Closing		
Cans — Steam injection	Pressure, moisture content, purity	Dry, saturated, high pressure
Glass Containers — Steam injection	Pressure, moisture content, purity	Dry, saturated, high pressure
Deaeration		
Preheating — Direct or indirect	Pressure, moisture content, purity	Saturated, low pressure
Vacuum, Production — Steam ejectors	Pressure, moisture content, purity	Dry conc., high pressure
Processing operation		
Dehydration — Steam radiators	Pressure, moisture content, purity	Dry, saturated, low pressure
Pasteurization	Pressure, moisture content, purity	Saturated, low pressure
Direct steam injection	Pressure, moisture content, purity	Dry, saturated, low pressure
Indirect — Tubular or plate heat exchangers	Pressure, moisture content, purity	Dry saturated, low pressure
Water cookers		
Sterilization		
Direct — Steam injection	Pressure and purity	Dry, saturated, high pressure
Indirect — HTST processing	Pressure and purity	Dry, saturated, high pressure
Atmospheric cookers	Pressure and purity	Saturated, high pressure
Pressure retorts	Pressure and purity	Saturated, high pressure
Plant and equipment sanitation		
Direct	Pressure, moisture content, purity	Dry, saturated, low pressure
Indirect — Waterheating	Pressure, moisture content, purity	Saturated, low pressure

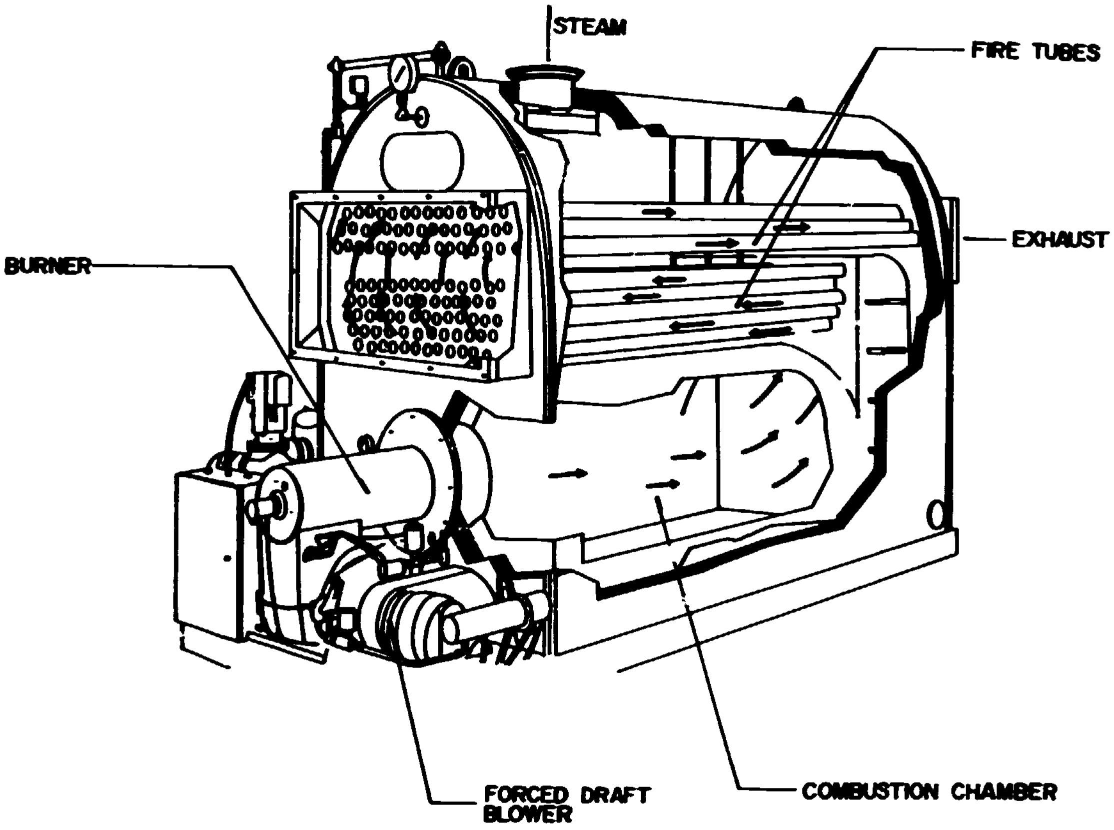


Figure 6.1 Typical Three-Pass Package, Fire-Tube Steam Generator
Source: Reference 6

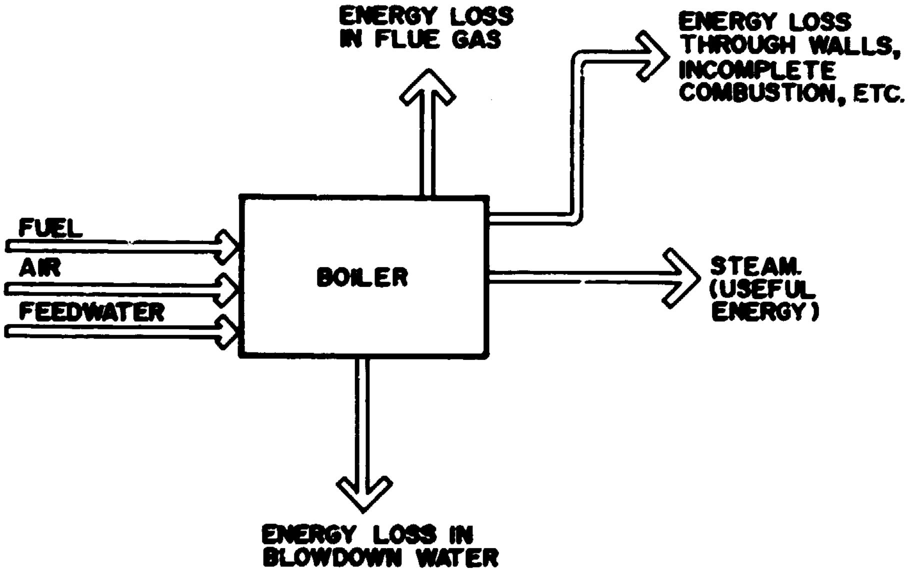


Figure 6.2 Boiler Losses

Table 6.2 Visual Indications of Burner Flame Condition

Source: Reference 8

Indication	Cause / Condition
Bright yellow flame verging on whiteness, no traces of smoke	Burner properly adjusted
Long, smoky flame	Insufficient combustion air, or insufficient atomizing steam
Reddish, dusty flame with flecks of smoke over the bright part	Deficient combustion air
Thin white flame	Too much excess air, or too much atomizing steam
One-sided flame, or sparking on one side, or showing sprays or streaks of blackoil	Burner tip is dirty, and oil is not atomizing properly
Uneven flame	Burner tip is dirty

(5) Reduce excess air and improve efficiency by using the lowest air-fuel ratios that will not cause combustion problems. (More discussion on this below). If excess air cannot be reduced to an acceptable level, overhaul or change the firing equipment.

(6) Clean tubes and other fireside heat exchange surfaces regularly or as soon as a predetermined temperature is reached. Cleaning should be thorough.

(7) Observe burner flame when unit shuts down. If flame does not cut off immediately, it could indicate a faulty solenoid valve. Repair or replace valves as necessary.

(8) Be sure oil strainers and filters are kept clean.

(9) Investigate the economics of using compressed air instead of steam for fuel atomization or soot blowing.

(10) Use waste materials as boiler fuel.

Reduce excess air to minimum

Savings from energy conservation through the reduction of excess combustion air can be determined from a nomograph (see Reference 7). Typical energy savings amount to 5 percent of the energy cost in operating a boiler.

It is common practice to use high excess air in a boiler furnace to ensure that air is not deficient, which is bad for three reasons: (1) it decreases efficiency, (2) it results in soot formation; and (3) the flue gases become potentially explosive. However, high excess air imposes an additional and useless heating load on the furnace.

Excess air is detected by measuring the oxygen level in the flue gas. The instrument used can be an Orsat analyzer or a Hagan cell. Once the percent oxygen has been measured, the excess air can be determined from tables (see Reference 16). It must be remembered that air leaks can result in a false reading and so these must be plugged.

Excess air can be reduced to as low as 12 percent for Diesel oil and 15 percent for Bunker fuel. The following is a suggested sequence of actions:

(1) Make a smoke test and adjust air supply to give the correct smoke number, as recommended by burner manufacturers.

(2) Check the draft and adjust the draft stabilizer as necessary.

(3) Check the C02 concentration in the flue gases and re-adjust the air supply to give the C02 reading recommended by the manufacturer.

(4) Re-test smoke and adjust the air supply again, and repeat alternate C02 and smoke tests until the right values are obtained.

Each adjustment of the air supply to correct the C02 concentration will, of course, affect the smoke density and vice versa. The necessary adjustment grows smaller each time until the correct air supply is achieved, giving the right values for both smoke and C02.

Investment for the installation of improved combustion controls and instrumentation is usually justifiable.

Low excess-air burners are available which reportedly can achieve complete combustion of oil with as low as 3% excess air. However, these burners require sophisticated control systems.

Retrofit boiler to use refuse as fuel

Many plants generate a large amount of combustible refuse which can be used as boiler fuel. Examples of these are rice hull, oil palm residues, coconut shells and husks, wooden crates, cardboard boxes, paper wastes and cloth rags. A firetube boiler retrofitted to burn oil palm residues is shown in Figure 6.3. Reference 6 is a useful guide for retrofitting oil-fired boilers to use solid wastes as fuel.

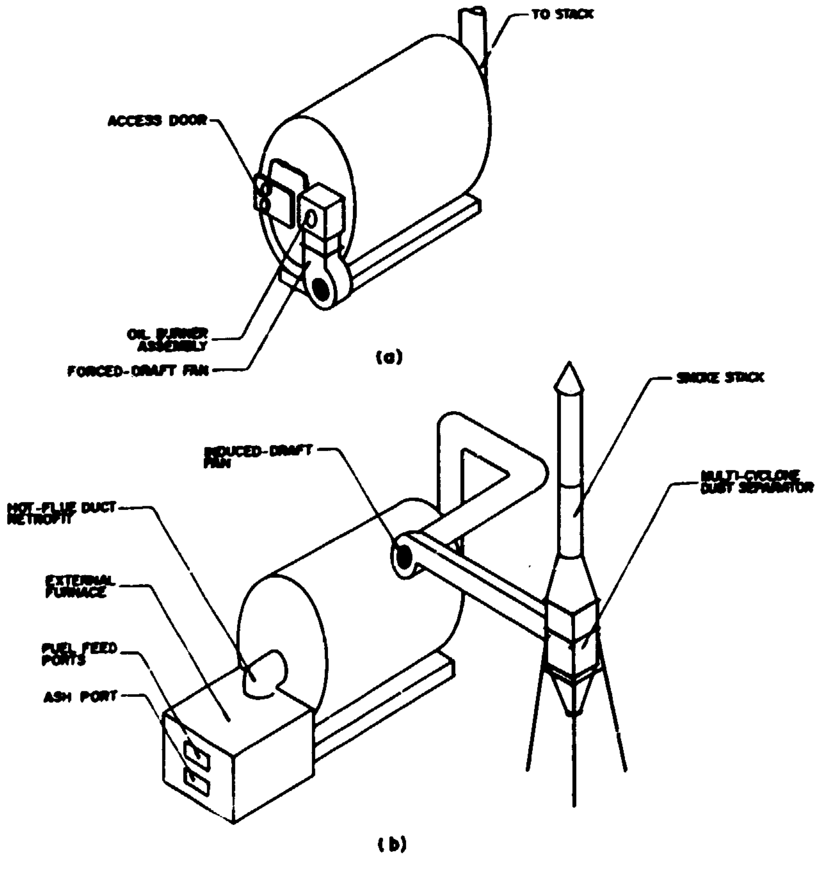
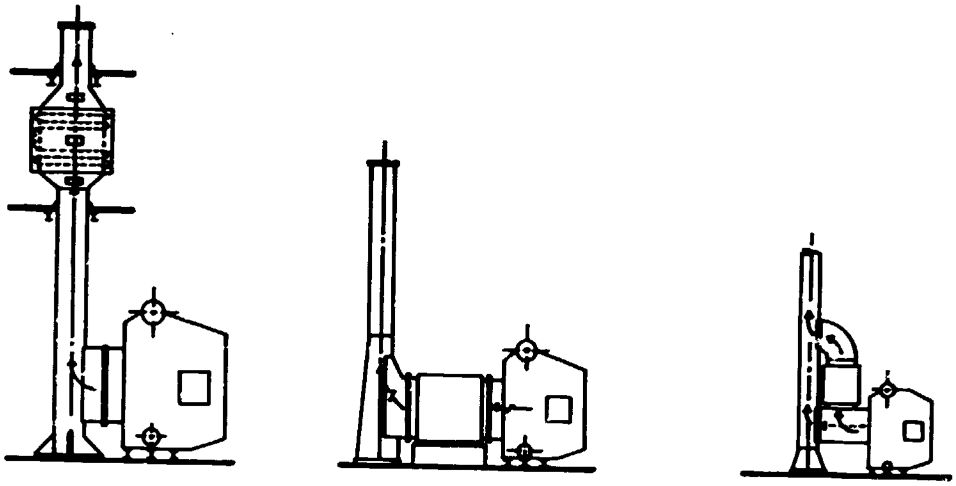


Figure 6.3 The Boiler of Menzi Agricultural Corporation: (a) Before Retrofitting, (b) After Retrofitting to Firing with Palm Oil Residues
Source: Reference 6

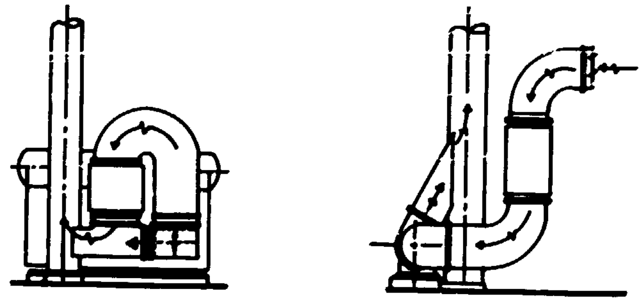
(b) *Flue Gases*

(1) Check smoke coming out of the stack; it should be free of haze. If not, burner adjustment is probably necessary.
(2) Check boiler stack temperature and keep log. If it is too high (more than 66°C above steam or water temperature), clean tubes and adjust fuel burner.
(3) If stack temperature is over 177°C, consider installing a finned-tube economizer or a regenerative-type air heater. Many packaged process-steam boilers have an optimum efficiency of about 85% at a stack temperature of 177°C. In general every temperature rise of 4.4°C reduces efficiency by about 1%.
(4) Use hot flue gases to preheat combustion air.
(5) Use flue gases in radiant heater for ovens and dryers.

Boiler flue gases are rejected to the stack at least 38°C to 66°C higher than the temperature of generated steam. Heat recovery can be accomplished by either installing an economizer to heat the feedwater or an air preheater for the combustion air. Normally, an economizer is preferable to installing an air preheater, although the inclusion of an air preheater should be given careful consideration in new installations.



a) STACK MOUNT b) PAD-MOUNTED c) DUCT BYPASS UPFLOW



d) DUCT BYPASS DOWNFLOW e) DUCT MOUNT

Figure 6.4 Typical Installations of an Economizer
Source: Reference 12

Install an Economizer to Recover Heat from Flue Gases

There are economizers available which can be economically retrofitted to boilers as small as 100 hp capacity. Typical installations are shown in Figure 6.4.

Typical annual savings is around 3 percent. An economizer is appropriate only if insufficient heat transfer surface exists in the boiler to remove the heat released in the furnace. Also, it must be remembered that with conventional economizers, there is a minimum temperature to avoid corrosion. If the flue gas temperature exceeds the minimum allowable temperature by 10°C or more, an economizer may be economically justifiable. Several economizer manufacturers should be consulted for quotes when considering purchasing an economizer. The following is a suggested sequence of actions:

(1) Determine the stack temperature after the boiler has been carefully tuned up. This includes operating as close to optimum excess air level as possible and keeping all heat transfer surfaces clean.
(2) Determine the minimum temperature to which stack gases can be cooled.
(3) Study the economics of installing an economizer on your boiler.

Preheat the Combustion Air

A combustion air temperature rise of 4.4°C yields an approximate 1 percentage point improvement in efficiency.

The air circulation system can be modified so that the hot air near the top of the boiler room is drawn in as the combustion air for the boiler. This is illustrated in Figure 6.5. In this system, boiler room doors and windows should be closed.

For larger boilers, a heat exchanger for preheating air can be installed in or near the stack.

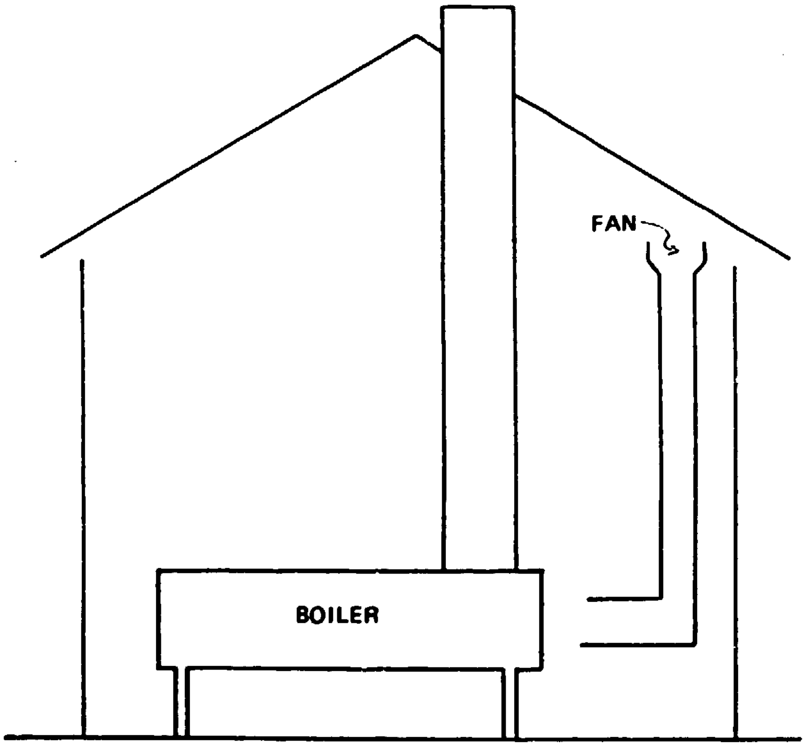


Figure 6.5 Capturing Waste Heat in the Boiler Room

(c) *Steam and Water*

(1) Insulate both hot and cold process and heating lines, and all steam pipes, for maximum energy conservation.
(2) Replace all obsolete packed steam expansion joints with bellows joints to prevent steam leakage.
(3) Investigate the economics of replacing leaky, high-maintenance gate-type steam valves with low-maintenance ball valves. Modern ball valve designs are available for up to 1724 kPa steam duty. (Ball valves are not designed for steam throttling service.)
(4) Return all condensate to boilers. In addition to saving expensive water treatment compounds considerable savings in fuel oil may be realized.
(5) Consider improved water treatment to minimize scale formation. For instance, a mere 1.6 mm of scale can reduce boiler heat transfer by 12%.
(6) Analyze and monitor total dissolved solids (TDS) to reduce any excessive blowdown with its resultant waste of treated hot water.
(7) Reduce blowdown rate.
(8) Recover heat from boiler blowdown.

Return condensate to boiler

The amount of fuel used for steam generation can be reduced 10 to 30% by returning steam condensate to the boiler plant for use as feedwater. Reference 1 gives procedures for estimating the energy savings that can be generated.

Carryout water treatment

Waterside cleanliness is very important in maximizing heat transfer. Scale or deposits which build up on the surfaces of metals serve as an insulator. The best solution is proper water treatment and periodic cleaning.

An indicator for scale or deposit buildup is the flue gas temperature. If at the same load and same excess air the flue gas temperature rises with time, this is probably due to scale or deposits. Visual inspection can confirm this.

The major water quality parameters along with the approximate limits and residual concentrations for boilers under 1380 kPa absolute are shown in Table 6.2. A more detailed discussion of water treatment is presented in Reference 5.

Reduce blowdown

Boiler blowdown is required to maintain dissolved solids concentration in the boiler water at acceptable levels. This operation is wasteful of energy since the purged water is hot. Reducing blowdown can result in annual savings of 1 percentage point. Reference 7 contains graphs useful for estimating energy savings from minimizing boiler blowdown. The following is a procedure for checking blowdown rate:

(1) Check to be sure mud blowdown is being used only for the removal of sludge.
(2) Observe the closeness of the various water quality parameters to the limits shown in Table 6.3. If alkalinity is near its maximum while TDS is much less than its limit, the treatment process can be changed and blowdown reduced; consult an expert.

Table 6.3 Major Water Quality Parameters
Source: Reference 8

WATER	PARAMETERS	LIMITS
Feedwater	Softness	less than 1 ppm
Feedwater	Oxygen	less than 20 ppb
Boiler water	Hardness	less than 1 ppm
Boiler water	Ph	9.5 – 11
Boiler water	TDS	less than 3500 ppm
Boiler water	Sulfite	30 – 60 ppm
Boiler water	Alkalinity	less than 800 ppm
Boiler water	Phosphate	20 – 40 ppm
Condensate	Ph	7.5
Condensate	TDS	less than 20 ppm

(3) Check other water quality parameters using standard chemical tests. These tests measure the residuals of phosphate or chelant and sulfite as well. Also, the level of TDS, alkalinity, suspended solids and silica should be determined.

(4) Adjusting the blowdown rate will change TDS, alkalinity, suspended solids and silica. The residual of any chemical feed is also affected by blowdown but should be changed by adjusting the chemical feed rate.

Recover heat from blowdown

Heat can be recovered from boiler blowdown by preheating the make-up water with the use of a heat exchanger. This is done most conveniently in continuous blowdown systems. The following is a suggested sequence of actions:

(1) Determine the methods and quantity of boiler blowdown.
(2) Determine the savings due to heat recovery. (Use Reference 7)
(3) Determine the cost of installing a heat exchanger and evaluate the economics.

To recover heat from blowdown, a tank into which the steam is expanded can be installed. This tank causes some of the blowdown water to flash to steam. The steam is then used to preheat the feedwater. The remaining liquid effluent from the flash tank can be run through a counterflow heat exchanger to preheat feedwater.

6.2.2 Conserving Energy through Boiler Maintenance

To perform optimally and conserve energy, a boiler must be properly maintained to be "clean" and "tight", Clean is a condition where the boiler firesides are free from soot and ash deposits and the watersides are free from scale and corrosion. Tight refers to a boiler free from water, steam and air leaks.

(a) *Keeping a Boiler Clean*

To maintain a "clean" boiler, periodic cleaning of firesides is recommended. Soot and ash should be removed to prevent corrosion. Burners should be cleaned and repaired if necessary. When the boiler is out of service, check the ignition system for proper flame performance. Improper flame adjustment (i.e., incorrect fuel-air mixture) causes boilers to operate at lower efficiencies and thus increases operating costs. To ensure clean watersides, periodically analyze the feedwater, steam condensate and blowdown. Impurities of dissolved minerals and gases in the water supply tend to cause scale, corrosion, carryover, and caustic embrittlement in boilers. Proper treatment can prevent or control these waterside problems.

(b) *Ensuring a Tight Boiler*

There are three general maintenance practices to ensure that a boiler is "tight". They are:

(1) Check steaming pressures
(2) Investigate abnormal water losses
(3) Check for leaking tubes

Steaming pressures should be observed to check for sudden drops or increases in pressures. It is important that gases used should be dependable. Replace old, worn out, or faulty gages with reliable ones. Defective safety valves are a common cause of safety hazards in boilers. When a valve fails to open at the set pressure, the usual cause is a building up of corrosive deposits around the bottom of the valve. The valve will then leak rather than open.

Abnormal leaks should be immediately investigated. A leak is generally indicated if a boiler loses more than 76 mm of water per month. This is determined by the amount of makeup water used. Makeup water should be kept to a minimum since it contains undesirable amounts of oxygen and carbon dioxide.

Leaking tubes must be repaired. A leak is usually indicated by an unusual "hiss" or a sudden demand for feedwater without a corresponding increase in load. A thorough inspection inside and out is important to ensure that all leaks are discovered and repaired.

Regular checkup allows early correction of incipient failures and eliminates excessive maintenance expenditures.

(c) *Boiler Operation and Maintenance*

Guidelines for boiler operation and maintenance which are important in energy conservation are enumerated below. More detailed preventive maintenance measures are found in Reference 5.

(1) Continued training of boiler operators is essential, particularly in full load operation with alternate fuels.
(2) Each boiler installation should include an on-stream gas analyzer to measure directly the volume by percent of oxygen and combustibles in flue gases. This should be monitored as often as necessary. If there is excessive air in the flue gases, the boiler fuel settings should be corrected immediately.
(3) Each installation should have and use a stack gas temperature monitoring device.
(4) Instrumentation and auxiliary equipment must be kept in first class condition.
(5) Boilers should be frequently checked for cleanliness and condition.
(6) Watch for unequal loading when boilers are operated in parallel on a common pressure controlled fuel line.
(7) Reduce boilers to low pressure on weekends or during low or non-production shifts, using the minimum pressure and number of boilers possible.
(8) Use waste steam or hot water from production operations for preheating boiler make-up water or use clean, wasted hot water for boiler make-up. Some examples:
    (a) If a vent blowdown manifold is used at retort installations, a water line installed in the manifold could utilize heat from the steam for preheating boiler make-up. The vent manifold would have to be sized large enough to meet requirements in the Good Manufacturing Practices Regulations 21 CFR 113, subtracting the area occupied by the water line.
    (b) If cans are cooled in the retort, suitable piping arrangements can be made to utilize the initial hot water for boiler make-up water.

   - (c) In water processing of glass containers the steamwater mixture from the pressure regulating valve overflow could be used for boiler make-up water or for heating boiler make-up water.
- (9) Investigate alternate sources of boiler fuels, such as filtered compressor lubrication oil or re-cycled motor oil.
- (10) Check steam distribution system for losses:
   - (a) Keep insulation in good condition.
   - (b) Check condensation return system for malfunctioning traps and leaks.
   - (c) Check for excessive steam vented to the atmosphere.
   - (d) Monitor use of treated make-up water; excessive use indicates losses needing correction.

6.3 STEAM SYSTEMS

A typical steam circuit is shown in Figure 6.6. When the boiler crown valve is opened, steam immediately rushes out into the main and goes through the steam distribution pipework to process equipment.

Energy losses occur in steam distribution and utilization through the condensation of steam, leaks and radiation heat losss. Sources of energy loss as well as ways of reducing these losses are shown schematically in Figure 6.7. For effective energy management, it is important to measure steam consumption. A steam metering installation is shown in Figure 6.8 where the metering is done downstream of a good quality reducing valve which maintains constant pressure.

To maintain good quality steam, it is important that it remains dry and free from air and non-condensable gases. Some provisions should be made to get these unwanted elements out of the steam space. In steam-using plants today, there is a general lack of water drainage and air venting. Resulting problems could include reduced heat output, wear in the control valve and occurrence of water hammer

A common fault in many installations is that water formed by the condensation of steam due to radiation is allowed to accumulate upstream (high pressure side) of the pressure reducing valve. This should be drained.

During the process operation, clouds of water vapor are often seen in the work area. This is extremely wasteful and indicates utilizing higher steam pressure than necessary. It would be better

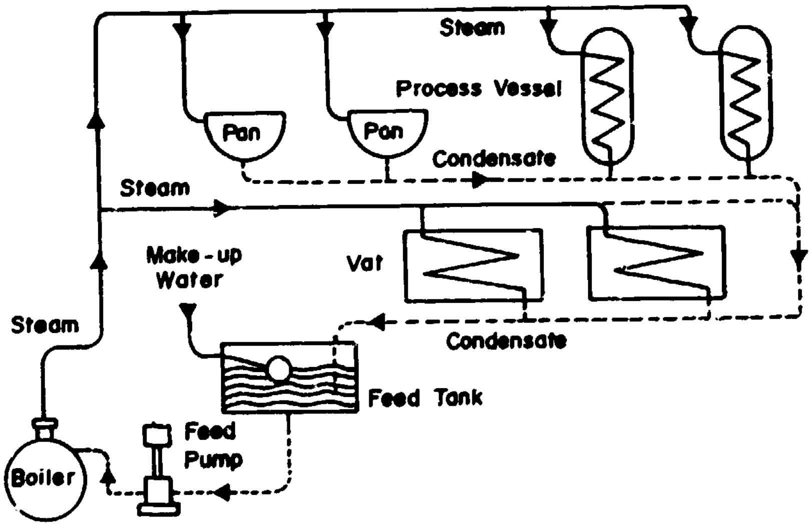


Figure 6.6 Typical Steam Circuit
Source: Reference 7

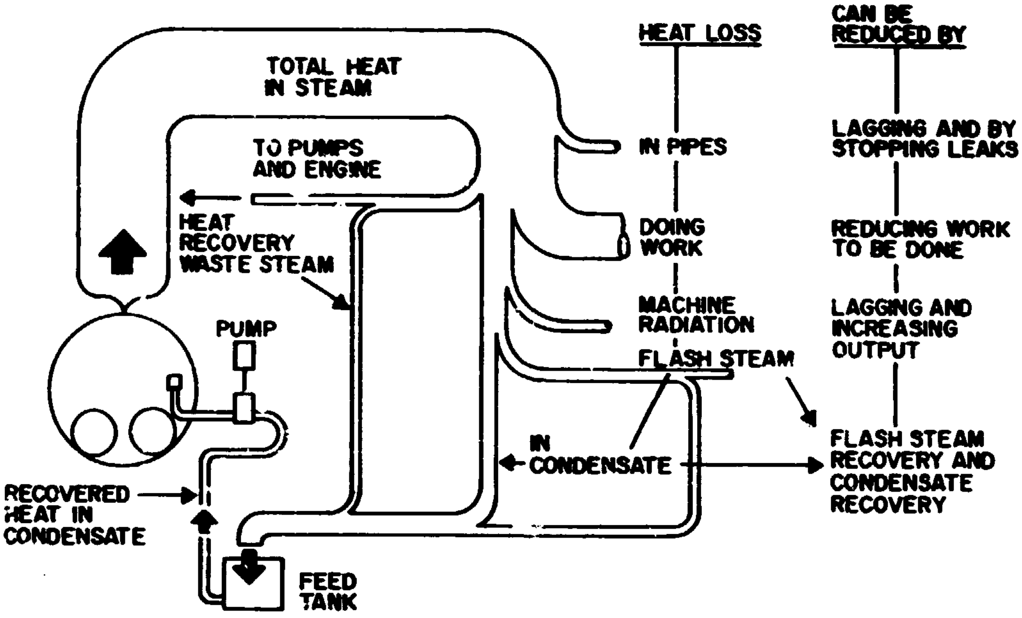


Figure 6.7 Losses in Steam System
Source: Reference 7

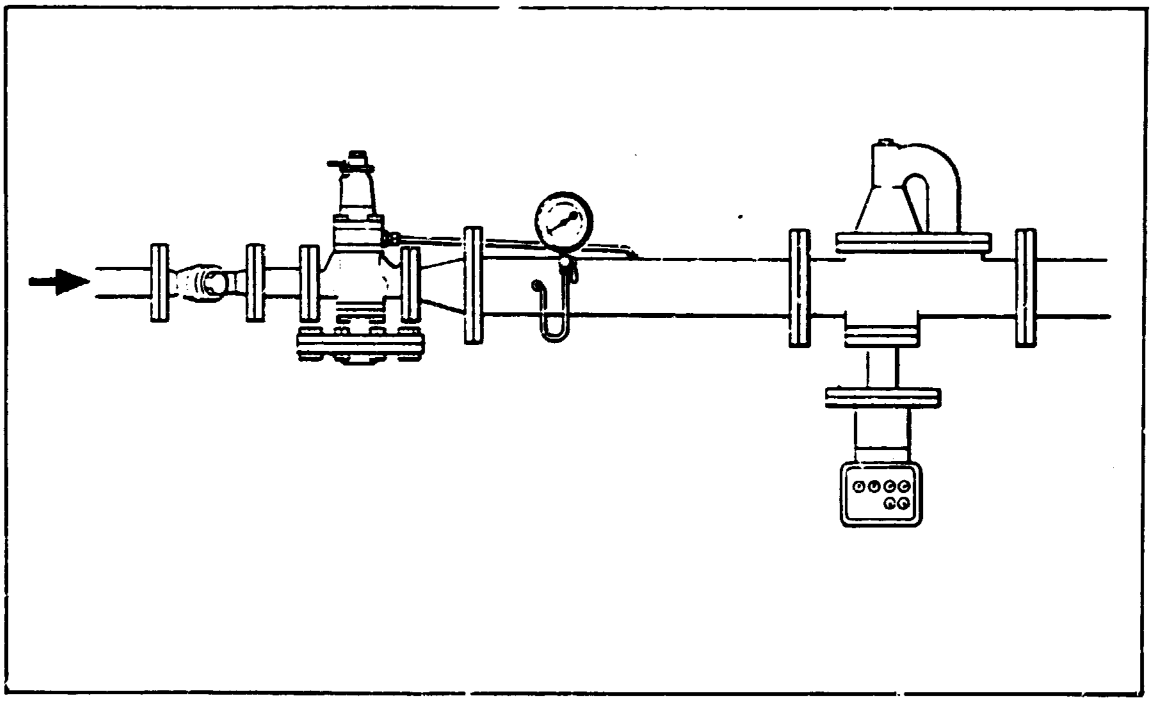


Figure 6.8 Integrating Steam Meter Installed after the Reducing Valve
Source: Reference 14

to use lower steam pressure, thus less steam will be needed and vapor clouds reduced. Consultation with a steam expert may be neccssary on this subject.

There are opportunities for conserving energy when one or more of the following situations exist in a steam system:

a. Steam lines are bare.
b. Insulation on steam and condensate lines are faulty.
c. Lines and valves are leaking.
d. Steam lines are noisy. Noise in the lines indicates the presence of condensate which must be removed.
e. Steam traps are of the wrong size. A stream trap serves to remove condensate in the steam line. It cannot effectively function if it is not of the appropriate size.
f. Steam condensate is thrown away.
g. Steam coils in processing tanks are dir y.
h. High pressure condensate is available.

6.3.1 Factors Affecting Energy Use in Steam Systems

(a) *Boiler efficiency.* A boiler which must cope with a peak load above its rating will operate at a reduced efficiency. As a result, the boiler may not be effective in providing good quality steam at the right pressure and at the right time.

(b) *Distribution.* The distribution system must supply steam to the process area in the right condition and in the right quantity. This requires minimizing losses along the line.

(c) *Utilization.* Proper utilization of steam requires seeing to it that the steam generating plant is properly loaded when steam is used, selecting and maintaining correct steam temperatures, observing correct drainage and air-venting practices and shutting down the boiler when steam is not needed.

(d) *Recovery of condensate.* Condensate represents useful heat which can be recovered.

(e) *Maintenance.* Energy is conserved when reducing valves, temperature controls, steam traps, insulation, and other facilities are maintained in good operating condition.

6.3.2 Energy Conservation Measures

(a) *Steam Distribution*

(1) Operate boilers at their designed pressures. This avoids priming and generation of wet steam. Distribution at high pressure requires smaller mains, and by local pressure reduction, dry steam at the required pressure can be more readily assured.

(2) Set pressure-reducing valves to provide a pressure at each point of use that is no higher than is absolutely necessary.

(3) Where large amounts of high-pressure steam are used for low-pressure applications, look for ways of generating useful work in pressure reduction. Steam turbines for power generation may be installed where feasible. Steam pressure may also be reduced by using it to drive air compressors.

(4) Where a widely fluctuating steam load exists, consider the use of an accumulator to enable operating the boiler more steadily and hence more efficiently. A steam accumulator is a pressure vessel containing water into which surplus steam is fed to raise its temperature. At peak demand times, the hot water provides steam at a lower pressure for suitable process uses.

(5) Develop regular inspection and maintenance schedules for all heat distribution facilities. Include joints and fittings, particularly steam traps. Initial inspections commonly reveal that as high as 7 percent of the steam traps in a plant are leaking.

(6) Correct all faults in the steam distribution system — particularly leaks — as soon as they are noted.
(7) Simplify all heat distribution systems and remove or seal off sections no longer in use.
(8) Insulate all hot pipes and other surfaces and ensure that the insulation does not become crushed or waterlogged.

(b) *Steam Utilization*

(1) To reduce steam requirements, determine for each process equipment, the optimum steam pressure, process temperature and time. Control these factors automatically.
(2) Load process equipment to capacity but do not overload. Reduce the number of units in use.
(3) Improve heat transfer rates by agitating or stirring the materials being heated and keeping heat exchange surfaces clean. Use dry steam and drain condensates quickly.
(4) Preheat incoming material by using heat recovered from other processes. In drying processes, remove water by mechanical processes such as allowing time for dripping or spin drying.
(5) Cut down waste and overprocessing. Materials should be removed immediately when they reach the desired condition.
(6) When the direct steam injection is used for heated tanks and vats, consider other possible methods like indirect steam heating with thermostatic control or direct-fired immersion tubes. Choose the most cost-effective system.

(c) *Heat Recovery from Steam*

(1) Make sure that there is a cost-effective use for recovered heat. The operation is pointless if there is no use for it.
(2) Keep recovered condensate hot and clean but minimize the amount produced before concentrating on recovery.
(3) Keep a record on the volume and temperature of recovered condensate, the volume and temperature of make-up water and the temperature of the feedwater. When changes occur, investigate the reasons.
(4) Make sure that condensate and feedwater tanks are properly insulated. They should be high enough to avoid pumping problems and large enough to prevent overflows.
(5) Recover flash steam whenever there is a use for it in a lower-pressure application. However, give priority attention to schemes which result in larger savings. A recovery system for flash steam is shown in Figure 6.9.
(6) Select the correct steam traps and keep them properly fitted, protected, cleaned and maintained. Checking of steam traps is illustrated in Figure 6.10.

6.4 ELECTRIC MOTORS

Much of the electricity consumed in a food processing plant is used up by motors. Motors serve as prime movers for such equipment as pumps, conveyors, compressors, can-sealing machines, and a variety of other equipment. Figure 6.11 shows the major sources of electric motor and drive losses.

Motors can be classified as single-phase or polyphase. Single-phase motors are mostly of fractional horsepower capacity. They are commonly the induction type and include the following sub-types: shaded-pole, split-phase, capacitor-start, permanent-split capacitor, and universal. Typical applications are fans, small pumps, compressors, commercial appliances, business equipment and farm machinery. Table 6.4 gives the characteristics and applications of single-phase motors.

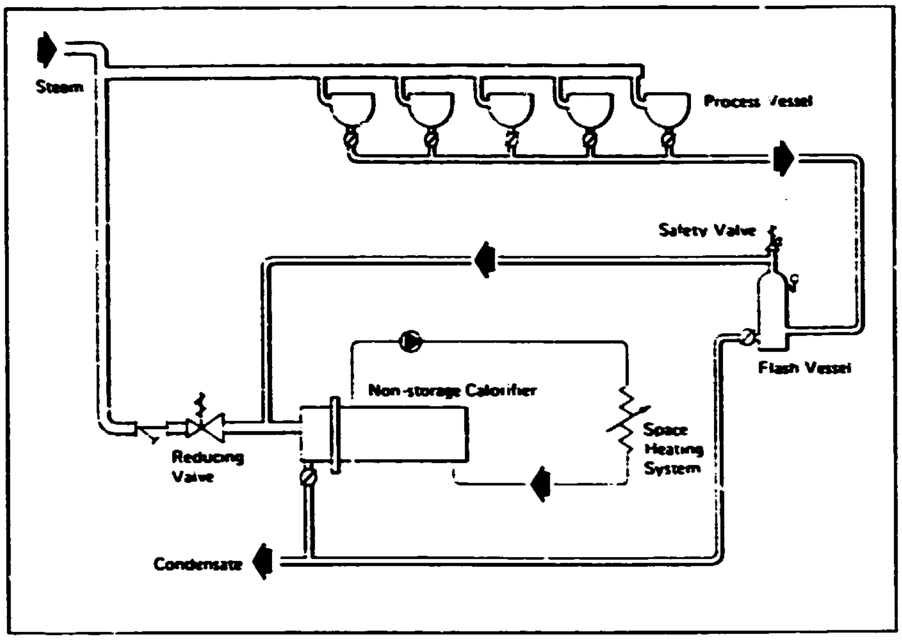


Figure 6.9 Flash Steam Recovery ·
Source: Reference 14

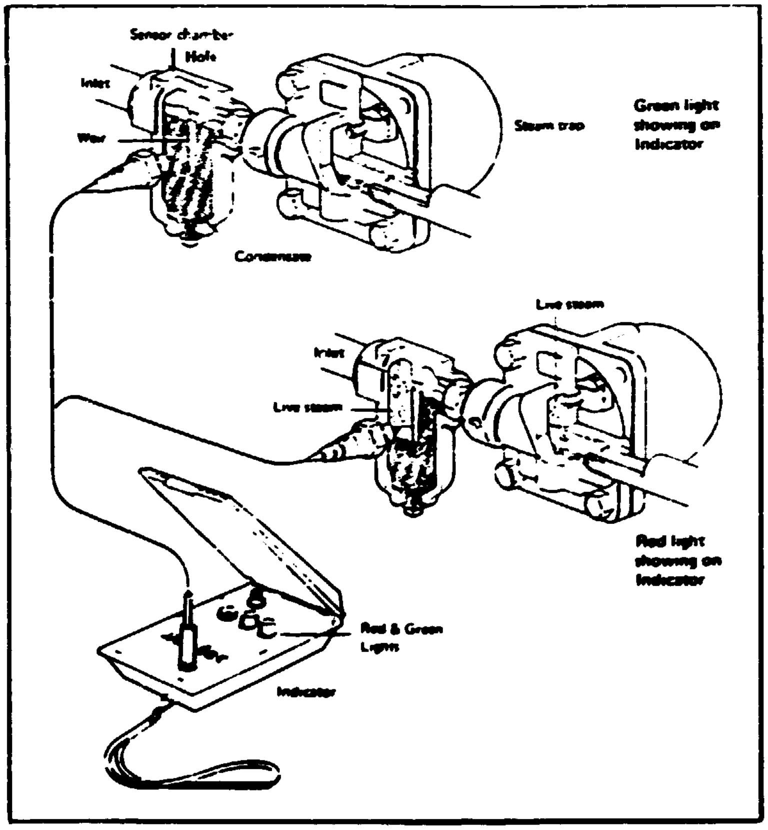


Figure 6.10 Steam Trap Checking, (a) Trap Working Correctly (b) Trap Passing Steam
Source: Reference 14

Polyphase motors are usually available in capacities of 1 hp or larger. They are of three types: induction, synchronous and multi-speed. Table 6.5 summarizes the characteristics, applications and efficiencies of induction motors. Synchronous motors have a higher efficiency than induction motors of equivalent rating and can improve the system power factor. When efficiency is a power synchronous motors might provide the solution. When system power factor improvement is a primary consideration, a 0.8 leading power factor synchronous motor may be chosen. Multi-speed motors can be designed for variable torque, constant torque or constant horsepower. For optimum efficiency, it is important to select the correct multi-speed motor characteristic for the load at all operating speeds.

6.4.1 Energy Conservation Measures

Potentials for conserving energy in electric motors can be found in the following areas:

(a) Selection of motors
(b) Maintenance of motor and motor-driven equipment
(c) Improper voltage
(d) Transmission losses
(e) Use of variable speed motor controllers.

Nomographs for quick estimation of energy savings from the following actions are available in Reference 7. They involve motor selection.

(1) Replace underloaded motors. It is not unusual to find in a plant motors running lightly loaded. Light loading causes a motor to operate at low power factor and reduce efficiency. Low power factor results in higher billing kWh for the same kWh consumption. Reduced efficiency means using more electricity than needed. Both contribute to a higher electric bill.

Table 6.6 is a useful reference for specifying motor size for a given load. Note, for example, that a 60 hp design B motor with synchronous speed of 1200 rpm operating at half load may possibly be replaced by a 30 hp motor at full load. Efficiency of both motors under these loads is the same at 88.5%. The choice now depends on first cost consideration and the limitations of the smaller motor to loads of 30 hp.

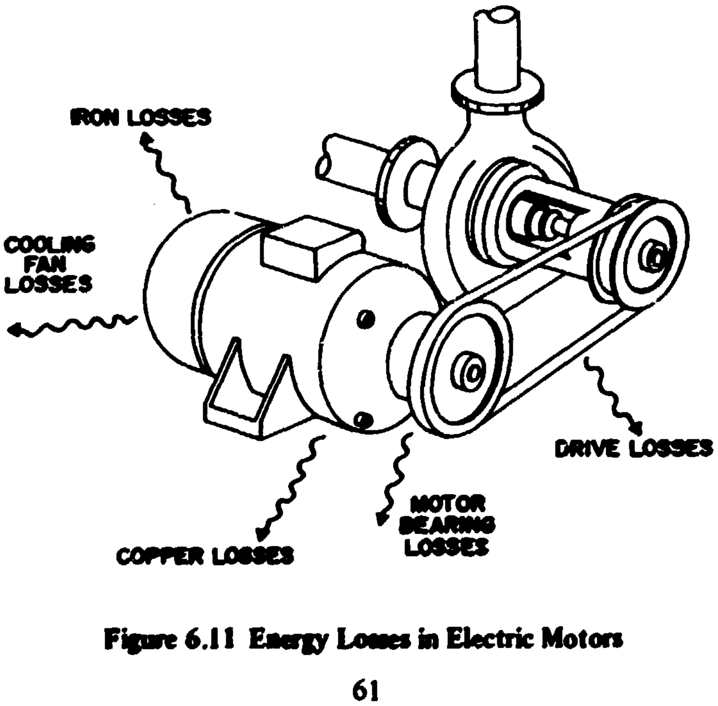


Figure 6.11 Energy Losses in Electric Motors

Table 6.4 Alternating-Current, Single-Phase, Fractional-Horsepower Motors Rated 1/20 to 1 Horsepower, 250 Volts or Less

Source: Reference 3

Application	Motor Type	Hp	Speed (rpm)			Starting Torque	Efficiency
Fans							
Direct drive	Permanent split capacitor	1/20-1	1625	1075	825	Low	High
	Shaded pole	1/20-1/4	1550	1050	800	Low	Low
	Split phase	1/20-1/2	1725	1140	850	Low	Medium
Belted	Split-phase	1/20-1/2	1725	1140	850	Medium	Medium
	Capacitur-start, induction run	1/8-3/4	1725	1140	850	Medium	Medium
	Capacitor-start, capacitor run	1/8-3/4	1725	1140	850	Medium	High
Pumps							
Centrifugal	Split-phase	1/8-1/2	3450			Low	Medium
	Capacitor-start, induction run	1/8-1	3450			Medium	Medium
	Capacitor-start, capacitor run	1/8-1	3450			Medium	High
Positive displacement	Capacitor-start, induction run	1/8-1	3450	1725		High	Medium
	Capacitor-start, capacitor run	1/8-1	3450	1725		High	High
Compressors							
Air	Split-phase	1/8-1/2	3450	1725		Low or Med.	Medium
	Capacitor-start, induction run	1/8-1	3450	1725		High	Medium
	Capacitor-start, capacitor run	1/8-1	3450	1725		High	High
Refrigeration	Split-phase	1/8-1/2	3450	1725		Low or Med.	Medium
	Permanent-split capacitor	1/8-1	3250	1625		Low	High
	Capacitor-start, induction run	1/8-1	3450	1725		High	Medium
	Capacitor-start, capacitor run	1/8-1	2450	1725		High	High
Industrial	Capacitor-start, induction run	1/8-1	3450	1725	1140, 850	High	Medium
	Capacitor-start, capacitor run	1/8-1	3450	1725	1140, 850	High	High
Farm	Capacitor-start, induction run	1/8-3/4	1725			High	Medium
	Capacitor-start, capacitor run	1/8-3/4	1725			High	High
Major appliances	Split-phase	1/8-1/2	1725	1140		Medium	Medium
	Capacitor-start, induction run	1/6-3/4	1725	1140		High	Medium
	Capacitor-start, capacitor run	1/6-3/4	1725	1140		High	High
Commercial appliances	Capacitor-start, induction run	1/3-3/4	1725			High	Medium
	Capacitor-start, capacitor run	1/3-3/4	1725			High	High
Business equipment	Permanent split capacitor	1/20-1/4	3450	1725		Low	High
	Capacitor-start, induction run	1/8-1	3450	1725		High	Medium
	Capacitor-start, capacitor run	1/8-1	3450	1725		High	High

Table 6.5 Characteristics and Applications of Polyphase Induction Motors

Source: Reference 3

Size	Classification	Starting Torque (% Rated Load Torque)	Break-down Torque (% Rated Load Torque)	Starting Current (% Rated Load Current)	Slip	Typical Application	Relative Efficiency
Integral hp Large	Design B Normal starting torque and normal starting current	70-275 60-100	175-300 175-200	600-700 600-650	1-5% 05-2%	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc. where starting torque requirements are relatively low	High
Integral hp Large	Design C High starting torque and normal starting current	200-250 150-200	190-225 190-200	600-700 600-650	5% max. 05%-2%	Conveyors, crushers, stirring machines, agitators, reciprocating pumps and compressors, etc., where starting under load is required	High
Integral hp	Design D	275	275	600-700 600-650	5-8% 8-13%	High peak loads with or without flywheels such as punch presses, shears, elevators, winches, hoists, oil-well pumping and wire-drawing machines	Medium at 5-8% slip, Low at 8-13% slip
Large	High starting torque and high slip	250-300	275-325 250-300	500-600 450-550	5-8% 8-13%		
Integral hp and large	Wound rotor	Any torque up to the breakdown value	175-275	Adjustible (depends on starting torque required)	Adjustable	Where high starting torque with low inrush, frequent starting, or limited speed control are required	Medium at full speed, lower at reduced speeds

Note: Design A motor performance characteristics are similar to those for Design B motors, except that the starting current is higher than the values shown in the table.

Table 6.6
Effect of Loading on the Efficiency and Power Factor of Design B Motors
Open and Enclosed Types
Three-phase, 60 hertz, 208-220-440-550-volt

hp	rpm (synchronous)	Efficiency		
		4/4 Load	3/4 Load	1/2 Load
1/2	900	66	60	53
3/4	1,200	70	68	64
3/4	900	68	63	55
1	1,800	76	74	68
1	1,200	71	70	64
1	900	70	66	57
1 1/2	3,600	79	76	69
1 1/2	1,800	79	76.5	72
1 1/2	1,200	76.5	76	71
1 1/2	900	74	73	67
2	3,600	81.5	78	73
2	1,800	80	78	73
2	1,200	77	76	73
2	900	75	74	69
3	3,600	82.5	82	80
3	1,800	81	81.5	77.5
3	1,200	80	79	75
3	900	7[illegible]	70.5	
5	3,600	83.5	83.5	81
5	1,800	85	85	83
5	1,200	82	81.5	80
5	900	81	80.5	79
7 1/2	3,600	86	85	82
7 1/2	1,800	84	83.5	81
7 1/2	1,200	83.5	83	80
7 1/2	900	82.5	82	79
10	3,600	86	86	84
10	1,800	85	85	84
10	1,200	84	84	83
10	900	83.5	83.5	81
15	3,600	86	86	84
15	1,800	86	86	85
15	1,200	87	87	86
15	900	84	84	82
20	3,600	86	86	85
20	1,800	87.5	87.5	86.5
20	1,200	87	87	86
20	900	86	86	85
25	3,600	87	86	85
25	1,800	88.5	88.5	87.5
25	1,200	88	88.5	87
25	900	87	87	86
30	3,600	89	88	86
30	1,800	89	89	88
30	1,200	88.5	89	86
30	900	88	88	87
40	3,600	89	88	86.5
40	1,800	89	89	88
40	1,200	89	89	88
40	900	88.5	89	88
50	3,600	89	88	86.5
50	1,800	89.5	89.5	88
50	1,200	89.5	89.5	88
50	900	88.5	88.5	87
60	3,600	90	89	87
60	1,800	90	90	89.5
60	1,200	89.5	89.5	88.5
60	900	88.5	88.5	87
75	3,600	90.5	90	88
75	1,800	90	90	89
75	1,200	90	90	89
75	900	89	89	88

Note 1: These values are not to be used for guarantees; consult motor manufacturer.

Note 2: For two-pole, totally enclosed fan-cooled motors, efficiency should be reduced 1 percent at 4/4 load, 2 percent of 3/4 load, and 3 percent at 1/2 load.

Source: Allis-Chalmeres Manufacturing Company

(2) Replace less efficient motor with a high-efficiency motor. Increasing efficiency by as low as 5% can effect substantial savings.

6.4.2 Conserving Energy through Maintenance

Proper care of motors will prolong equipment life, save unwarranted expenditures, and conserve energy. Detailed preventive maintenance procedures can be found in Reference 5. The following is a summary of activities to be performed on a regular basis for the maintenance of motors:

(a) Check alignment of motors to driven equipment; align and tighten as necessary.
(b) Check for loose connections; correct as necessary.
(c) Keep motors clean
(d) Eliminate vibration.
(e) Replace worn bearings.
(f) Tighten belts and pulleys.
(g) Clean motor windings; use a soft brush and slow-acting solvent.
(h) Replace/repair broken or cut wires.
(i) De-energize excess transformer capacity.
(j) Provide proper maintenance and lubrication of motor-driven equipment.
(k) Check power meter accuracy.
(l) Lubricate motor and drive bearings on a regular basis to help reduce friction and excessive torque, which can result in overheating and power losses. Additional friction can develop in motors due to dust or lack of lubrication. This friction causes excessive wear on parts and subsequent misalignment of gears of belts in the driven machines. This causes the system to work harder, reducing operating efficiency and increasing energy consumption.
(m) Check for overheating, which could be an indicatic of a functional problem or lack of adequate ventilation.
(n) Check for an overvoltage or low voltage condition on motors; correct as necessary.
(o) Check for excessive noise and vibration; determine cause and correct as necessary
(p) Keep fan blades clean.
(q) Inspect drive belts; adjust or replace as necessary to ensure proper operation. NOTE: Proper belt tension is critical
(r) Inspect inlet and discharge screens on fans; keep them free of dirt and debris at all times.
(s) Check for packing wear which can cause excessive leakage; repack to avoid excessive water waste and shaft erosion.
(t) Inspect bearings and drive belts for wear and binding; adjust, repair, or replace as necessary.

6.5 AIR COMPRESSORS

Compressing air is costly, and the efficient production and use of compressed air can yield valuable energy savings

The choice of the right air compressor is an important consideration in conserving energy. For air requirements of 170 m^3/min or less, the reciprocating compressor is generally the most efficient. Above 170 m^3/min, the centrifugal compressor gives better m^3/min-to-power ratios. Special requirements involve additional considerations for compressor selection. For instance, if the compressed air must be oil-free, the alternative choices would be an oil-free reciprocating, a dry helical screw or a centrifugal compressor. Table 6.7 shows several types of air compressors and their corresponding capacity ranges and specific energy requirements. A typical compressed air system is shown in Figure 6.12.

The performance of the compressed air system not only depends on the compressor but also on the choice of pipes used, the piping layout and the performance of individual equipment being serviced.

Table 6.7 Capacity Range and Specific Energy Requirements of Different Types of Compressors
Source: Reference 7

Compressor Type	Capacity Range litre/sec fad	Specific Energy Requirement kW/litre/sec
Reciprocating:		
Single Stage	Up to 47	0.38
Two Stage	47 to 3000	0.30
Rotary Screw	47 to 1400	0.40
Rotary Vane	Up to 570	0.42
Centrifugal	570 to 8500	0.33

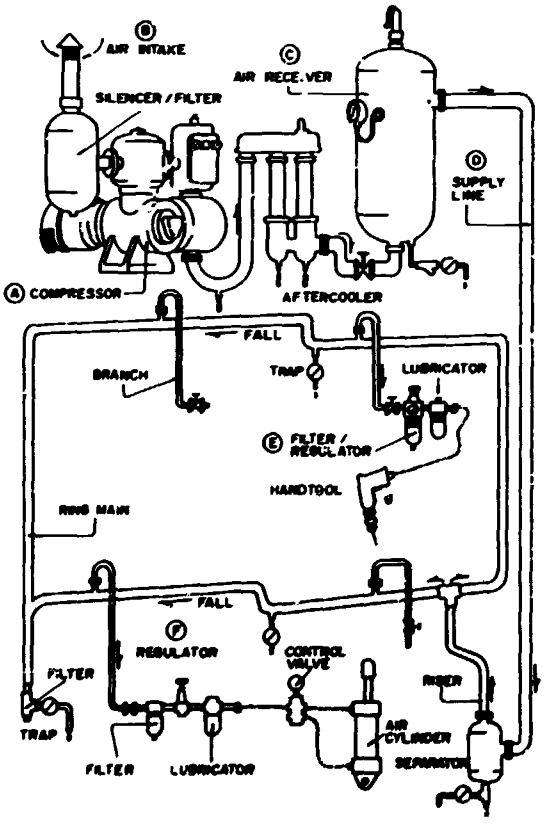


Figure 6.12 Basic Components of a Compressed Air System

6.5.1 Energy Conservation Opportunities

(a) Entering air temperature. Reducing the inlet air temperature by 15°C increases the mass of air delivered by 5% for the same electrical input.

(b) Discharge pressure. Operating at higher pressure than required results in higher maintenance costs and reduced efficiency.

(c) Selection of compressor type. As earlier mentioned, proper matching of load requirements and compressor type is important to ensure efficient operation.

(d) Air leaks. Common sources of air leaks are valves, couplings, flanges, pipe joints and flexible hoses.

(e) Air misuse. Expensive compressed air should never be used for cooling hot products. This duty is better performed by a fan or fog spray.

(f) Faulty lubricators and filters. These conditions result in pressure losses.

(g) Pipe size and pipe layout. Pressure losses are higher in longer and smaller pipes and in layouts which presents higher flow resistance.

(h) System maintenance. Things to check include: Lubrication, condition of rotors, presence of vibration, excessive discharge temperature and pressure, tension in belts and adequateness of cooling.

(i) Receiver capacity. The air tank should be sized to meet average and peak demands so that the compressor operates close to highest efficiency at all times.

6.5.2 Energy Conservation Measures

Reference 11 provides the following measures for conserving energy in air compressors. A more detailed discussion of operation and maintenance tips are given in Reference 13.

(a) Determine the optimum pressure required for satisfactory operation of all items of equipment. Do not use higher pressures than necessary.

(b) Match compressors to pressure and volume requirements and avoid oversizing.

(c) Operate compressors at just below their maximum capacity, but do not overload them.

(d) Simplify distribution maintenance and control by using matched individual compressors to serve particular groups of machines or tools.

(e) Provide compressors or boosters for items of equipment which operate intermittently or which require pressures markedly different from those needed by the main system.

(f) Switch compressors off when not in use.

(g) Use non-working periods to find and rectify leaks and to clean the system. Do not install further compressors without first thoroughly checking for loads.

(h) Maintain simple records of compressor performance to enable faults to be detected quickly.

(i) Site air inlets in cold, dry, clean positions and clean filters regularly. Cool the air between and after compression stages

(j) Recover heat from cooling operations and use some to reheat the compressed air, if possible.

(k) Keep air distribution lines clean, dry and warm. Avoid any accumulation of water or oil by sloping lines correctly towards accessible drain points.

(l) Challenge every use of compressed air, particularly for continuous applications.

6.6 LIGHTING SYSTEMS

Industrial lighting covers a wide range of tasks, operating conditions and economic considerations. Lighting must provide adequate visibility in areas where raw materials are transformed into finished products. It must not only serve as a production tool and as a safety factor but should also contribute positively to the over-all environmental condition of the work space.

The typical components of a lighting system are shown in Figure 6.13.

There are opportunities for conserving energy in lighting when one or more of the following conditions exist in a plant:

a. Unoccupied areas are lighted
b. Lighting levels exceed established standards.
c. Luminaires and lamps are dirty.
d. Walls and surfaces are dirty or dark-colored.
e. Lights are turned on in areas where natural light is sufficient.
f. Inefficient lamps are being used.
g. Lighting schemes are poorly designed.

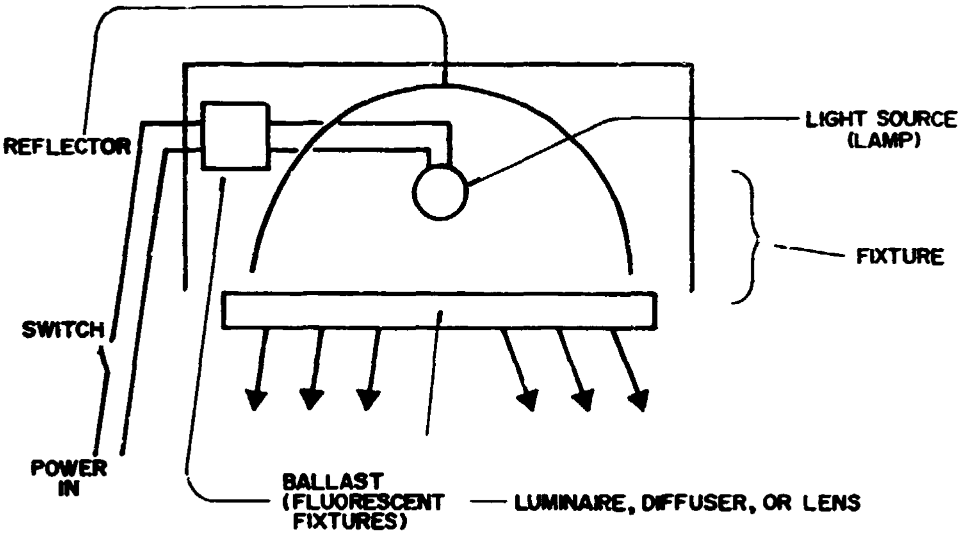


Figure 6.13 Typical Components of a Lighting System.

6.6.1 Factors Affecting Energy Use in a Lighting System

In looking for measures to conserve energy in lighting, the following factors can be kept in mind:

(a) *Desired illumination level.* As a general rule, lighting levels in the workplace should be no greater than those recommended in the Philippine Electrical Code. Table 6.8 gives levels of illumination recommended by the Illuminating Engineering Society.

(b) *Placement of lights.* Uniform illumination inside a room does not make the most effective of energy. It is usually advisable to place and orient lights so as to illuminate work stations.

(c) *Design of lighting systems.* The best possible lighting system should be designed based on the nature of the work area and the desired illumination level. Secondary factors are ease of relamping and maintenance requirements.

(d) *Lamp efficiency.* Replacing existing low-efficiency lamps with lower-wattage more efficient types for the same illumination level will result in reduced total costs.

6.6.2 Energy Conservation Measures

Reference 15 gives six basic rules for achieving good lighting coupled with energy conservation. They are enumerated below. A seventh is added which involves the installation of skylights in appropriate areas:

Table 6.8 Characteristics of Various Lamp Types

Source: Reference 15

Lamp type (A) Clear bulb (B) bulb with diffusing or fluorescent layer	Luminous efficacy in lumens per watt (lm/W)		Color rendering (colour rendering index)		Color appearance	Useful life in hours (lamp lumen depreciation 80%	Luminance in candela per cm^2 (cd/cm^2)
	lamp	lamp + ballast					
Normal incandescent lamp 100W (A)	14	14*	excellent	(100)	excellent	1,000	700
Normal incandescent lamp 100 W (B)	13	13*	excellent	(100)	excellent	1,000	3
Halogen incandescent lamp 100W (A)	30	30*	excellent	(100)	excellent	100	1,500
Halogen incandescent lamp 1,000W (A)	22	22*	excellent	(100)	excellent	2,000	1,700
High-pressure mercury lamp 400W (A)	52	49	modest	(20)	modest (blue)	20,000	460
High-pressure mercury lamp 400W (B)	57	54	modest	(40)	reasonable	20,000	12
Blended light lamp 250W (B)	22	22*	modest	(40)	reasonable	6,000	5
High-pressure sodium lamp 400W (A)	120	110	modest	(25)	modest (yellow)	12,000	600
High-pressure sodium lamp 400W (B)	117	107	modest	(25)	modest (yellow)	12,000	25
Metal halide lamp 400W (A)	80	75	reasonable	(65)	good	10,000	600
Metal halide lamp 400W (B)	75	70	reasonable	(65)	good	10,000	14
Fluorescent lamp 40W (A)	80	65	excellent	(95)	excellent	9,000	0.8
Low-pressure sodium lamp 180W	183	150	poor		poor	16,000	10

* No ballast required.

(a) *Use the most efficient light source practicable.*

(1) Gas discharge lamps (mercury, fluorescent, or sodium) are more efficient than incandescent lamps.

(2) In general the higher the wattage of a lamp, the more efficient it is.

(3) Cool white fluorescent lamps are more efficient than daylight lamps of the same wattage.

(4) Fluorescent and incandescent lamps with internal reflectors give more light in the reflected direction than normal lamps.

(b) *Use the lamp light output efficiently.*

(1) Efficient luminaires reflect a greater amount of light on the visual task with less wattage.

(2) Luminaires with reflectors but without screening have the highest light output ratio, so that they should be the first choice when it comes to optimum energy utilization, if the presence of glare is of minor importance.

(3) Of the luminaires with screening, those with lamellae louvers have in general the highest efficiency. Those with opal diffusers have the lowest efficiency.

(4) High quality control gear ensures minimum wattage loss.

(c) *Maintain lighting equipment in good order.*

(1) Lamps and luminaires must be kept clean and a regular cleaning schedule must be instituted to ensure that the lighting system is producing the lighting level at which it was designed. Dust and dirt accumulating on lamps and luminaires can cut down light output by as much as 50%.

(2) Periodical inspection of the lighting system will lead to timely replacement of defective lamps and accessories which continue to consume electricity without giving off light.

(3) In some cases, group replacement of lamps may be advisable.

(d) *Use well-designed energy effective lighting schemes.*

(1) Select the most efficient combination of luminaire and lamp to meet the recommendation or requirements with respect to uniformity, glare control, color rendering and color appearance.

(2) Use the possibility of the integration of lighting and air conditioning. With this system the efficiency of the luminaires can be increased by 10-15% and the total energy consumption of the building can be decreased.

(3) The illumination level should be suited to the purpose and after installation, maximum performance should be continued by regular maintenance.

(4) Cost of operation and energy usage should be considered when designing new lighting schemes and not simply the initial cost of the installation.

(5) Maintain a high power factor to increase the electrical efficiency of the building power distribution system in addition to permitting more effective use of the utility power capacity.

(e) *Control the switching operation and usage of the lighting installation.*

(1) Local lighting should be used if higher lighting levels are needed only at certain places.

(2) Occupants should be reminded to turn off lights if daylight is adequate.

(3) It is always more economical to turn off incandescent lighting when a working or living space is empty.

(4) The long standing question of whether it is more economical to switch fluorescent lamps off or to leave them on has finally been resolved because of the energy shortage. The need to save energy now dictates that users turn lights off for any period when they are not in use. The high cost of power now outweighs any advantage gained in lamp life.

(5) If you must reduce your fluorescent lighting, remove all lamps from a two-lamp preheat ballast. This assures that ballast life is not adversely affected. Removal of only one lamp from a two-lamp preheat ballast circuit can seriously shorten ballast life and can shorten the life of the remaining lamp.

(6) Switching should be designed such that lighting fixtures in individual offices, integral areas, separate sections etc. can be switched off when not required. In short, limit the number of fixtures per circuit to provide greater flexibility.

(f) *Consider the effect of surrounding decor.*

(1) Avoid dark surfaces in the space because these absorb light. For higher reflectances, use light colors on walls and ceilings.

(2) Light, pleasantly-designed interiors of buildings assure an environment in which workers can be productively effective.

(3) Limit the use of additional decorative lighting.

(g) *Install skylights.* In many plants, the power required for lighting production areas, warehouses or offices can be significantly reduced by installing skylights.

6.7 CANNING

This section will cover canning equipment which require large amounts of heat and water. These are the hot can washer, exhauster, and retort. Energy conservation in electric motors which power mechanical equipment (e.g., conveyors, sealing equipment, etc.) is discussed in section 6.4.

6.7.1 Canning Process

Figure 6.14 shows the general flowchart of the canning process. Empty cans are sometimes inverted to rid them of debris, washed, and rinsed with hot water. The cans are then drip-dried, usually in the inverted position

Filling is usually by hand in small to medium scale establishment, but in large plants automatic filling equipment predominate. Filled cans are heated with steam or hot water to remove dissolved gases. This step, called exhausting, is usually done by passing the cans through a steam-filled enclosure or exhaust box. After exhausting, the cans are sealed and washed to remove bits of food, sauce, oil or dirt sticking to the outside of the cans. Washing these contaminants off is important because in retorting and pressure-cooling some water may seep through the seams. Even only a small amount of contaminant entering the can will ruin the product. In retorting, the cans are heated with pressurized steam to a temperature and for a period sufficient to kill almost all harmful micro-organisms in the food. The time required for the retort to attain the proper processing temperature is called the "come-up time". After processing, the cans are cooled with water under pressure, usually in the retort. Compressed air is introduced to maintain the pressure, otherwise too rapid pressure loss due to steam condensation may cause the can contents to expand too quickly and damage the seams. Sometimes, hydrostatic water cooling is used in place of retort cooling.

The cans must be withdrawn from the cooling water while they are still hot so that they will dry quickly in air. After that they are labeled and packaged. Sometimes, the cans are first polished before labeling.

6.7.2 Hot Can Wash

The can washers require a lot of hot water not only for rinsing but also for the detergent solution. As shown in Figure 6.14 there are two points in the canning process where hot can washing is usually done. Aside from cleaning (filtering) and recirculation, other methods of conserving energy and water are:

(a) *Re-use of hot water or steam generated from other processes.* An example of this is the use of hot water from pressure – cooling in the retort. This spent cooling water is clean and has a high temperature. Other sources of heat for hot-water generation are venting steam, retort drainings, etc. Another example is the use of cascading in rinsing or washing.

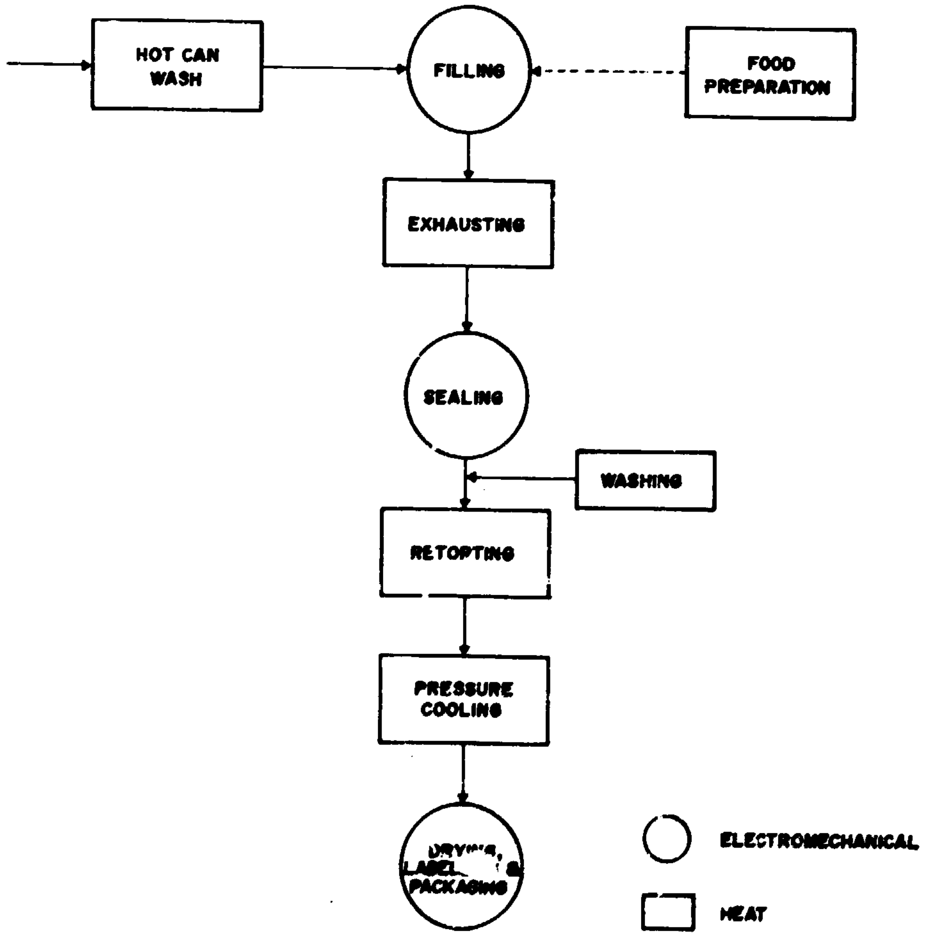


Figure 6.14 General Process Flowchart for Canning

(b) *Monitoring and limiting the use of hot water.* Usually, workers are not aware of the large amounts of hot water being consumed in cleaning and washing. It is recommended that flowmeters be installed in water consuming equipment and consumption patterns recorded and studied. If possible consumption standards should be set for reference and evaluation purposes. Studying the volume temperature, cleanliness, and use of the water system will usually reveal opportunities for conservation.

(c) *Waste heat recovery.* This includes the use of heat exchangers to pre-heat make-up water for washing. Condensate may be recovered from steam kettles, exhaust boxes, steam boxes, and the retort drain line to produce hot water.

6.7.3 Exhausting

A typical continuous exhaust box is shown in Figure 6.15. Steam is injected into the box through perforated tubes. The cans travel the length of the steam-filled exhaust box on a conveyor. Steam escapes from the open ends of the box, while condensate drains from the bottom collector. Some suggestions of conserving energy in open exhaust boxes are:

(a) Reduce the amount of steam escaping from the ends by decreasing the area of the openings. Provisions must be made for adjusting the end openings depending on the can size.

(b) Recover the condensate for hot-water production. If the exhaust box, conveyor, and cans are clean, the condensate can be used directly. Otherwise, a heat exchange system may be used.

(c) Use proper insulation on hot external surfaces, steam lines, etc. In a typical stainless steel housing exhauster, the combined heat loss is about 230 watts per square meter of outside surface.

(d) Use hot water for exhausting if possible. Much of the steam input in open-ended exhausters escapes to the atmosphere. This is wasteful and produces an uncomfortably hot and humid working environment. The use of hot water for exhausting will eliminate excessive steam loss; if direct heating is utilized, it will reduce the boiler load.

(e) Hot filling should be done when practical to reduce the heat requirement for exhausting. Sauces, oil, or brine should be poured in hot.

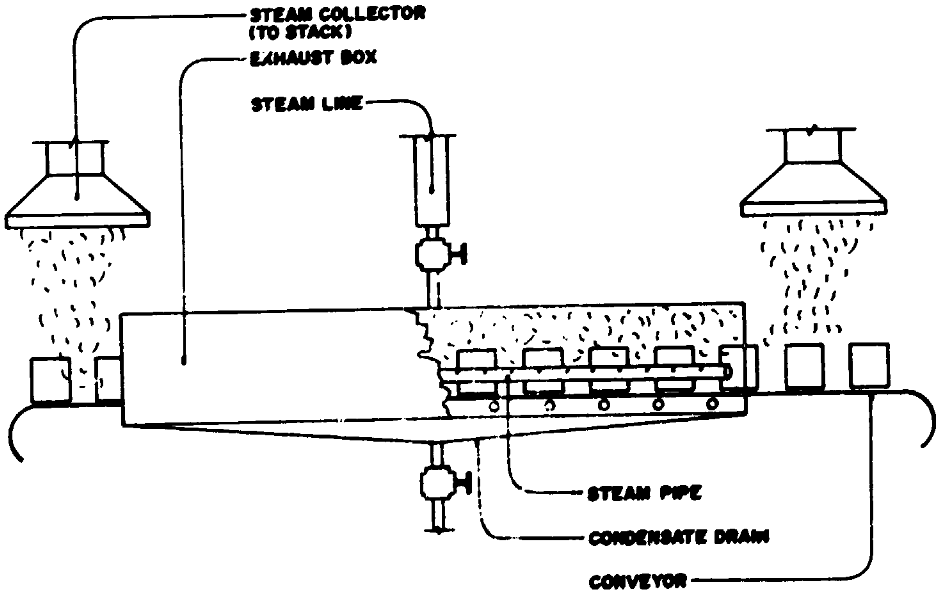


Figure 6.15 Typical Continuous Exhauster

6.7.4 Retorts

Retorts are the major steam consuming equipment in the canning process. Figure 6.16 shows the energy flow through the retort. Vents are open at the start of processing to allow air to be driven out by steam. This is important because air acts as an insulator and may cause under-processing or non-uniform processing. Bleeders allow air in the supply steam to escape; they are open throughout the retorting process.

Some energy conservation guides for retorts are:

(a) Insulate the retort. Heat loss due to radiation and free-air convections of exposed retort metal is substantial. For example for an external surface temperature of 100°C, the combined heat loss is approximately 1 kW per square meter.

(b) Investigate the possibility of using drainings or condensate, venting steam, and water from pressure cooling to produce hot water. Clean condensate may be returned to the boiler.

(c) Install automatic air venting. This method has several advantages over manual air venting. It is very difficult to distinguish between steam and a mixture of air and steam. Therefore, it is virtually impossible for the operator to know precisely when to stop venting. A lot of steam is wasted in usual practice of closing the vent after a fixed number of minutes at a specified temperature. Automatic air venting will ensure that only the minimum amount of steam required for complete venting will be expelled to the atmosphere. Another advantage is that correct venting will be automatically and reliably done. Also, bleeders will no longer be necessary, thus saving steam. Figure 6.17 shows a horizontal retort with automatic air venting.

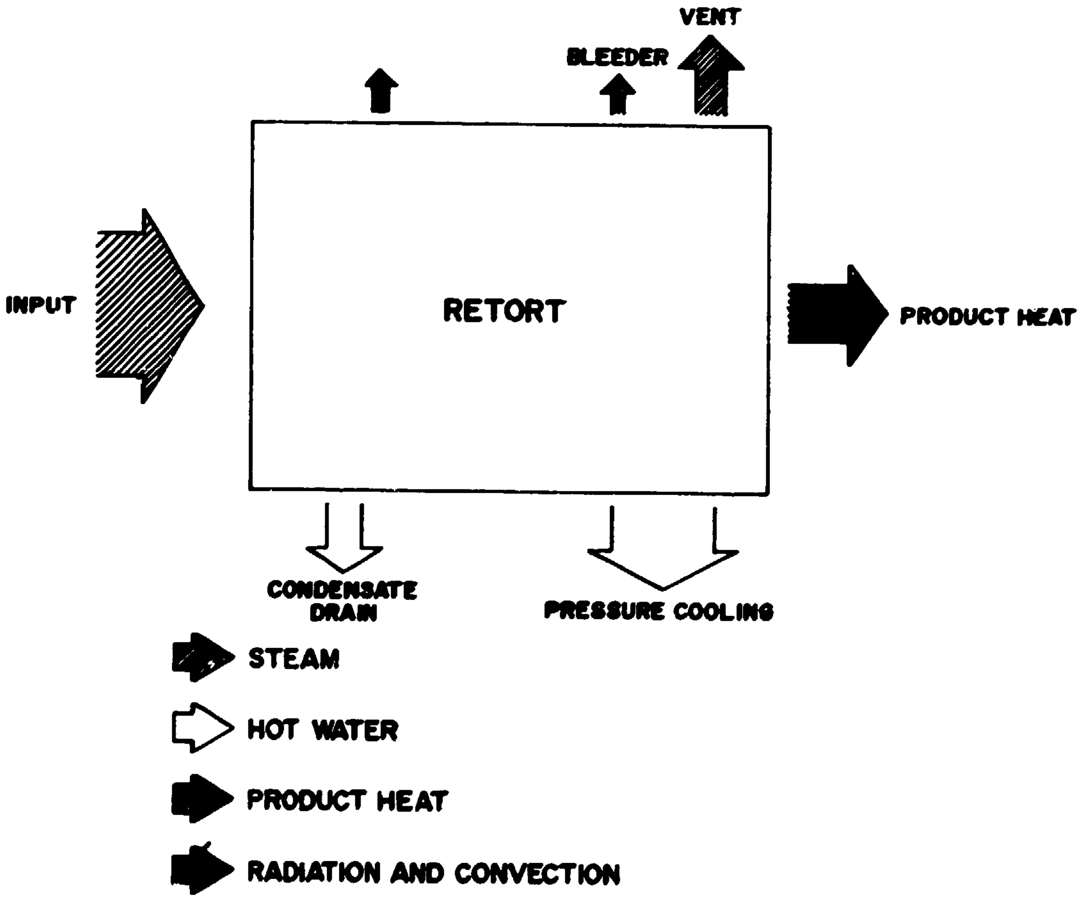


Figure 6.16 Heat Distribution in Retort

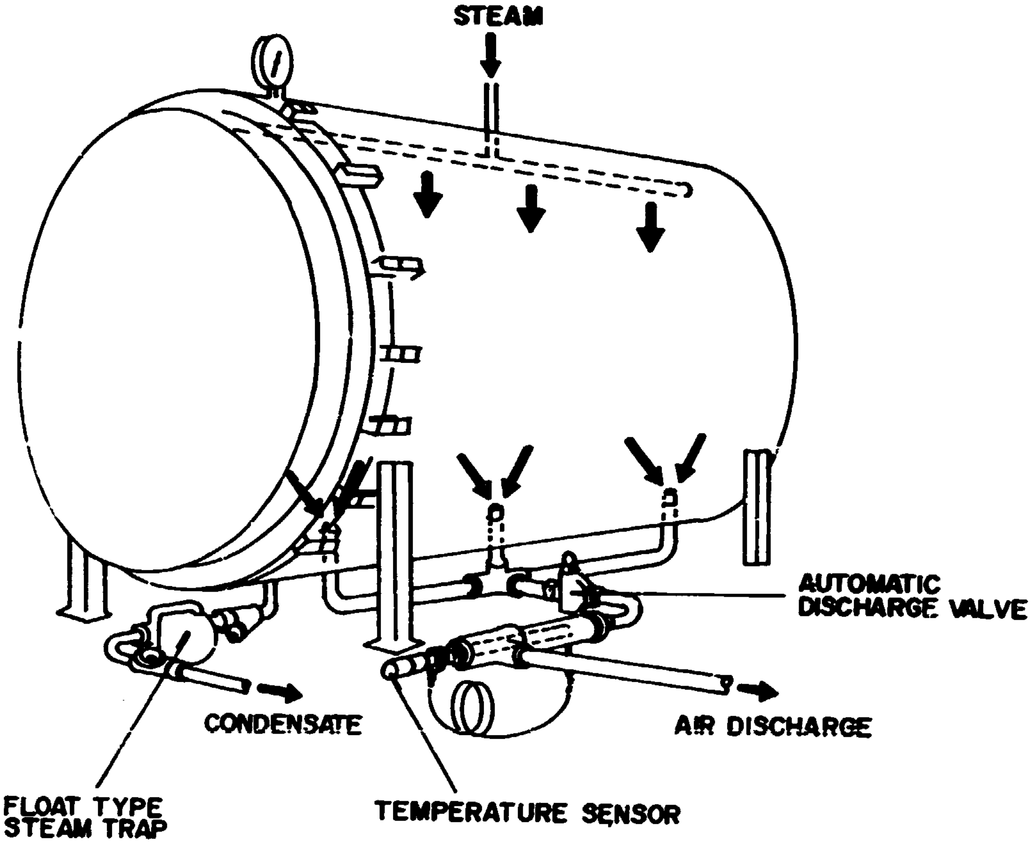


Figure 6.17 Horizontal Retort with Automatic Air Venting

Source: Reference 15

(d) In place of steam venting consider using mechanical vacuum pumps for removing air before retorting. It is apparent from Figure 6.18 that a lot of steam is used for venting. The high initial cost of the mechanical pump is offset by the savings in steam.

(e) In "clean" or asceptic canning operations, product-to-product heat exchange may be done.

(f) In continuous retorts, avoid pre-heating and venting too soon. Base these activities on the production schedule.

(g) If compressed air for pressure cooling is used, check and eliminate leaks in equipment, pipes, etc. to reduce compressor running time.

6.7.5 Layouting

Canning process equipment (including the boiler) must be located in the same vicinity to save heat and energy used for transport. Water, steam and materials flow should be considered in designing the canning layout. Product heat may be lost while moving the cans from the exhauster to the sealer and to the retort. Steam from a distant boiler house may have lost a lot of its heat through the piping when it reaches the canning area. Also, additional piping and insulation is required. These are only some of the factors that make layouting important from an energy viewpoint. Particular plants have unique problems and opportunities for energy conservation through improved equipment layouting.

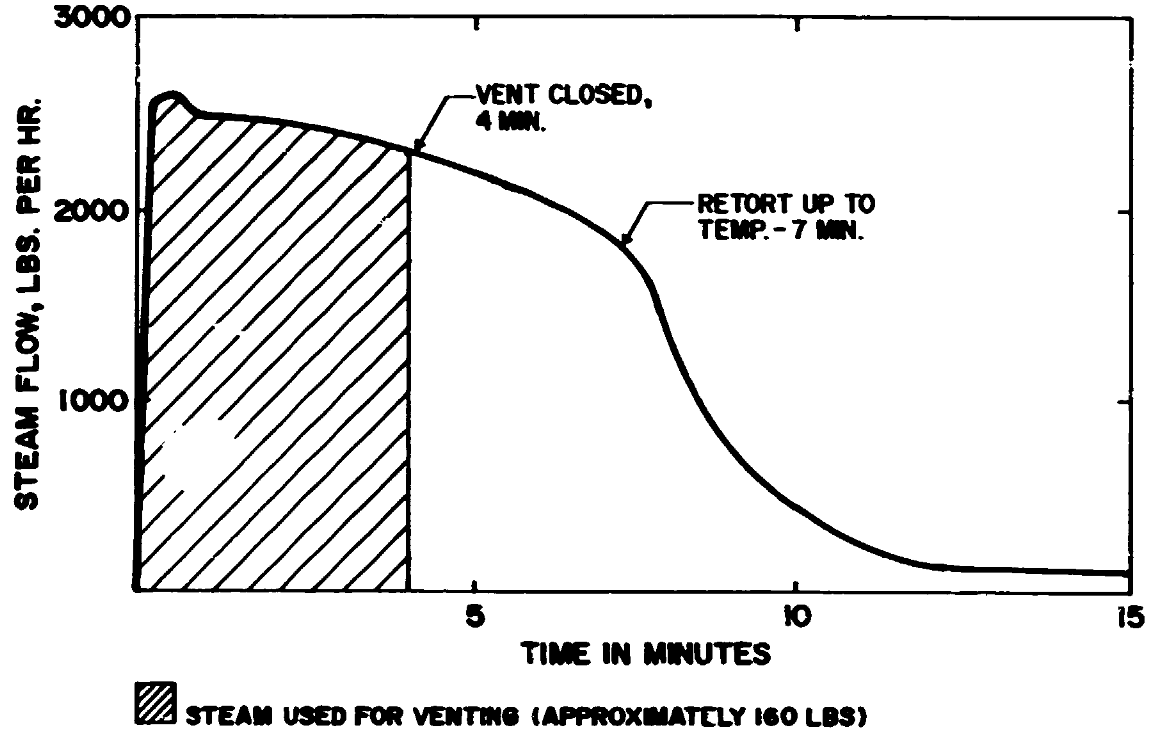


Figure 6.18 Typical Steam Consumption Curve for Retorting
Source: Reference 10

REFERENCES:

1. Casper, M.E. ed., *Energy Saving Techniques in the Food Processing Industry,* Noyes Data Corporation, Park Ridge, New Jersey, 1977.

2. Dryer, D.F. and Maples, Glennon, *Boiler Efficiency Improvement,* 3rd ed., Boiler Efficiency Institute, Auburn, Alabama, U.S.A., 1981.

3. *Energy Efficiency and Electric Motors,* Conservation Paper No. 58, prepared by Arthur S. Little & Co. for the Federal Energy Administration, U.S.A., August, 1976.

4. Gonzales, O.N. et. al, *Philippine Handbook on Canned Low-Acid Foods,* National Institute of Science and Technology, NSTA, Manila, 1982.

5. *Guides to Industrial Preventive Maintenance for Energy Conservation,* U.P. National Engineering Center and Bureau of Energy Utilization, Quezon City, Philippines, April 1986.

6. *Guides to Retrofitting Oil-fired Boilers, Kilns and Other Furnaces to Use Alternative Fuels,* U.P. National Engineering Center and Bureau of Energy Utilization, Quezon City, Philippines, July 1985.

7. *Guides to Quick Estimates of Energy Costs for Industrial Use,* U.P. National Engineering Center and Bureau of Energy Utilization, Quezon City, Philippines, May 1985.

8. "How to Conserve Energy by Really Trying", *Business Day,* Quezon City, Philippines, November 18, 1975.

9. Joslyn, Maynard A. and Heid, J.L., *Food Processing Operations,* The AVI Publishing Company, Inc., Westmont, Connecticut, U.S.A., 1976.

10. Lopez, Anthony, *A Complete Course in Canning,* Book I, 11th ed., The Canning Trade, Inc., Baltimore, Maryland, 1981.

11. Payne, Gordon A., *The Energy Manager's Handbook,* 2nd ed., Westbury House, IPC Business Press, Ltd., Surrey, England, 1980.

12. "Retrofit Boiler Economizers", a brochure of Waste Heat Technologies, Inc., Wadsworth, Ohio, U.S.A.

13. Ropp, Robert H. and Tibrewala, Rajen K., *Conserving Energy in Electric Motors, Pumps and Compressors,* The Systematic Energy Conservation Management Guide, Vol. 6 American Management Associations, 1978.

14. "Steam and Energy Conservation", Spirax Sarco Ltd., Charlton House, Cheltenham, England, 1980.

15. "Air Venting of Large Steam Spaces", Spirax Sarco Ltd., Charlton House, Cheltenham, England, 1974.

16. "Direct Steam Injection", Spirax Sarco Ltd., Charlton House, Cheltenham, England, 1971,

17. Fule, Jean B., "Steam in the Food Industry", Steam Systems Phils., Inc., Parañaque, Metro Manila.

APPENDIX I

Nomographs for Quick Estimation of Energy Costs and Savings

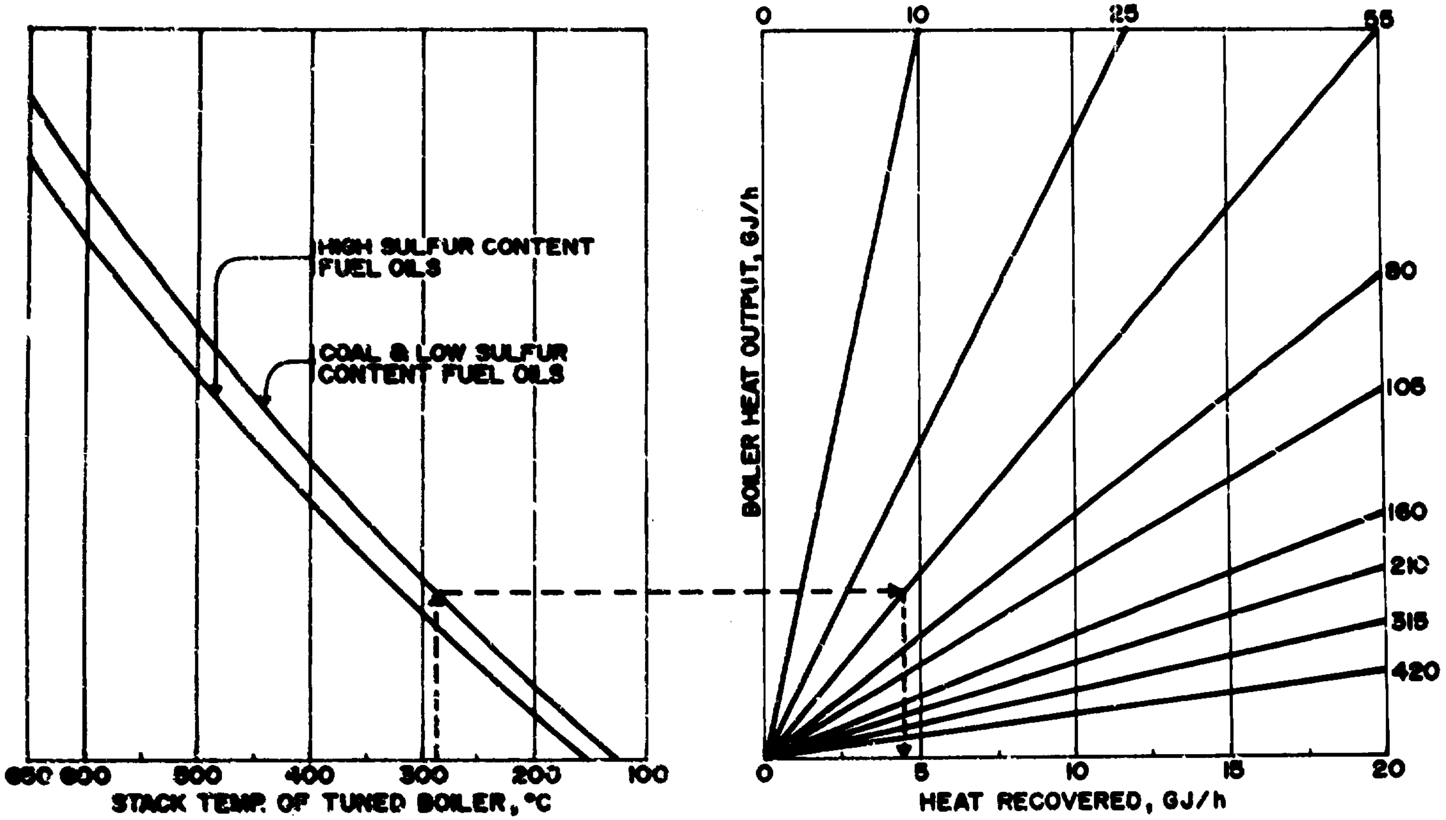
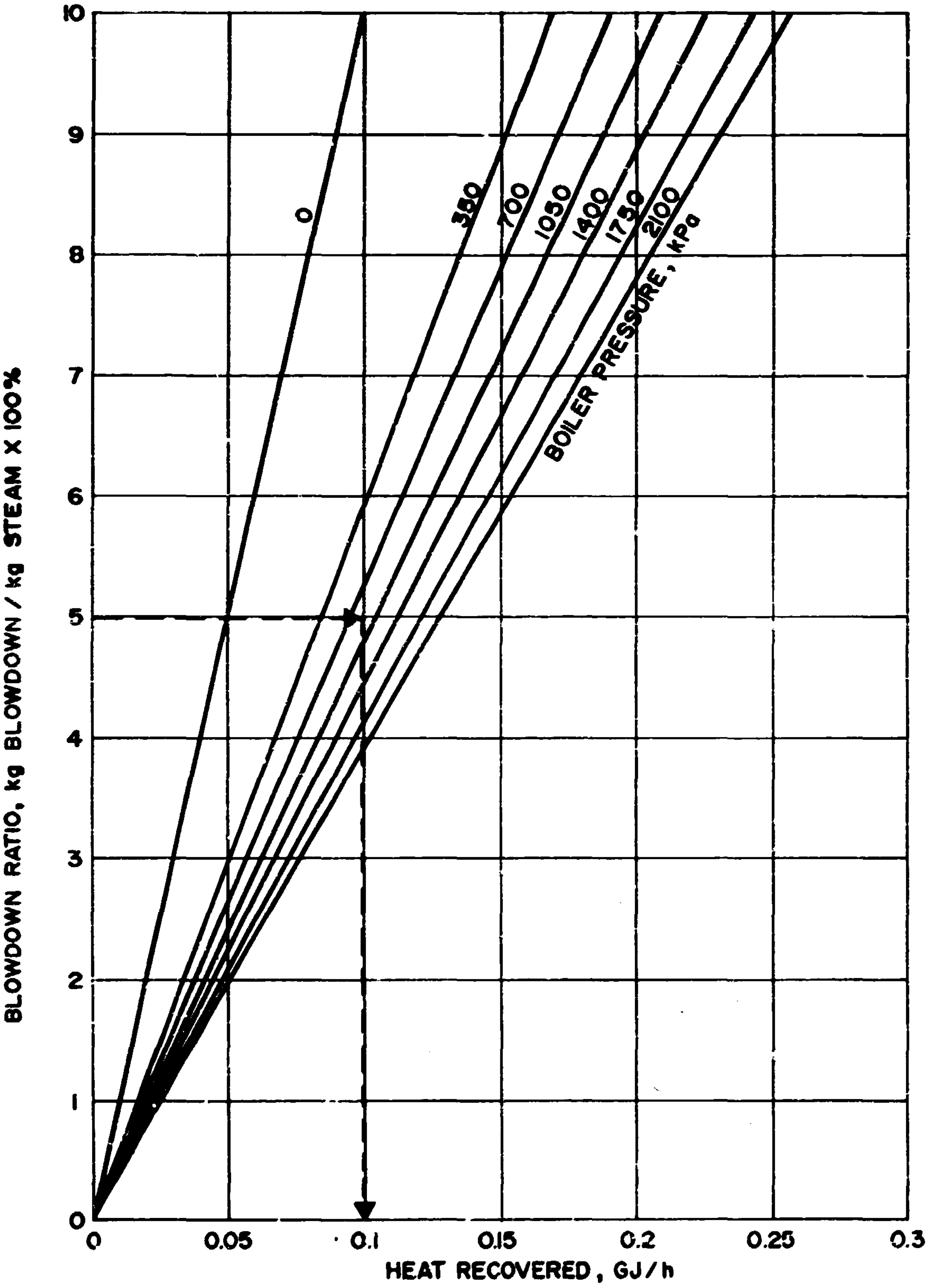


Figure A.1 Heat Recovered from Boiler Flue Gases

Source: "How to Cut Energy Costs", Industrial Energy Extension Service, Georgia Tech.



NOTE: GRAPHS ARE BASED ON A STEAM PRODUCTION RATE OF 4,500 kg/h AND 70% HEAT RECOVERY.

Figure A.2 Heat Recovered from Boiler Blowdown

Source: "How to Cut Energy Costs", Industrial Energy Extension Service, Georgia Tech.

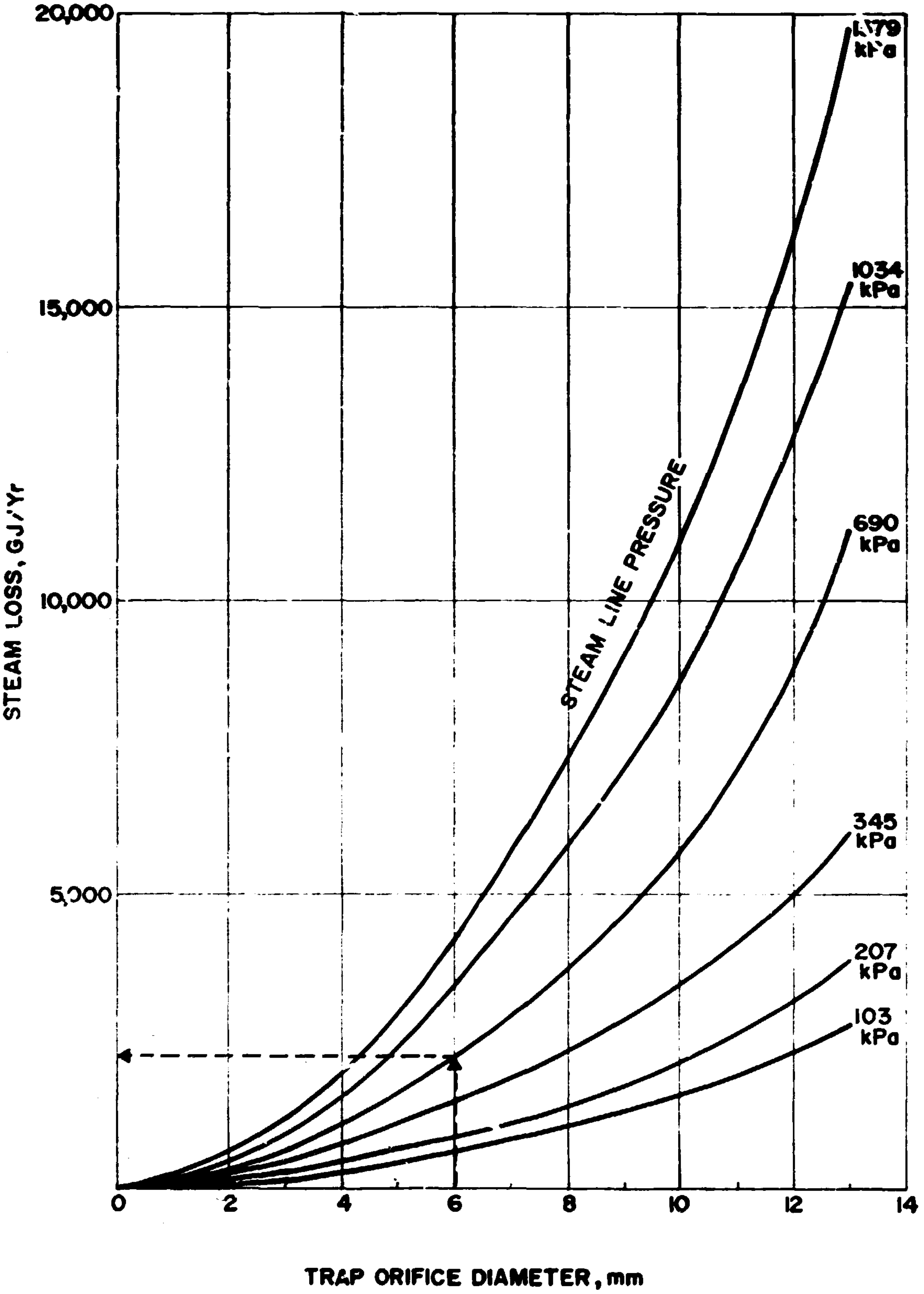


Figure A.3 Steam Loss Through Leaks

Source: U.S. National Bureau of Standards Handbook No. 115, September, 1974.

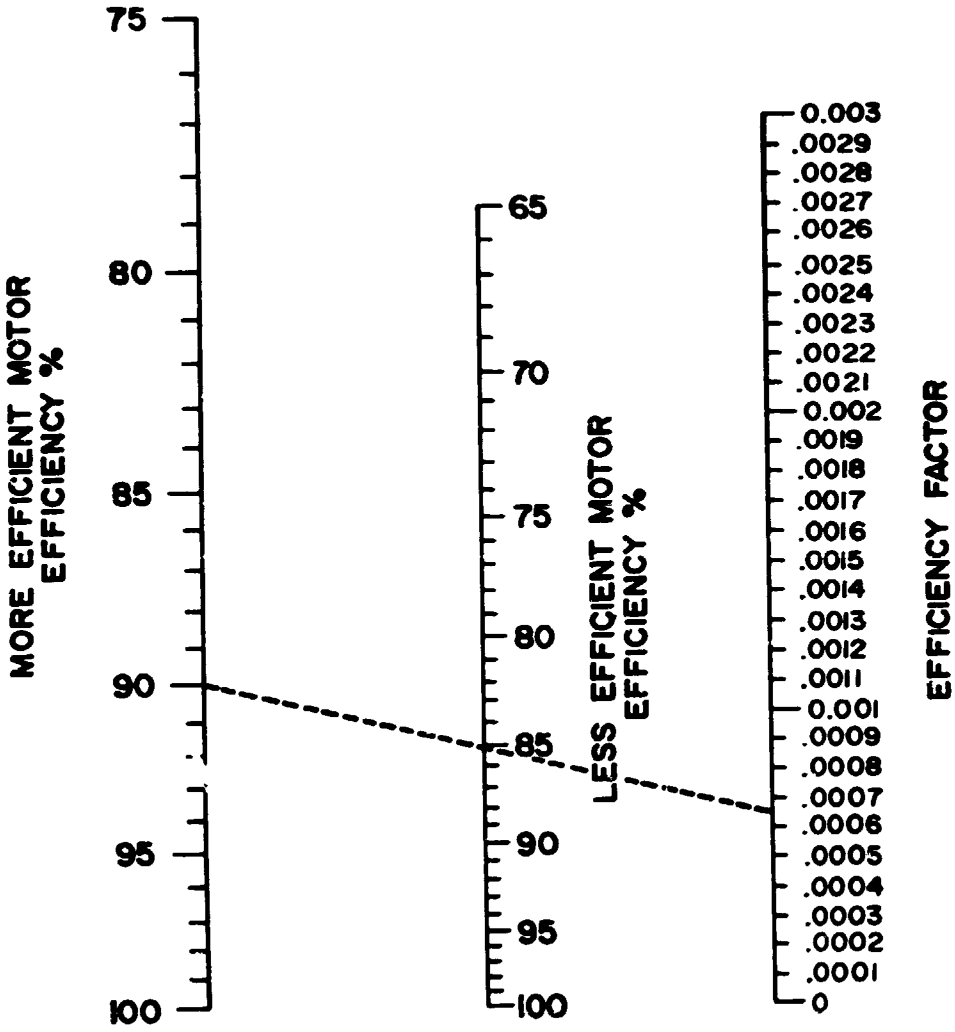
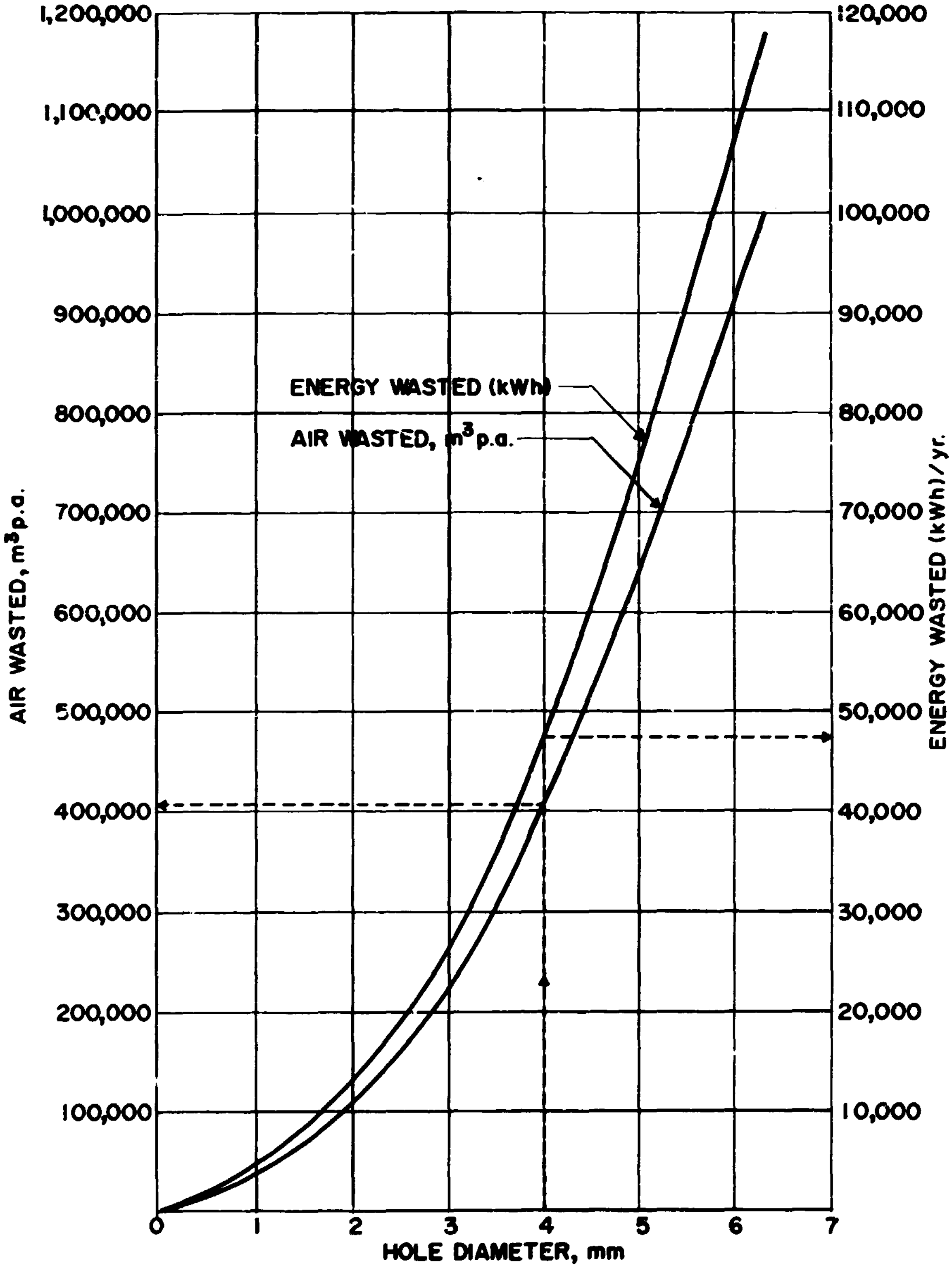


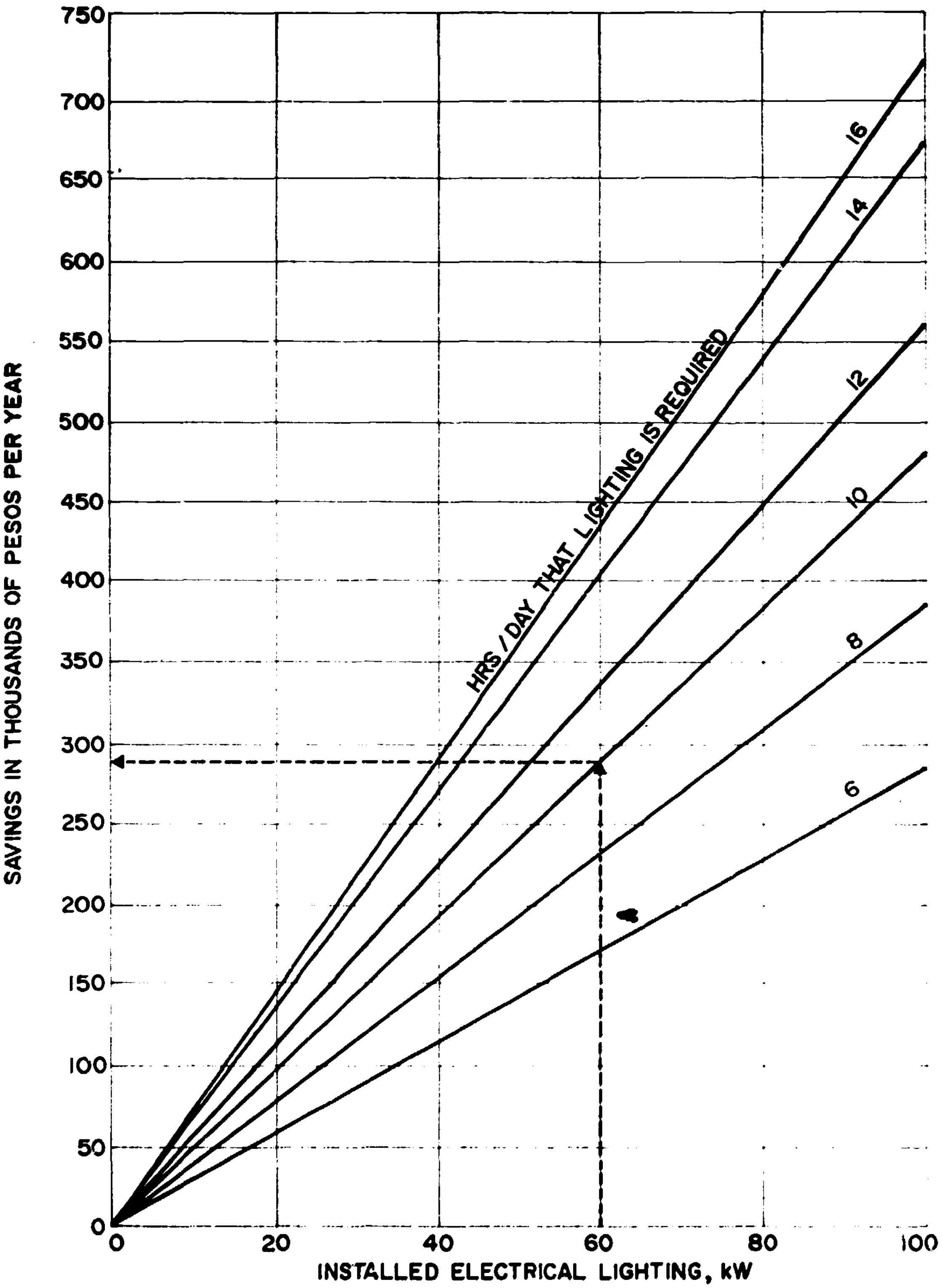
Figure A.4 Calculation of Savings with an Efficient Electric Motor

Source: "Reducing Your Electricity Costs by Improving the Efficiency of Electricity Uses", Energy Management Advisory Service, Sydney, Australia.



NOTE: THE CURVES ARE BASED ON THE FOLLOWING ASSUMPTIONS:
DISCHARGE PRESSURE = 700 kPa
1 kWh = 8.5 m³ AIR DELIVERED
800 HRS/ANNUM OPERATION

Figure A.5 Air and Energy Wasted vs. Equivalent Hole Diameter of Air Leaks



NOTE: THE GRAPHS ASSUME THAT: SKYLIGHTS PROVIDE 80% OF LIGHTING REQUIREMENTS, COST OF LIGHTING IS P 2.00/ kWh AND 300 OPERATING DAYS IN A YEAR.

Figure A.6 Peso Savings Due to Installation of Skylights

Source: Adapted from "How to Cut Energy Costs", Industrial Energy Extension Service, Georgia Tech.

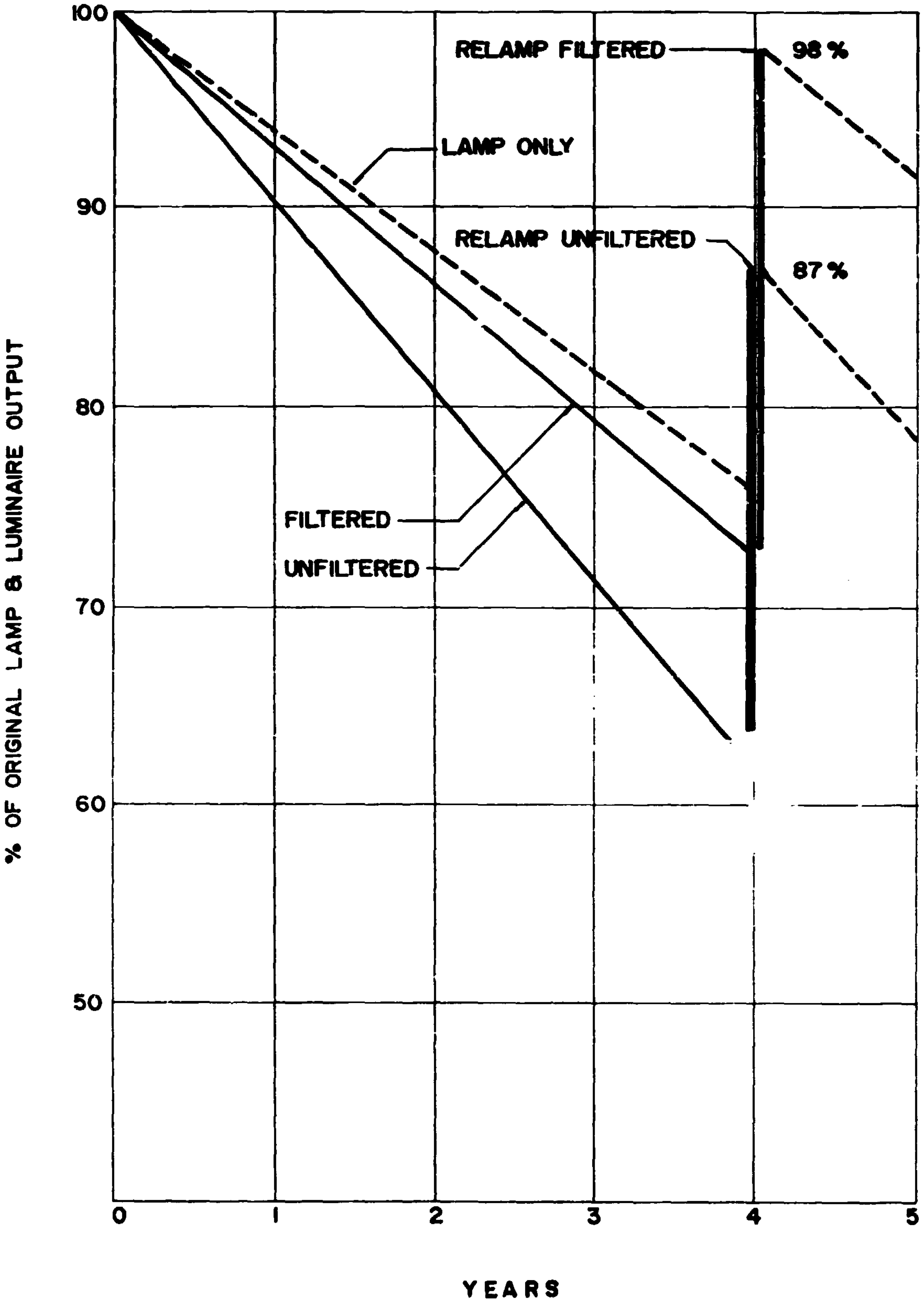
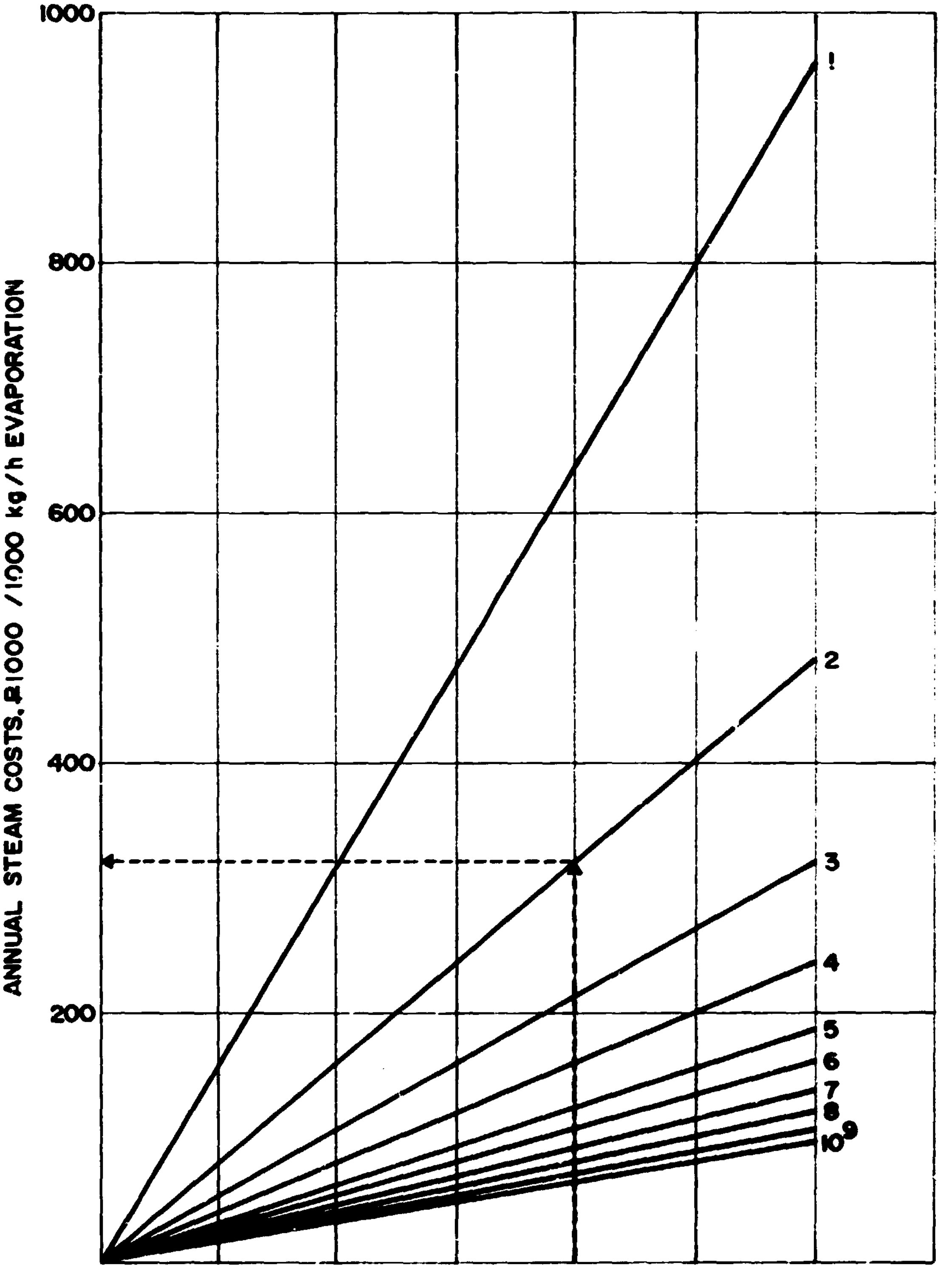


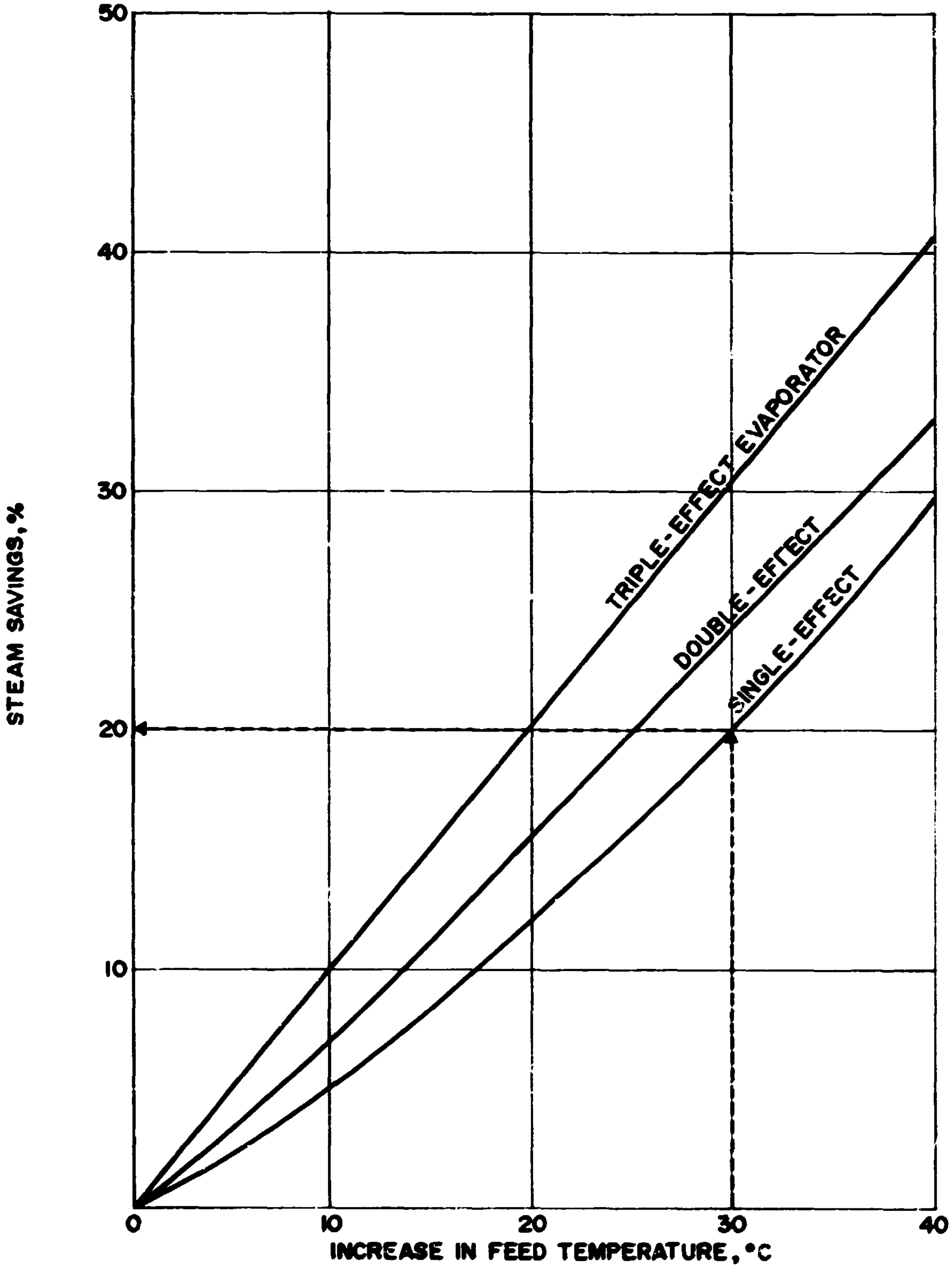
Figure A.7 Decrease of Lamp and Luminaire Output with Time
Source: General Electric, Inc.



NOTE: THE GRAPHS ARE BASED ON: 300 24-hr DAY/YR 0.9 N kg H_2O EVAPORATED PER kg OF STEAM WHERE N IS THE NUMBER OF EFFECTS.

Figure A.8 Steam Costs for Multiple Effect Evaporation

Source: Adapted from "How to Cut Energy Costs", Industrial Energy Extension Service, Georgia Tech.



NOTE: THE GRAPHS ARE BASED ON A FEED RATE OF 45,450 kg/h, AN EVAPORATION RATE OF 12,300 kg/h, A MAXIMUM FEED TEMPERATURE OF 80 °C AND NO BOILING-POINT RISE.

Figure A.9 Steam Savings vs. Increase in Feed Temperature

Source: Upgrading Existing Evaporators to Reduce Energy Consumption.

APPENDIX II

Typical Energy Efficiencies

Table A.1: Typical Process Efficiencies

General Equipment Category	Desired Process Efficiencies	Typical Process Efficiencies (In the Field)	Remarks
1. Boilers (steam)	78 to 81%	74 to 80%	These are boiler energy conversion efficiencies assuming good combustion efficiency. If you don't return your condensate, insulate lines, fix leaking fixtures, clean heat exchanges, use good boiler feed water treatments and a host of other things, your system efficiency may fall to 40 to 60% or lower.
2. Ovens			
A. Warm Air 21°C to 371°C	50 to 60%	35 to 40%	Ovens can and will vary all over because of such things as dirty combustion equipment, using the oven at a greater than design rate, too much weight in racks to hold ware and too little material being dried, the amount of exhaust (does it vary with solvent level or temp. etc.?), if the heat exchangers are clean and in good repair, and if the system is struggling in a negative pressure condition – to mention a few. These deserve your time.
B. Warm Air & I.R. 21°C to 371°C	60 to 75%	50 to 60%	
C. Direct Fired Ovens 21°C to 371°C	55 to 65%	35 to 45%	
3. Low Temperature Furnaces			
A. 538°C to 982°C (Batch)	60 to 40%	30 to 20%	Variations from the norm may result from: inadequate refractory or its maintenance, the combustion ratio, whether the furnace cycles or not (goes from room temp. to max. and cools down to room temp. again or not), whether a muffle or indirect system is used or not, if the cycle is accurately monitored, if the customers' specifications are realistic or not, etc. If radiant tubes are used, consider using a waste heat recuperator. On all open flued furnaces, install furnace pressure controls to reduce air infiltration.
B. 538°C to 982°C (Continuous)	40 to 30%	25 to 15%	
C. Coil Anneal (Bell) Radiant Tube	22 to 24%	4 to 7%	
D. Coil Anneal (Bell) Flat Flame	26 to 28%	9 to 14%	
E. Strip Anneal Muffle	24 to 30%	7 to 12%	

Typical Engineering Data

Table A.2 Energy Equivalents and Energy Units

1 UNIT OF:	EQUALS								
	boe	toe	tce	GJ	kWh	kcal	Btu	HP-h	CV-h
Bbl. of Oil Equiv. (boe)	1.00	0.14	0.20	5.80	1611.1	1385×10^3	5.497×10^6	2160.5	2190.7
Tonne of Oil Equiv. (tce)	7.22	1.00	1.43	41.87	11630	10×10^6	39.68×10^6	15596	15812
Tonne of Coal Equiv. (toe)	5.05	0.70	1.0	29.3	8141	7×10^6	27.77×10^6	10917	11068
Gigajoule (GJ)	0.172	0.024	0.034	1.00	277.7	238.8×10^3	0.948×10^6	372.5	377.7
Kilowatt hours (kWh)	0.62×10^{-3}	86×10^{-6}	123×10^{-6}	3.6×10^{-3}	1.00	860	3412	1.341	1.360
Kilocalorie (kcal)	0.722×10^{-6}	10×10^{-6}	14.3×10^{-6}	4.187×10^{-6}	1.163×10^{-3}	1.00	3.968	1.56×10^{-3}	1.58×10^{-3}
British Thermal Unit (Btu)	0.182×10^{-6}	25.2×10^{-9}	36.0×10^{-9}	1055×10^{-9}	0.293×10^{-3}	0.252	1.00	$.393\times10^{-3}$	$.398\times10^{-3}$
HP-hour (Imperial) (Hp-h)	0.463×10^{-3}	64.1×10^{-6}	91.6×10^{-6}	2.68×10^{-3}	0.746	641.2	2544.5	1.00	1.014
HP-hour (Metric) (CV-h)	0.456×10^{-3}	63.2×10^{-6}	90.3×10^{-6}	2.65×10^{-3}	0.735	632.4	2509.6	0.986	1.00

NOTE: A tonne of oil equivalent is usually assigned a value of 10 million kilocalories. Oil with an energy content of 10 million kilocalories per tonne would have a specific gravity of about 0.90 and an API gravity of about 25. It would thus be midway between distillate and residual fuel oils in both gravity and energy contents and might therefore be termed more accurately a "fuel oil equivalent". By averaging distillates and residual we obtain a ratio 7.0 barrels per tonne equivalent, which on the basis of 41.87 gigajoules per tonne equivalent (10 million kilocalories) yields 6.0 gigajoules per barrel of oil equivalent. The barrel of oil equivalent defined as 5.8 gigajoules is therefore a slightly "lighter" fuel, equal to 42.7 gigajoules per tonne and 7.22 barrels per tonne of oil equivalent.

Table A.3 Industry Guidelines for % CO_2 and Excess Air

Ultimate CO_2 content of Dry Stack Gas for Perfect Combustion:

Fuel	% CO_2
Blast Furnace Gas	25.1
Coal	18.6
Coke Oven Gas	9.4
Natural Gas	12.0
Oil	15.4
Propane	14.0
Wood	20.0

Excess Air Required for Good Combustion:

Fuel	% Excess Air
Blast Furnace Gas	15-25
Coal	10-40
Coke	20-40
Coke Oven Gas	5-10
Natural Gas	5-10
Oil	8-15
Refinery Gas	8-15
Wood	25-50

Table A.4 Approximate Net Heat Contents of Commonly Use Fuels

	EQUALS			
	Bbls of oil equivalent	Tonnes of oil equivalent	Tonnes of Coal equivalent	Gigajoules (10^9 joules)
1 TONNE OF:				
Coal	5.05	0.70	1.00	29.3
Lignite	2.01	0.28	0.40	11.7
Peat	2.53	0.35	0.50	14.7
Coke	4.91	0.68	0.97	28.5
Charcoal, Briquettes	4.98	0.69	0.99	28.9
Firewood (air dried)				
Pine	2.34	0.32	0.46	13.6
Hardwood	1.60	0.22	0.32	9.3
Bagasse (30% moisture)	2.17	0.30	0.43	12.6
Agricultural Wastes	2.00	0.28	0.40	11.6
Dung Cakes	1.53	0.21	0.30	8.9
Nut Shells	3.40	0.47	0.67	19.7
Dry Straw	3.02	0.42	0.60	17.5
LNG	9.10	1.26	1.80	52.8
LPG	7.79	1.08	1.54	45.2
Gasoline	7.59	1.05	1.50	44.0
Kerosene/Jet Fuel	7.43	1.03	1.47	43.1
Gas Oil/Auto Diesel	7.36	1.02	1.46	42.7
Industrial Diesel	7.29	1.01	1.44	42.3
Residual Oil	7.07	0.98	1.40	41.0
Asphalts	7.22	1.00	1.43	41.9
Lubes				41.4
Petrochemical Feedstocks	7.59	1.05	1.50	44.0
Petroleum Coke	6.00	0.83	1.19	34.8
Ethyl Alcohol	4.76	0.66	0.94	27.6
Methyl Alcohol	4.10	0.50	0.71	20.9
1 BARREL OF:				
LNG	0.60	0.08	0.12	3.5
LPG	0.67	0.09	0.13	3.9
Gasoline	0.90	0.12	0.18	5.2
Kerosene/Jet Fuel	0.97	0.13	0.19	5.6
Gas Oil/Diesel	1.00	0.14	0.20	5.7
Industrial Diesel	1.02	0.14	0.20	5.9
Residual Oil	1.05	0.15	0.21	6.1
Asphalts	1.21	0.17	0.24	7.0
Lubes	1.00	0.14	0.20	5.8
Petrochemical Feedstocks	0.90	0.12	0.18	5.2
Petroleum Coke	1.29	0.18	0.26	7.5
Ethyl Alcohol	0.60	0.08	0.12	3.5
Methyl Alcohol	0.47	0.06	0.09	2.7
100 m^3 OF:				
Natural Gas	6.00	0.83	1.19	34.8
Town Gas	2.88	0.40	0.57	16.7
Producer Gas	1.02	0.14	0.20	5.9

Note: The figures in this table are net heating values (reduced from gross values by the latent heat of vaporization of water formed in combustion). These figures, commonly used in Europe, are appropriate representations of heat release in furnaces, kilns and boilers. In the United States the practice is to use gross heats of combustion. Some typical values for the ratio of net to gross are as follows:

Fuel	Net/Gross Ratio
Natural Gas	0.90
Fuel Oil	0.94
Coal	0.98

Table A.5 Density and Gross Heating Value of Fuels

PETROLEUM	API°	kg/L	Btu/lb	kcal/kg	kJ/kg	kJ/L
Premium	61.0	0.7351	20,500	11,389	47,683	
Regular	59.0	0.7428	20,750	11,528	48,264	
Average Gasoline	60.0	0.7389	20,620	11,456	47,962	
Kerosene	47.1	0.7923	19,800	11,000	46,706	
Diesel	36.0	0.8448	19,650	10,917	45,706	
Fuel Oil	15.0	0.9569	18,600	10,333	43,263	41,398
Avturbo	47.1	0.7923	19,800	11,000	46,055	
Naphtha	60.0	0.7389	20,620	11,456	47,962	
Avgas	64.6	0.7216	20,950	11,639	48,729	
LPG	–	0.550	21,180	11,767	49,264	
NON-PETROLEUM						
Methanol	46.3	0.796	6,600	5,333	22,329	
Ethanol	46.7	0.794	12,800	7,111	29,773	
Coconut Oil	21.5	0.9248	15,748	8,749	36,630	
SOLID FUELS						
Coal			9,000	5,000	20,934	
Bagasse at 50% Moisture			4,000	2,222	9,304	
Wood Waste at 30% Moisture			4,000	2,222	9,304	
Rice Hull			6,000	3,333	13,956	
Coconut Shell			8,630	4,794	20,073	
Coconut Husk			7,400	4,111	17,212	
ELECTRICITY			Btu/kWh	kcal/kWh	kJ/kWh	
At 33% Thermal Efficiency			10,340	2,606	10,909	
At 100% Thermal Efficiency			3,412	860	3,600	

NOTE:
1 kg = 2.2046 LB
1 Btu = 0.252 kcal = 1.05506 kJ
1 kWh = 3600 kJ

Table A.6 Chemical Analysis of Fuels

LIQUID FUELS	API°	C	H	S	O	N	ASH	
Gasoline	55.5	84.5	15.4	–	–	–	0.0	
Kerosene	41.8	84.7	15.3	–	–	–	0.0	
Diesel	32.7	85.5	13.0	0.8	–	–	0.7	
Fuel Oil:								
Heavy	16.7	84.7	12.4	1.1	–	–	1.8	
Light	27.2	95.6	12.0	0.4	0.6	0.5	0.9	
LPG	–	82.43	17.57	–	–	–	0.0	
Methanol	46.3	37.48	12.58	–	49.94	–	0.0	
Ethanol	46.7	52.14	13.13	–	34.73	–	0.0	
Coconut Oil	21.5	76.28	10.87	–	12.85	–	0.0	
SOLID FUELS	BTU/LB	C	H	S	O	N	ASH	MOISTURE
Coal:	12,750	79.8	2.5	0.6	7.3	0.8	9.0	6.0
	11,630	65.8	5.7	0.5	18.1	1.1	8.8	7.9
	8,710	49.7	6.4	0.4	31.9	0.8	10.8	21.9
	7,050	41.3	6.7	0.4	42.6	0.7	8.3	34.0
Wood:	3,591	48.99	6.20	-	44.25	0.06	0.50	30
Bagasse	4,000	47.0	6.5	–	44.0	–	2.5	50

$$\text{NHV (Btu/lb)} = \text{GHV (Btu/lb)} - \frac{\%\text{H}/100}{0.001} \times 1/2 \times 0.018 \times 1050$$

$$= \text{GHV (Btu/lb)} - 94.50\ (\%\text{H})$$

$$\text{NHV (kcal)} = \text{GHV (kcal/kg)} - \frac{\%\text{H}/100}{0.001} \times 1/2 \times 0.018 \times 583$$

$$= \text{GHV (kcal/kg)} - 52.47\ (\%\text{H})$$

$$\text{NHV (kJ/kg)} = \text{GHV (kJ/kg)} - \frac{\%\text{H}/100}{0.001} \times 1/2 \times 0.18 \times 2442$$

$$= \text{GHV (kJ/kg)} - 219.78\ (\%\text{H})$$

Table A.7 Thermodynamic Properties of Selected Gases

	CO_2	H_2O	O_2	N_2	CO	H_2	SO_2
HW	0.044	0.018	0.032	0.028	0.028	0.002	0.064
S(298)	51.072	45.106	46.004	45.770	47.214	31.208	39.298
HF(298)	– 94.054	– 57.798	0.000	0.000	– 26.417	0.000	– 70.947
GF(298)	– 94.265	– 54.646	0.000	0.000	– 32.783	0.000	– 71.741

H(T) – H(298): Enthalpy relative to 298 °K. kcal/mol

	CO_2	H_2O	O_2	N_2	CO	H_2	SO_2
0 °K	– 1.803	– 1.750	– 1.550	– 1.530	– 1.331	– 1.426	– 2.522
100	– 1.344	– 1.243	– 1.104	– .081	– 1.085	– 1.011	– 1.725
200	– 0.731	– 0.653	– 0.580	– 0.565	– 0.567	– 0.529	– 0.893
298	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.016	0.14	0.012	0.012	0.12	0.011	0.018
400	0.882	0.748	0.633	0.640	0.645	0.602	0.016
500	1.852	1.544	1.363	1.313	1.324	1.235	2.093
600	2.912	2.393	2.105	2.024	2.041	1.904	3.237
700	4.048	3.291	2.832	2.766	2.791	2.604	4.433
800	5.249	4.232	3.689	3.534	3.568	3.327	5.669
900	6.506	5.211	4.320	4.324	4.367	4.071	6.937
1000	7.808	6.224	5.369	5.185	4.832	4.832	8.229
1100	9.148	7.268	6.234	5.954	6.016	5.605	9.540
1200	10.518	8.338	7.110	6.787	6.858	6.388	10.866
1300	11.912	9.432	7.996	7.628	7.709	7.180	12,206
1400	15.325	10.548	8.887	8.475	8.565	7.977	15.556
1500	14.752	11.583	9.784	9.426	9.426	8.779	14.915
1600	16.188	12.836	10.683	10.181	10.289	9.584	16.282
1700	17.632	14.004	11.584	11.037	11.154	10.393	17.656
1800	19,080	15.186	12.487	11.895	12.019	11.203	19.035
1900	20.530	16.382	13.390	12.753	12.884	12.016	20.420
2000	21.982	17.591	14.294	13.611	13.749	12.831	21.801

Where MW = Molecular Weight, kg/mol
S(298) = Entropy at 298°K, cal/mol°K)
HF(298) = Heat of Formation at 298°K. kcal/mol
GF(298) = Gibb's Free Energy at 298°K. kcal/mol

Table A.8 Usual Amount of Excess Air Required for Fuel-Burning Equipment

Source: Reference 4

Fuel	Type of Furnace or Burners	Excess Air, %
Pulverized Coal	Water-cooled furnaces	15–20
Crushed Coal	Cyclone furnaces	10–16
	Stoker-fired, forced-draft chain grate	15–50
Coal	Stoker fired, forced-draft underfeed	20–50
	Stoker-fired, natural draft	50–65
Fuel Oil	Common practice	10–20
	with careful apportion of air in multiburner systems and high turbulence	1–5%
Acid Sludge	Cone and hat, flame type burners, steam atomized	10–15
Natural, Coke Oven and Refinery	Register type burners	5–10
	Multifuel burners	7–12
Blast-furnace Gas	Intertube nozzle type	15–18
Wood	Dutch oven (10–20% through grates) and Hott type	20–25
Bagasse	All furnaces	50–100
Black Liquor	Recovery furnaces for kraft and soda pulping processes	5–7
Biomass		50–100

APPENDIX IV

Financial Evaluation Methods

This chapter presents some of the most commonly used financial evaluation methods. They are usually classified into two broad categories namely discounting methods and non-discounting methods. Discounting methods take into account total costs and benefits over the life of the investment and the timing of cash flows. Cash flows occuring at different times are converted to a common basis. Non-discounting methods do not usually consider the time value of money.

NON-DISCOUNTING METHODS

Payback Methods

Payback methods are designed to measure the time to recover the original investment. They measure cash recoverability of a project rather than profitability. These methods are simple to understand and apply. They are also known as pay-out or pay-off methods.

$$\text{Payback} = \frac{\text{capital investment}}{\text{net annual savings}}$$

Example: A project requiring ₱100,000 capital investment and a net savings of ₱40,000 per year will have a payback of 2.5 years.

$$\text{Payback} = \frac{₱100{,}000}{₱40{,}000/\text{yr}} = 2.5\ \text{yr}$$

Simple Rate of Return

The rate of return methods are designed to calculate the percentage or rate which an investment is going to return. The comparison of this rate with the cost of capital tells the decision-maker whether the investment is good or bad.

$$\underset{\text{(SRR)}}{\text{Simple Rate of Return}} = \frac{\text{annual earnings}}{\text{investment}} \times 100\%$$

The simple rate of return formula provides some indication of profitability.

Example: A project requiring ₱100,000 capital investment and net savings of ₱40,000 per year will have a simple rate of 40%.

$$\text{Simple Rate of Return} = \frac{₱40{,}000}{₱100{,}000} \times 100\% = 40\%$$

Return on Investment (ROI)

ROI methods are also known as accounting rate of return methods. The ROI criteria measure the effect of the decision on accounting reports such as profit and loss statements.

$$\text{Accounting ROI} = \frac{\text{net income}}{\text{investment}} \times 100\%$$

The amounts to be used in the numerator as net income and in the denominator as investment are arbitrarily defined to conform with accounting conventions.

ROI methods appeal to managers because they state results of an investment decision according to rules that may be used to evaluate a manager's controllable operating performance.

Example:

		Cash Flow			
		0	1	2	3
(1)	Net Income	–	100	200	150
	Investment bases				
(2)	Original Cost	300	300	300	300
(3)	Book Value, end of Period	300	300	200	100
	Return on Investment (ROI)				
(4)	Basis of original cost	–	33.3%	66.7%	50%
	Basis of book value	–	33.3%	100%	150%

DISCOUNTING METHODS

Net Present Value Method (NPV)

This method calculates the differences between the present value of the benefits and the costs resulting from an investment. A positive net present value means that the financial position of the investor will be improved by undertaking the investment; a negative net present value means that the investment will result in a financial loss. In using the net present value method, it is important to evaluate the costs and benefit of each alternative over an equal number of years.

The formula for calculating the net present value is as follows.

$$NPV\,(i) = \sum_{t=0}^{N} F_t \,(1+i)^{-t}$$

where NPV = net present value of investment at the given interest i.

F_t = net cash flow at year t, t = 0, 1, 2, . . . N

N = economic life of the investment

i = interest rate or discount rate

Net Annual Value Method (NAV)

This method takes essentially the same form as the net present value method. The difference is that all costs and benefits of the net annual value method are converted to a uniform annual basis instead of to present value.

The formula for calculating the net annual value is as follows:

$$NAV\,(i) = \sum_{t=0}^{N} F_t \,(i+i)^{-t} \quad \frac{i\,(1+i)^n}{(1+i)^n - 1}$$

where: $NAV(i)$ = net annual value at the given interest rate i.
F_t = net cash flow at year t.
i = discount rate or interest rate
N = economic life.

Benefit/Cost Ratio Method

The benefit/cost ratio method expresses benefit as a proportion of costs where benefits and costs are discounted to either a present value or an annual value equivalent. To be worthwhile, an investment must have the benefit cost ratio greater than 1.

The formula (with benefits and costs discounted to present value) is as follows:

$$B/C\,(i) = \frac{\sum_{t=0}^{N} B_t\,(1+i)^{-t}}{\sum_{t=0}^{N} C_t\,(1+i)^{-t}}$$

where: $B/C\,(i)$ = benefit-cost ratio at the given interest i.
B_t = cash flow of net benefit at year t
C_t = cash flow of net cost at year t
i = discount rate or interest rate
N = economic life of the investment.

Internal Rate of Return Method (IRR)

This method calculates the rate of return an investment is expected to yield. The IRR expresses its investment alternative in terms of rate of return (a compound interest rate). The expected rate of return is the interest for which total discounted benefits become just equal to total discounted costs. The criterion is to accept a project for which the IRR is greater than the discount rate i. The criterion for selection among mutually exclusive alternatives is the highest incremental IRR.

System of Units

Table A.9 Symbols of Units

Symbol	Unit
m	metre
km	kilometre
L	litre
min	minute
h	hour
d	day
yr	year
a	annum
kg	kilogram
kg/h	kilogram per hour
t	tonne (= 1000 kg)
tpa	tonnes per annum
J	joule
kJ	kilojoule
GJ	gigajoule
W	watt
kW	kilowatt
MW	megawatt
kWh	kilowatt hour
MWh	megawatt hour
kV	kilovolt
kVA	kilovolt ampere
MVA	megavolt ampere
lm	lumen
lx	lux. (= 1 lm/m^2)
$W/m^{\circ}k$	watts per metre kelvin
W/m^2	watts per square metre
W/sr	watts per steradian
MB	thousand barrels
TOE (toe)	tonne of oil equivalent
MTOE (MToe)	thousands TOE

Table A.10 SI Prefixes

Name	Symbol	Factor by which the unit is multiplied
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	u	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Table A.11 Selected Conversion Factors to SI Units

US or Metric Unit	Multiply by	To Obtain SI Unit
slug	14.594	kg
lbm	0.4539	kg
tonne (2204.6 lbm)	1,000	kg
cu ft	0.028	m^3
U.S. gallon	3.785×10^{-3}	m^3
	3 785	L
barrel of oil (42 U.S. gallons)	159	L
Btu	1,055.1	J
kcal	4,187	J
hp–h	2.685	MJ
Btu/h	0.2931	W
hp	746	W
Btu/h–ft^2	3.1525	W/m^2
Btu/lbm	2.326	kJ/kg
kcal/kg	4.187	kJ/kg
Btu/ft^3	37.26	kJ/m^3
psi	6.895	kPa

Table A.12 Non-SI Weight Units

1 UNIT OF:	EQUALS				
	t	kg	sh. ton	l. ton	lbs
tonne (metric ton, t)	1.0	1000	1.102	0.984	2205
kilogram (kg)	0.001	1.0	$1102\text{x}10^{-6}$	$984\text{x}10^{-6}$	2.205
short ton (sh. ton)	0.9072	907.2	1.0	0.893	2000
long ton (l. ton)	1.016	1016	1.120	1.0	240
pound (lb)	$0.45\text{x}10^{-3}$	0.454	$0.5\text{x}10^{-3}$	$0.446\text{x}10^{-3}$	1.0

Note: Tonne and kilogram are taken as force units here.
kg is metric, not SI in this case.
Tonne as a weight unit is sometimes written as tonnef.
to distinguish it from the metric unit of mass which goes
by the same name (see Table A.3)

Table A.13 Volume Units

1 UNIT OF:	EQUALS						
	bbl	b/d	gal	I.G.	m^3	L	cu ft
Barrel (bbl)	1.0	$2.74\text{x}10^{-3}$	42	34.97	0.159	159	5.615
Barrel per day (b/d)	365	1.00	15,330	12,764	58	58,035	2,049
US Gallon (gal)	$23.8\text{x}10^{-3}$	$65\text{x}10^{6}$	1.00	0.833	$3.785\text{x}10^{-3}$	3.785	0.134
Imperial gal. (I.G.)	$28.5\text{x}10^{-3}$	$78\text{x}10^{-6}$	1.201	1.00	$4.546\text{x}10^{-3}$	4.546	0.161
Cubic meter (m^3)	6.289	0.017	264.2	220.0	1.00	1000	35.3
Litre (L)	$6.29\text{x}10^{-3}$	$17.2\text{x}10^{-6}$	0.264	0.220	0.001	1.00	0.035
Cubic foot (cu ft)	0.178	$0.49\text{x}10^{-3}$	7.48	6.23	0.028	28.3	1.00

Checklist of Energy Conservation Opportunities

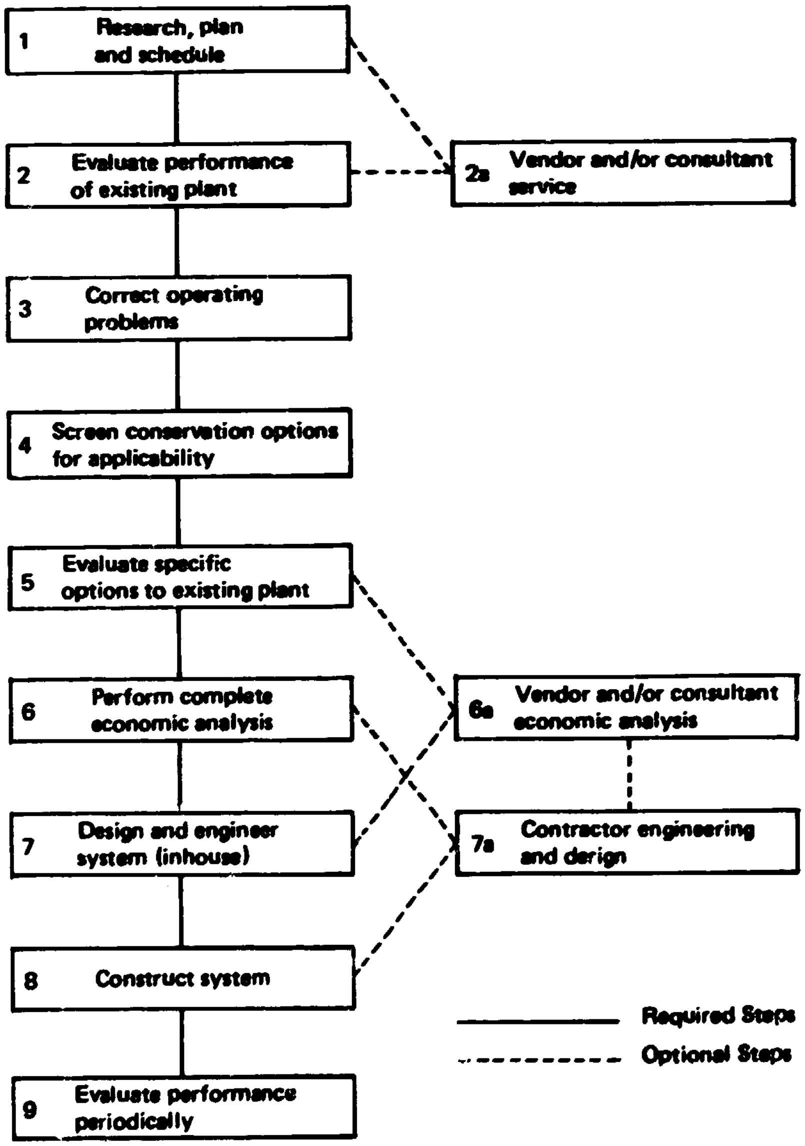


Figure A.10 Steps in Implementing an Overall Energy-Conservation Program.

APPENDIX VII

How to Conduct an Energy Audit

An energy audit is the starting point for implementation and control of the energy conservation program. It is a critical examination of an energy consuming facility. The typical objectives for conducting an audit are to set energy conservation goals, develop energy standards, identify and analyze energy saving opportunities, and establish an accounting and reporting system.

The Energy audit is usually categorized into 3 levels of activity:

1. Primary or Preliminary Audit

   It consists of recording and analyzing energy use by cost center or equipment over a fixed period of time (1-3 days).

2. Detailed Audit

   It consists of recording complete energy use data for every cost center over a fixed period of time and calculating energy balances and efficiencies. This takes weeks, sometimes months to finish.

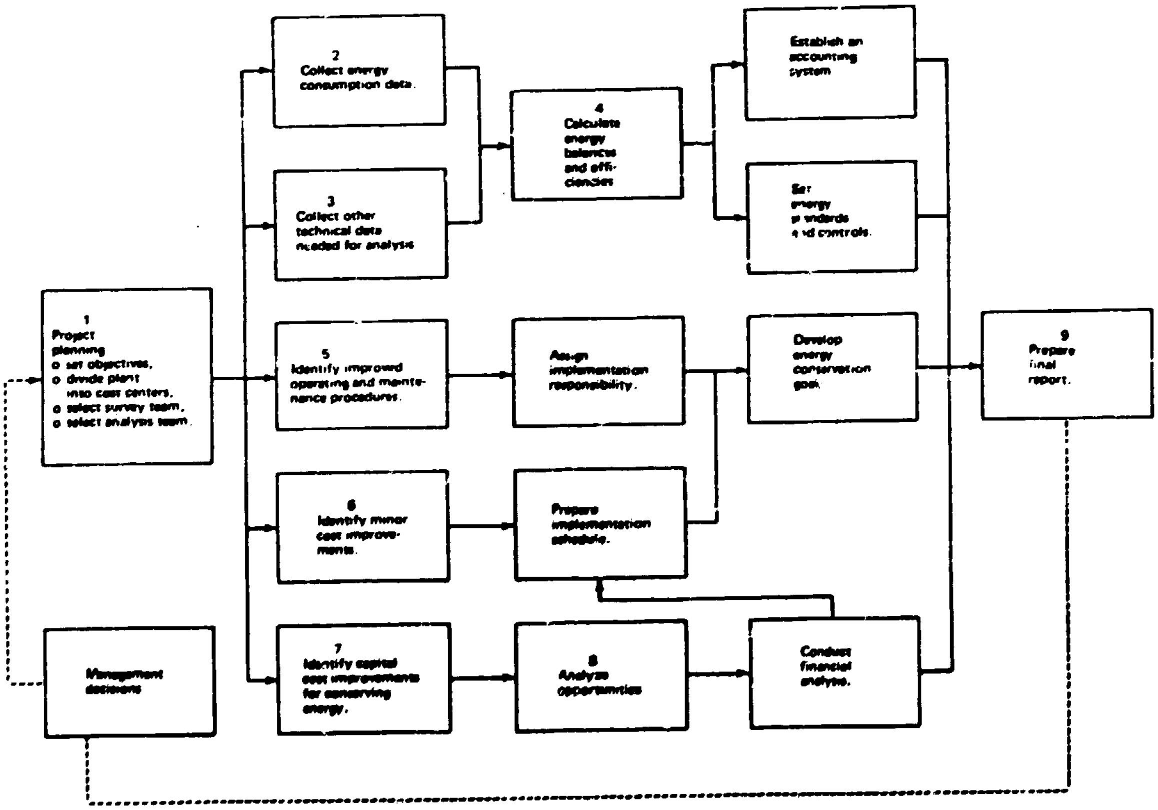


Figure A.11 The Auditing Process

3. Plant Surveys

It consists of identifying obvious energy wastage situations, recommending measures through improved maintenance and operating practices. It also involves recommending and analyzing energy conservation opportunities which require minor expense or major capital investments.

Auditing process consists of both observing the cost center and analyzing the results of observation. A step-by-step approach for conducting a detailed audit is shown in Figure A.11. A sample of a final report checklist is shown in Table A.14.

Table A.14 Final Report Checklist

Operating unit ________ Cost center ________ Date audited ________

	Yes	No
1. A statement of ojective of the audit	x	
2. Names of individuals conducting audit	x	

Survey Team	Analysis Team

3. A statement of assumptions (if any)

	Yes	No
4. *Primary Audit Data*		
Purchased energy records (Table A.15)		
Generated/marketed energy records (Table A.16)		
Recycled energy records (Table A.17)		
Energy records summary (Table A.18)		
5. *Detailed Audit Data*		
Electrical energy audit (Table A.19)		
Oil energy audit		
Gas energy audit		
Coal energy audit		
Other		
6. *Other Technical Data*		
Raw material energy (Table A.20)		
Production and general records (Table A.21)		
7. A summary of energy balance and efficiency calculations		
8. Details of energy balance and efficiency calculations		
9. A checklist of applicable energy conservation measures	x	
10. *Analysis of opportunities summary*	x	
Cost of energy at point of use (Table A.22)		
Measuring performance and setting economic objectives (Table A.23)	x	
11. Summary of capital projects analysis		
12. Details of capital project analysis		
13. Data for cost accounting system		
14. A statement of other findings		
15. A checklist of enclosures	x	

Table A.15 Purchased Energy Records

Year ______

Operating unit ______ Cost Center ______ Prepared by ______ Date ______

Type of fuel	Purchased Electricity							Fuel Oil No. 2			Fuel Oil No. 6			Coal type ___			Other			Total	
Units	kWh used	Max kW Demand	Demand Charge	Power Factor adj.	Fuel adj.	Total $	kWh	L	$	kJ	L	$	kJ	Tonne	$	kJ		$	kJ	$	kJ*
Column No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(23)	(24)	(25)	(26)	(27)
Jan.																					
Feb.																					
March																					
1st qtr																					
April																					
May																					
June																					
2nd qtr																					
Jul.																					
Aug.																					
Sept.																					
3rd qtr																					
Oct.																					
Nov.																					
Dec.																					
4th qtr																					
Year Total																					

*kJ = kWh x 3600

Table A.16 Generated/Marketed Energy Records

Year_____

Operating unit______

Energy generated by name of cost center Type of energy steam

*Fuel used in generation coal **Energy used by name of cost center

Month (1)	Input tonne of Coal (2)	Input kJ (3)	Cost of Input Fuel ₱ (4)	Other Costs of Generation *** (5)	Generated kWh (6)	Output kJ (7)	Total Cost in ₱ (8)
Jan.							
Feb.							
Mar.							
1st Qtr.							
Apr.							
May							
June							
2nd Qtr.							
Jul.							
Aug.							
Sept.							
3rd Qtr.							
Oct.							
Nov.							
Dec.							
4th Qtr.							
Total							

(Use standard conversion factors for kJ/unit of fuel.)

* If more than one type of fuel is used for generation of electricity, prepare three more columns similar to Columns 2, 3, and 4 for another fuel.

** If energy is supplied to more than one cost center, a separate form should be prepared for each cost center.

*** The utility department's non-energy costs which must be allocated to various cost centers are listed here.

Table A.17 Recycled Energy Records

Operating unit ______________________ Year __________

Energy supplied by name of department

Type of fuel replaced or saved natural gas

Type of energy steam condensate

Energy used by name of cost center

Month (1)	(recycled) Volume in____ Units (2)	Total kJ Received (3)	Cost of* Recycling (4)	Fuel Used in Generation ____Units (5)	Total kJ Used (6)	Cost of Fuel (7)	Total Cost (4) – (7) (8)	Fuel Saved by Recycling ____Units (9)	Total kJ Saved (10)	₱ Saved (11)
Jan.										
Feb.										
Mar.										
1st Qtr.										
Apr.										
May										
June										
2nd Qtr.										
Jul.										
Aug.										
Sept.										
3rd Qtr.										
Oct.										
Nov.										
Dec.										
4th Qtr.										
Total										

* If a cost center is recycling its own energy, only this column will go in the summary records.

Table A.18 Energy Records – Summary

Operating unit _____ Cost center _____ Year _____

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Month	Total Purchased		Total Generated/ Marketed		Total Recycled		Total Energy	
	kJ	₱	kJ	₱	kJ	₱	kJ	₱
Jan.								
Feb.								
Mar.								
1st Qtr.								
Apr.								
May								
June								
2nd Qtr.								
Jul.								
Aug.								
Sept.								
3rd Qtr.								
Oct.								
Nov.								
Dec.								
4th Qtr.								
Total								

Table A.19 Detailed Energy Audit–Electrical

Operating Unit ____________

Prepared by ____________

Date of audit ____________

Cost center ________ Month ______ Year ______

Item	Rated W (1)	W Used (2)	hrs Used (3)	kWh (4)	kJ (5)
A. *All usage except motors*					
Office lighting					
Outside lighting					
Tank heaters					
Ovens					
Other					
B. *Motors*					
Ventilating fans					
Air conditioners					
Hand tools					
Motor No. 1					
Compressor No. 1					
Other					
			Total		

Note 1: W = V x A. For fluorescent tubes, add 20% for ballast (multiply rating by 1.20). For 3-phase motors, W = V x A x 1.732.

Note 2: Rated W times the fraction of FL usually about 70%. If the operating current has been measured, use V times the measured current (times 1.732 if it is 3-phase motor).

Note 3: Estimated number of hours used during each month.

Note 4: For all items in A multiply (1) and (3) and divide by 1,000. For all items in B, multiply (2) and (3) and divide by 1,000.

Note 5: Use 3600 kJ per kWh for accounting purposes.

Table A. 20 Raw Material Energy Records

Cost Center

Month	Raw Material "A"			Raw Material "B"			Raw Material "C"			Total Raw Material kJ	Total Conversion kJ	Total Conversion & Raw Material kJ
	kg	kJ/kg	kJ	kg	kJ/kg	kJ	kg	kJ/kg	kJ			
Jan.												
Feb.												
Mar.												
Qtr. 1												
Apr.												
May												
June												
Qtr. 2												
July												
Aug.												
Sept.												
Qtr. 3												
Oct.												
Nov.												
Dec.												
Qtr. 4												
Total												

From Column 8 energy records Summary (Table A.18)

Table A. 21 Production and General Records

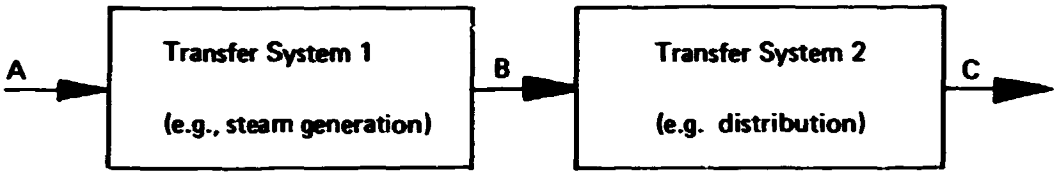
Operating Unit ____________________ Year ____________

Product line ____________________ Cost center ____________

Space ___ Sq.m.

Exposure ____________________

Month (1)	Units Produced (2)	Actual Direct Labor hrs. Used (3)	Normal Production Capacity (4)	Normal Direct Labor hrs. (5)	Cooling Degree Days (6)	Energy Used for Pollution Control (7)
Jan.						
Feb.						
Mar.						
1st Qtr.						
Apr.						
May						
June						
2nd Qtr.						
Jul.						
Aug.						
Sept.						
3rd Qtr.						
Oct.						
Nov.						
Dec.						
4th Qtr.						
Total						



A = point of entry (purchased energy)
B = midpoint.
C = point of use (useful energy).

Figure A. 12 Plant Energy Schematic

Table A. 22 Calculating Unit Cost of Energy*

	Fuel No. 2	Oil No. 6	Coal	Other
1. Total Cost (from purchased energy records)				
2. Total kJ (from purchased energy records)				
3. ₽/kJ (at point of entry) $\frac{(1)}{(2)}$				
4. Energy efficiency of Transfer System 1				
5. Variable operating costs of Transfer System 1 in ₽/kJ output				
6 ₽/kJ at point of exit to Transfer System 1 $\frac{(3)}{(4)} + (5)$				
7. Energy efficiency of Transfer System 2				
8. Variable operating costs of Trasnfer System 2 in ₽ /kJ output				
9. ₽ /kJ at point of use (6) + (8) (7)				

Refer to Figure A.12

Table A. 23 Monitoring Economic Performance and Setting Economic Objectives

Operating unit ____________ Cost center ____________ Month ____________

Product, equipment, process ____________ Year ____________

	Actual		*Standards or benchmarks (if available) or industry norms Column 3	Variance from Standards Column 4	Revised target standards after implementation	
	Last mo Column 1	Last 12 mo average Column 2			Phase I Econ. measures Column 5	Phase II Econ. measures Column 6
1. Total input energy in kJ						
2. Total useful output in kJ or in units of product or labor hrs.						
3. Energy Efficiency or standard						
4. ₱/kJ of input energy						
5. Total ₱						

* All figures in the table are per month.

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