THE FINAL REPORT
OF
THE STUDY
ON
THE RATIONAL USE OF ENERGY
IN
INDUSTRY
IN
THE ARGENTINE REPUBLIC
(II)

REFERENCE FOR FORMULATING TECHNICAL GUIDELINE

OCTOBER, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the Argentine Republic, the Japanese Government decided to conduct a study on the Rational Use of Energy in Industry, and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Argentina a study team headed by Mr. Takashi Niikura of the Energy Conservation Center on two occasions; from December 8 to December 23, 1987 and from February 22 to March 31, 1988, and then headed by Mr. Mitsuo Iguchi of the Energy Conservation Center on one occasion, from September 26 to December 3, 1988.

The team held discussions with concerned officials of the Government of the Argentine Republic, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the rational use of energy in industry and to the promotion of friendly relations between our two countries.

I wish to express my sincerest appreciation to the officials concerned of the Government of the Argentine Republic for their close cooperation extended to the team.

October, 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Contents

– Reference for Formulating Technical Guideline –

1. Character of Guideline

1. Character of Guideline

Of the technical items that would be useful to INTI in preparing a guideline for the promotion of energy conservation in food factories, those which are considered particularly important are summarized below.

(1) Materials usable

1) As a manual for diagnostic guidance

2) As data to determine the extent of progress of rational use of energy

3) As texts for seminars

(2) The materials provided should be sufficiently understandable by engineers 4 to 5 years after their graduation from college or university, even though they may not be engaged in the industry concerned.

(3) The materials provided are limited to a scope covering the processes of the factories surveyed by us so that they would not differ from the present industrial state of the Argentine Republic. Basic items and numeric values, procedures for energy conservation, and instances useful for reference are included in the scope.

It is expected that INTI will prepare a guideline referring to this report and also the information INTI acquired by its own survey of the factories.

2. Diagnostic Procedure

2. General Diagnostic Procedures

(1) Factory Diagnostic Procedure

The general factory diagnostic procedure is shown in the chart below.

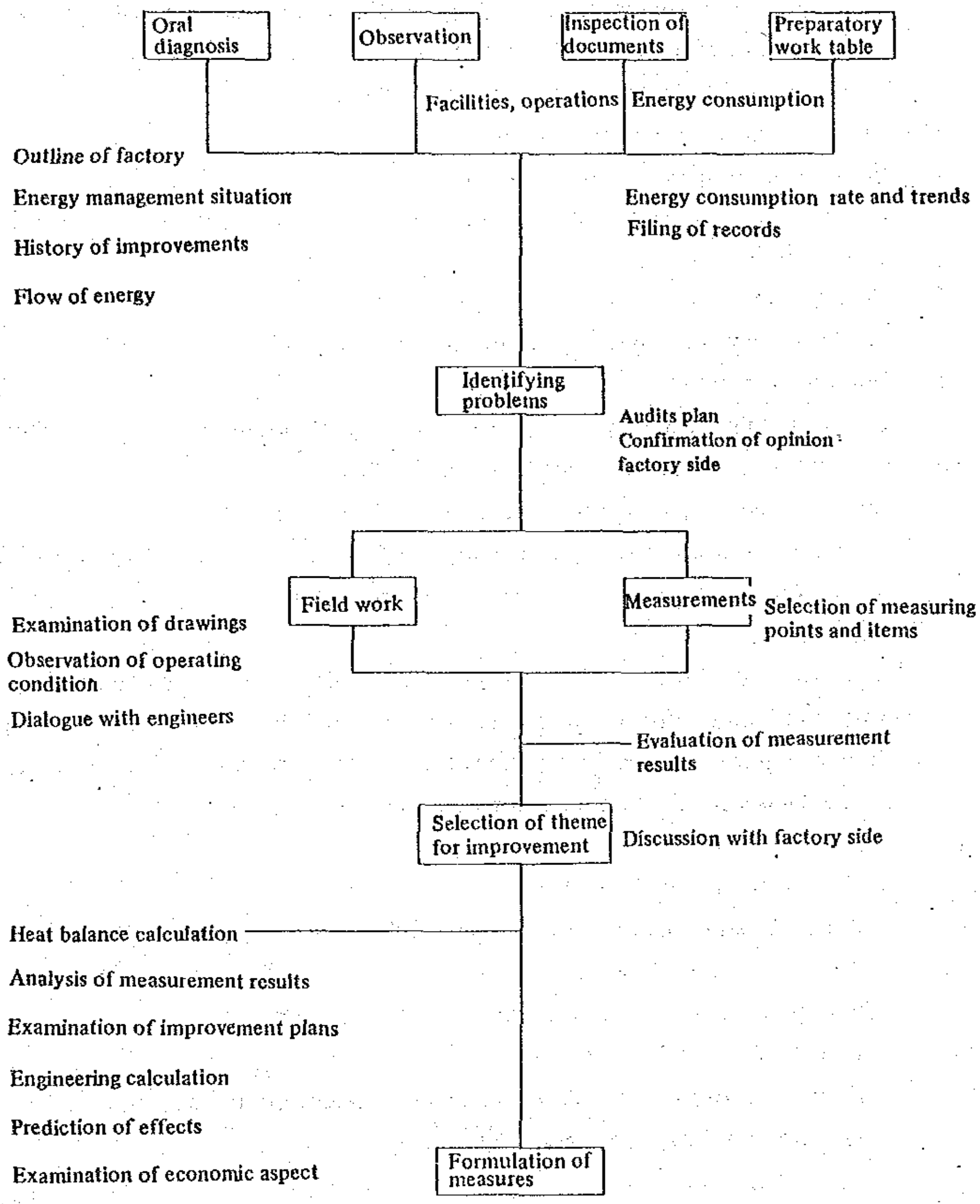


Figure 2–1

1 Acquiring General Information on Factory

The understanding of and enthusiasm about energy conservation on the part of the manager, the steps taken so far for energy conservation, and the problems pointed out by the factory will be determined.

1. Factory outline (name of factory, type of business, capital, sales, number of employees, brief history, market share, and position in the industry)
2. Production of main products in the past 4 years
3. Energy consumption in the past 4 years
4. Production processes of main products
5. Types, capacities, and operating conditions of main energy consuming facilities such as boiler
6. Energy flowchart
7. Electrical one-line diagrams; condition of power receiving facilities
8. Equipment layout
9. Problems pointed out by the factory management and desired to be checked
10. Energy conservation measures taken in the past
11. Energy conservation measures planned for the future
12. Business condition of the industry and the factory, and factors negatively affecting the promotion of energy conservation measures

2 Preparing Diagnostic Plan

(a) The factory will be generally inspected while listening to explanations by the factory staff, and information on the following will be obtained by checking the preliminary questionnaire, energy consumption data, and production records.

Problems with the factory equipment and operations
Important diagnostic points
Technical level of the factory
Age and maintenance of the factory equipment
Stability of operating rate
Energy consumption unit and its change with time

(b) A diagnostic plan will be determined.

Equipment or processes requiring primary attention in diagnosis
Measuring points, items, and time
Work assignments

(c) The diagnostic plan will be shown to the factory staff to obtain their understanding of it, and ask for their cooperation in implementing the plan.

Adjustment of the production plan
Making holes for insertion of probes of measuring instruments or taking samples
Preparations for power supply

3 Measuring and Surveying According to Diagnostic Plan as Follows

Selection and arrangement of measuring instruments
Entry of data into measuring instruments to set conditions

Checking whether proper data is obtained

Approximate analysis of the measurement results using a portable computer for analysis

Checking the detailed structure and dimensions of the equipment referring to equipment drawings or by actual measurement

Identifying problems by observation of operation

Hearing from engineers

Checking data (energy prices, fund cost, etc.) required for evaluating the economic effects of the improvement measures

4 When all the measurement results are ready, improvement items to be proposed after analysis of the results to be made later will be worked out, and explained to the factory staff. Then, improvement items to be proposed through a report will be determined.

5 Studying Improvement Proposal

On the basis of the data entered in the check list, measurement recording sheets, floppy disk recordings, and drawings, analysis of heat and electricity consumption will be made, involving heat balance calculation, heat transfer calculation, and fluid conveyance power calculation; energy conservation measures with modifications or addition of equipment will be studied; and a proposal best suited to the existing conditions of the factory involved will be prepared.

At the same time, an appropriate cost necessary for the proposed improvements and the expected results will be calculated. On the basis thereof, economic evaluation of each improvement proposed will be made using a common index and procedure, and the practicability and priority of the proposed measures will be specified.

The influence, produced incidental to the implementation of the improvement measures will also be studied, and the points to be borne in mind in their implementation will be presented.

(2) Check Points of Diagnosis

In Japan, the Ministry of International Trade and Industry sets forth the items to be observed by factory operators as criteria in achieving the rational use of energy within technically and economically possible limits.

The Ministry classifies the energy conservation techniques into the 7 following categories, which are not compulsory but serve as guidelines.

- Rationalizing fuel combustion
- Rationalizing heating, cooling, and heat transfer
- Preventing heat loss by radiation, heat conduction, etc.
- Recovery of waste heat for reuse
- Rationalization by energy conversion from heat to motive power, etc.
- Preventing electricity loss by resistance, etc.
- Rationalization by energy conversion from electricity to motive power, heat, etc.

These guidelines will be of help in making energy conservation diagnosis, so the Japanese criteria, quantitative indices and examples of improvement measures taken for rational use of energy are shown for reference as below.

1 Rationalization of Fuel Combustion

Optimizing Air Ratio

Standard air ratio

Table 2–1 Boiler (Load factor: 75 to 100%)

Amount of evaporation	Solid fuel	Liquid fuel	Gaseous fuel
Large boiler for electric company	1.2 – 1.3	1.05 – 1.1	1.05 – 1.1
30 tons/h or more	1.2 – 1.3	1.1 – 1.2	1.1 – 1.2
10 to 30 tons/h	–	1.2 – 1.3	1.2 – 1.3
< 10 tons/h	–	1.3	1.3

Table 2–2

Industrial Furnaces (Using liquid and gaseous fuels; 200,000 kcal/hour or more)

Continuous billet heating furnace	1.25
Metal melting furnace for casting, metal heating furnace, continuous heat treatment furnace, thermal decomposition furnace, reforming furnace, cement kiln, continuous glass furnace	1.3
Gas generating furnace, crude oil heating furnace, alumina kiln, lime kiln	1.4

Burner selection — Type, Size, Turn down ratio
Maintenance, Cleaning Tip

Better atomization — Fuel temperature, Viscosity
Proportion of atomizing air or Steam to fuel
Fuel pressure
Dispersion reagent
Emulsified fuel

Prevention of air intrusion — Furnace pressure control
Reduction of opening, Double door, Sealing
Shortening door opening time

Advanced automatic control	Fuel air ratio control by oxygen content in exhaust gas
	Fuel air ratio control by carbon oxide content in exhaust gas
	Fuel air ratio cascade control
	Fuel air ratio cross limit control
Load levelling	Optimum load sharing
	Operation unit number control
	Steam accumulator
Flame temperature raise	Combustion with enriched oxygen
	Gas atomized fuel oil comustion
Lower combustion temperature	Fluid bed combustion
	Catalystic combustion

2 Rationalization of Heating Cooling and Heat Transfer

Heating in Furnace

Optimum extracting temperature	Setting work standard
Search for best heat pattern	Temperature distribution, Heating velocity
	Improvement flow of gas in furnace
Optimum load	Optimum load on furnace bed
	Load sharing to multiple facilities
	Load levelling
Material charging improvement	
Improvement of furnace shape	
Decrease heat content of furnace body and conveyor	Lighten the weight
Increase of flame emissivity	Modification to direct firing
	Submerged combustion
	Electric resistance heating
	Far infrared beam heating
	Microwave heating
	Induction heating

Heating by Steam

- Adjusting steam pressure to proper level
- Perfect air purge
- Improvement of direct steaming

Heat Transfer

Decrease of heat transfer resistance	Prevention of scaling, Sludge deposit, Frost
	Boiler Feed water quality control

	Reagent injection
	Optimum blow off of boiler water
	Tearing off condensate film, Defrosting
	Cleaning of heat transfer surface, Soot blowing, Filter cleaning
Improvement of heat transfer coefficient	High-speed gas flow, Jet heating, High-speed burner
	Fluid bed heat transfer
	Mist cooling
Heat exchange system	Addition of heat exchanger
	Minimization of exergy loss
Advanced heat exchanger	High heat conductivity material
	Shape of heat transfer tube
	Heat exchanger tube arrangement
	Enlarging heating surface, Fin plate
	Buffer plate, Turbulence accelerator
Operation	
Start/stop time optimizing	Use of remained pressure of boiler
Decrease of load	Air conditioning (Temperature, Rate of air circulation)
	Utilization of holding heat of material from previous process
	Shortening of waiting time between processes
	Shortening of furnace idling time
	Lot concentration
	Distillation (Optimum reflux ratio, selection of feed or extraction tray)
Process	
Controlling method improvement	Decrease of margin
Automation	
Heat utilization as cascade	Multiple effect evaporator, Vapor recompression
	Increasing distillation tray
	Plant integration
	Inter-factory energy pooling
Separation process	Mechanical separator instead of heating process
	Separation through membrane
	Adsorption
	Extraction, Super critical separation

Improvement of layout	Shortening of transport distance Prevention of complicated transport Decrease of idling time through shortening of transport path
Mildening of operation condition of reactor	Improvement of catalyser Improvement of reagent Bio reactor
Change of product specification	Avoidance of overmuch quality Material not requiring heat treatment in next process
Change of raw material	Recycle
Scale up	Shortening operating time by increasing electric power
Modification of continuous process	
Modification to high speed process	
Simplified process	Hot charge
Use of high-efficiency devices	

3 Prevention of Heat Loss caused by Radiation, Conduction etc.

Table 2–3 Standard Furnace Outer Surface Temperature (Ambient temperature 20° C; except rotary furnaces)

Internal temperature	Outer ceiling surface	Outer wall surface
1,300	140	120
1,100	125	110
900	110	95
700	90	80

Prevention of leakage	Inspection and Repair Selection and Maintenance of steam trap Reinforcing seals of rotary parts and joints
Narrowing heat radiating surface area	Improvement of steam piping route Removing unnecessary pipe Shutting main valve of unused pipe, or Inserting blind plate
Insulation	Enforcement of insulation at flange and valve Use of heat insulating material of low heat conductivity Lowering emissivity of insulator cover Setting cover, lid

	Maintenance of insulator
	Use of lightweight heat insulation material for batch furnace (bulk specific gravity 1.3)
Preventing loss of internal gas flow and radiation	Reducing size of openings, closing openings, or mounting doors on openings
	Shortening door open time
Optimum boiler water blow	

4 Recovery & Utilization of Waste Energy

Standard Waste Gas Temperature

Table 2–4 Boiler (Load ratio 100%; ambient temperature 20° C) (Unit: °C)

Amount of evaporation	Solid fuel	Liquid fuel	Gaseous fuel
Large boiler for electric companies	145	145	110
30 tons/h or more	200	200	170
10 – 30 tons/h	–	200	170
< 10 tons/h	–	320	300

Table 2–5 Industrial Furnaces (Liquid fuel; air ratio 1.2; ambient temperature 20° C)

(Unit: °C)

Furnace outlet exhaust gas temperature	Exhaust gas temperature after waste heat recovery (°C); waste heat recovery ratio (%)		
	20 million kcal/h or more	5 to 20 million kcal/h	1 to 5 million kcal/h
500 (°C)	200 (20	200 (20)	
600	290 (20)	290 (20)	
700	300 (30)	330 (25)	370 (20)
800	370 (30)	410 (25)	450 (20)
900	400 (35)	490 (25)	530 (20)
1,000	420 (40)	520 (30)	570 (25)
> 1,000	(40)	(30)	(25)

Waste Energy	Exhaust gas, air Waste water, Waste liquor Condensate Hot solid (hot cokes) Mechanical energy (water head) Unused pressure (top pressure recovery turbine, fluid coker) Byproduct combustible gas Coldness of liquified natural gas Natural energy (solar energy, out door air temperature)
Use	Heating material Heating air for combustion or process Preheating boiler feed water Preheating fuel (oil, gas) Steam generation Power generation, Electricity generation Air conditioning Distric heating Refrigeration Fish breeding Warming green house Snow melting
Measures	Heat exchanger, Heat pipe Fluid bed (suspension preheater) Heat pump Heat transport reagent Waste heat boiler, Vacuum evaporation type water heater Turbine (steam, organic reagent) Total enthalpy heat exchnager

5 Rationalization of Conversion from Heat to Power

Elevation of exergy efficiency	Steam condition upgrade Combined system Cogeneration Recovery of drive power at low steam pressure
Operation improvement in power plant	Improvement of turbine, Nozzle shape Vacuum maintenance of condenser (cleaning, water temperature) Optimization of power plant use

	Variable pressure operation according to load
	Auxiliary equipment load control, Revolution
	Optimizing back and extraction pressure
	Peak shift (Use of electricity during midnight hours and holidays, heat storage as ice)
Direct electricity	Generation
	Fuel cell
	Magneto hydro dynamics
Improvement of engine efficiency	
Rational operation of steam ejector	Optimization of number of stages,
	Steam pressure
	Substitution to vacuum pump

6 Prevention of Electricity Loss by Resistance

Power Transportation	
Higher voltage	
Lower temperature	
Direct current	
Wiring	
Minimization of length	Arrangement of receiving facility and load
	Improvement of wiring route
Improvement of wiring way	
Optimization of wire size	
Balancing loads between 3-phase	
Transformer	
Optimum capacity	
Load allotment, Adjusting the number of operating units	
Connection way	
Cutting off in unused time	
Facilities	Minimization of resistance at contact point
Improvement of power factor	Installing condenser (Capacitor)
	Power factor control by synchronous generator
	Avoidance low load running of motor
Operation	
Suppression of peak demand	Load levelling
	Demand controll
Circuit voltage optimizing	

Use of low-loss devices
Superconductive

7 Rationalization of Conversion from Electricity to Power, Heat etc.

Motor	Advanced type Optimum capacity
Power transmission	Improvement of transmission Transmission belt (Material, relaxation degree) Lubrication control
Operation Preventing idling, Intermittent running	Keeping rated voltage
Fluid transportation Reduction of load	Decrease of flow (Preventing leakage) Reducing pipe resistance (Rationalizing pipe route, cleaning pipes) Lowering suction temperature Selection of transport measures High-efficiency devices, Impellers, Movable blades
Optimizing equipment capacity	Shape of impeller
Control	Revolution speed control (VVVF, clutch, pole change) Unit number control
Energy recovery	Regenerative braking
Electric heating Reduction of load	Hot charge Furnace charging method, Optimum power input pattern Reducing contact resistance
High-efficiency devices	Modification of frequency convertor Direct heating (Direct electric resistance heating, induction heating, dielectric heating, microwave heating, plasma heating)
Comparative study between electric and combustion heating methods	
Air conditioning	Reduction of load Shape, Structure, Direction, Surroundings of building

	Induction of outdoor air, Total enthalpy heat exchange Prevention of outdoor air invasion (automatic door, curtain) Optimum rate of air circulation Insulation Isolation of heat generating body, Lighting facilities Localized air conditioning Zoning (Setting different condition by zone) Far infrared ray heating
Ventilation	Filter cleaning Lowering flow resistance in duct Fan rpm control Optimum size of humidifier nozzle
Control	Return water temperature control
Operation	Water quality control in cooling tower line Cleaning of heat exchanger
Lighting	
Optimum illuminance	
Better interior finishment of room	Wall color
Improving lighting fixture arrangements	
Utilization of daylight	
Enforcement of turn-off unnecessary lamps	
Illumination control	
Cleaning fixtures	
Replacing bulbs at proper intervals	
High efficiency facilities	Lamp, stabilizer
Electrolysis	
Reduction of resistance at contact point	
Voltage lowering	Lowering overvoltage, Improvement of electrode
Adjusting hot bath temperature and concentration, inter-electrode distance	
Others	Electric precipitator intermittent charge

3. Energy Management

3. Energy Management

In reducing energy consumption as well as in raising teh efficiency and level of production and quality, it is necessary, first of all, to use an equipment appropriate to the purpose and well maintained and to properly operate it. It would be most effective for energy conservation to reduce equipment failures and raise product yeild. Secondly, consider the possibility of improving the present equipment and operating procedures, repeat surveys and operation tests, and thus seek a better way.

It is no exaggeration to say, therefore, that the awareness and willingness of all the factory employees can vitally affect the performance of the factory. Improving factory management to lead the employees in that direction is extremely significant. Energy management can be defined as an organization effort to achieve energy conservation.

(1) Defining Management Policy

Facoty owners and executive have come to have growing interest in energy conservation because of growin awareness of the energy situation and the need for improving the profitability of factory operation. If the factory owner wants to take a step forward from mere by having wishes and start a company-wide activity, he must show his policy and his definite attitude to implement it to all the employees. Specifically, he must set a quantitative target, specifying the percentage of reducing energy consumption per ton of product and the date of achieving the target; an upper limit of annual investment; and a period in which the investment is to be recovered.

When the management defines the direction to proceed, the employees will be able to have confidence in doing work the way the management wants it to be done. Because all the employees will have the same thing in mind, they will be able to cooperate with one another more smoothly than before.

After the management presents a comprehensive factory operation policy, the individual departments set more concrete, specified targets which can be achieved in not so long a time within the scope of their own responsibilities to meet the management policy. Such targets will be shown in a more familiar, understandable form so that the department managers can expect full understanding of the targets and cooperation on the all of the employees.

In formulating such concrete targets by each departments, a committee, such as the one mentioned later, must examine their fitness with the company target set forth in the management policy.

(2) Organizing for Promotion of Energy Conservation

In a movement that involves many persons at different levels, such as a movement for energy conservation, some one must be assigned to lead it. In the case of a small factory, a person may be assigned to lead a movement. In the case of a large factory, an organization may be formed for that purpose.

Such an organization takes the responsibility of keeping attention to the progress of energy conservation and, if a delay is found, checks for its cause and takes steps to achieve the end.

Specifically, it collects data on energy consumption, compares the acquired data with the plan, seeks ideas for improvement, checks them, distributes the budgets, manages the progress of work, formulates education plans, makes preparations for appointing a committee, and undertakes other duties.

A committee is effective for coordinating the different departments – production, sales, material purchase, equipment maintenance, accounting, etc. – to ensure smooth communication among them and satisfactory implementation of the plan. It must examine the effects of the energy conservation measures to be undertaken on the individual departments, and thus confirm that they will not adversely affect the overall earnings of the factory.

The head of a committee must be the factory manager who has responsibilities and authority regarding production, or some one next to him. Otherwise, nothing can be decided or executed.

An energy conservation measure developed from an excellent idea cannot produce a good result if the workers do not adequately understand its meaning or utilize it on their jobs. There are many successful instances of using a QC (quality control) circle for energy conservation. A QC circle improves the human relations on the job, makes use of the willingness inherent in the human beings, and thus lets the workers find their jobs enjoyable. It would be necessary to provide good conditions to facilitate work such as education, incentives until the employees become aware that a QC circle is something good and necessary for themselves. The operator are always face to face with the energy consuming equipment and know best the phenomena arising from changes in the operating conditions. It would be very effective for energy conservation to make use of the information they have and the idea they might be able to offer.

(3) Scientific and Organizational Activities

Accurate information on energy consumption is essential to implementing an energy conservation plan. Without data on consumption rates which may vary with production, equipment, type of product, or kind of material, a plan for concrete measures cannot be drawn up. In other words, it can be said without exaggeration that factory data has countless suggestions for improvement. If you check the data with an awareness of the problems, you'll be able to find such suggestions in the data. Thus, install meters when necessary, record their readings, and periodically process them to find the needed information. Remember that it is important to process the data by mathematical statistics and determine whether differences are significant.

When an improvement plan is implemented, the results must be followed up. Efforts must be made to raise the quality of work according to the PDCA circle advocated by Dr. Deming. The PDCA circle determines the purpose of a theme as shown in Figure 3–1, draws up a plan to attain it, trains the workers on the way of implementing the plan, checks the results of the plan executed, evaluates the results, formulates a standard out of the results if found satisfactory, and takes remedial actions if the results are not satisfactory. When one step is completed, the PDCA circle takes another step to achieve a higher target. This method is useful for not only energy conservation but also raising work quality in any field.

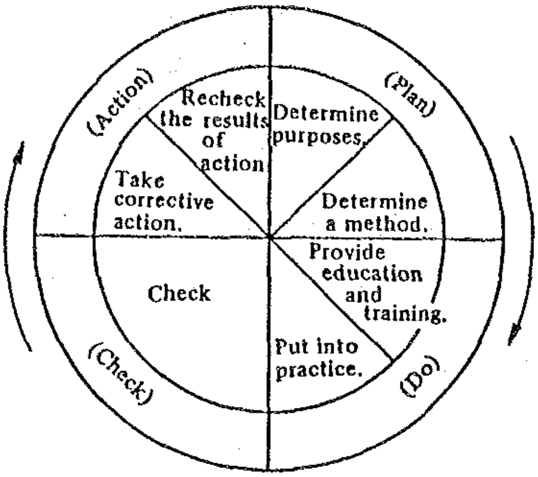


Figure 3–1 Deming Circle

In the first stage of preparing a plan, there may be many points attracting worker attention. Therefore, an improvement proposal system should be made effective use of. Individuals, workshops, QC circles, or staff members should be allowed to present proposals. Once a proposal is offered, don't ignore it, but examine it at a committee, etc. in a short time. Adopt it as much as possible depending on the case, ask the proposer to modify the proposal, and give a reward for it. If the adopted proposal is found effective, commend the proposer so that the other workers will be aware of the importance of taking part in the efforts for energy conservation. If a proposal is found not acceptable, give the reason for it and advice to the proposer.

In the stage of doing or impleting a plan, explain the purpose of the planned improvement to all the workers and ask them to cooperate in implementing the plan. Let them report anything amiss concerning the work, no matter how minor it may seem, so that it can be carefully dealt with. Otherwise, the plan may end up in a failure.

Conduct a check periodically, report the check results to the committee and factory manager. Also let the workers know them so that they will be more interested in them. It is important to define evaluation criteria first of all. It is undersirable to carelessly change them in the course of implementing the plan.

If good results can be expected by implementing an improvement plan, establish a operation standard to lay down rules to be observed by the workers, and teke the necessary measures for the equipment so that the operators will not have to bear excess burdens. Such actions are necessary for ensuring lasting effects.

If significant results are consecutively produced by implementing a plan, announce the improving process of it, use it as a reference in other cases, commend the persons involved, and thus encourage others to follow suit.

(4) Providing Education and Information

Employees willing to cooperate cannot make improvements unless they know how.

They will be more willing to take part in improvement plans if you not only point out problems but also let them propose their ideas for improvement. Institutional education is important for this purpose. Seminars may be held, or guidebooks may be distributed to this end. In the Argentine Republic, there are companies which are enthusiastic about education and send their staff for training outside.

In many cases, however, the knowledge acquired by it is limited only to the staff members that have received the training. It is not shared by the other staff members and workers. If ones who have received external training act as lecturers for training within the company and transfers their knowledge to the others, they will be able to improve the overall level of the company and at the same time confirm their own knowledge.

It is also desirable to actively exchange information with others in the same trade, material suppliers, and customers who buy the products. Competition among companies is something necessary, but exchanging technical information within a certain scope on a give-and-take basis will be conductive to raising the level of the trade as a whole, strengthening international competitiveness, and enhancing the mutual profit as a result. Announcing data on consumption rates, for example, will help stimulate a motive for competition. The joint research arrangements centered around INTI, which are undertaken in part of the Argentine Republic, area very good system and should be extended to cover other companies.

4. Food

4. Food

4.1 Characteristics of Use of Energy in the Food Industry

There are many kinds of food which are processed in many ways using energy in different ways. However, the characteristics common to food processing can be summarized as follows:

(a) Heating and cooling are repeated in many cases.

(b) Very high temperature is not needed because organic materials are processed. Steam is generally used as a heat source to avoid partial overheating.

(c) Quality must be maintained above all else in view of sanitation. Thus, care must be exercised when using exhaust heat.

The generation and use of steam is dealt with in a separate section because it also concerns other industries. Here, items useful for preparing guidelines, mainly regarding the processes of the juice concentration factory and cannery, are discussed.

4.2 Fruit Juice Concentration Industry

4.2.1 *General Situation*

The Argentine Republic produces many kinds of fruit, of which grapes and apples in particular are produced in large quantities.

The area along the Rio Negro from Alto Valle to Valle Inferiorextending100 km east to west and 12 km south to north is a large apple producing zone with an annual production of 900,000 to 1,000,000 tons. About 50 percent of the production is exported, and about 20 percent is consumed at home. The remainder is processed.

Juice is produced from fruit that does not meet the shape and size requirements, and therefore varies in production from year to year depending on crops. Apple production was especially large in 1987, in which 700,000 tons of apples were processed into juice. In 1988, however, about 350,000 tons of apples are likely to be processed into juice. Concentrated fruit juices are mainly exported to North America for business use.

About a gallon of juice is produced from 40 kg of apples, and much thermal energy is needed to evaporate a lafge amount of water from juice.

4.2.2 Production Process

The production process is shown in Figure 4–2 Material fruit is crushed and pressed into juice, from which perfume is extracted. (In cases, the juice is concentrated without extracting perfume from it.) Then, the juice is heated to sterilize. (In cases, the juice may be preconcentrated.) The juice then goes through the enzyme treatment process, centrifugal separation process, and filtering process to remove the pectins, starch, and other suspended matter that will coagulate when heated. After separating the solids from the liquid, the juice is concentrated in multi effect evaporators to a Brix level at which quality is stable.

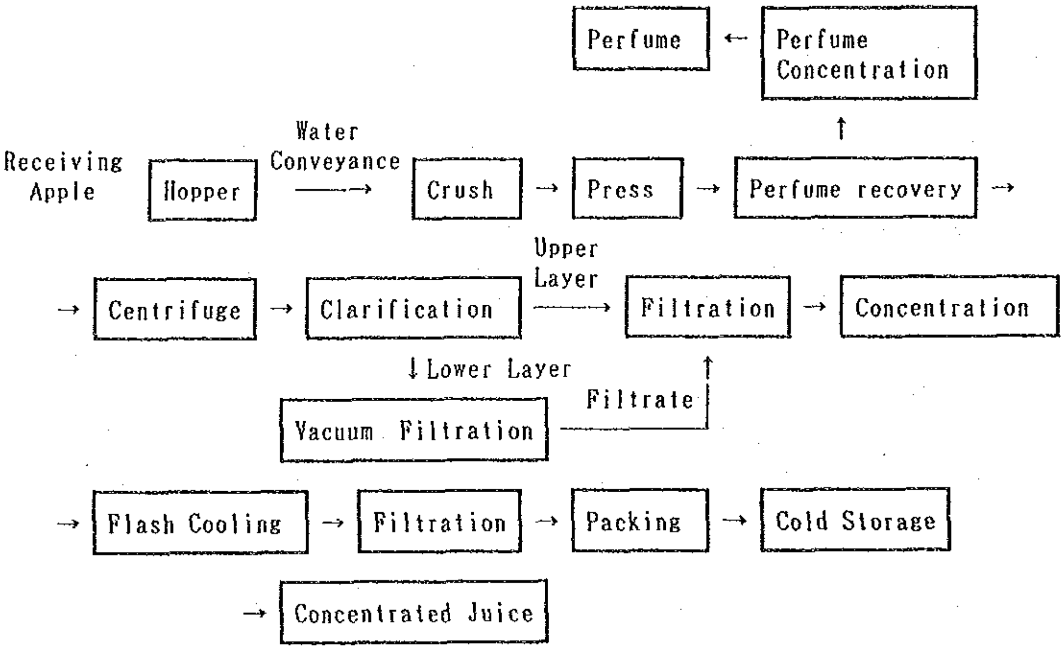
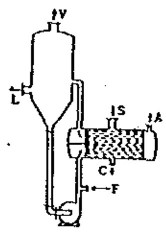


Figure 4–1 Production Process

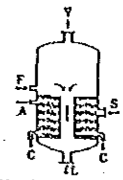
Band press and screw press are used to press the material fruit. Solids are separated from the liquid by a combination of a settling tank, various types of centrifugal separators (decanter type, cylinder type, disk type), and filters (filter press, leaf filter, vacuum filter, ultra filter). Some juice factories use reverse osmosis separators (RO) and freeze separators to concentrate the juice, but multi-effect evaporators are generally used for that purpose.

The liquid heater may be of a type which uses a shell and tube type heat exchanger or a plate type heat exchanger installed outside the evaporators (Figure 4–2), or a type which has a calandria built into the evaporators (Figure 4–3), or a type which concentrates the liquid by letting it run down the heating surface as a thin film. (Figure 4–4). The type shown in Figure 4–2 is easy to replace and clean the heating part, while the type shown in Figure 4–3 is the most used of all types. The liquid falls through the large tube in the center (called the downtake), and rises again through the small pipes to circulate while being heated. The type shown in Figure 4–4 is suited to concentrating a liquid highly viscous and sensitive to heat because the liquid is concentrated while it runs down the heating surface as a thin film. Vacuum units for evaporators include the barometric condenser or surface condenser, both for steam condensation, and the steam ejector or vacuum pump, which are used for discharging inert gas.



External heating forced circulation system

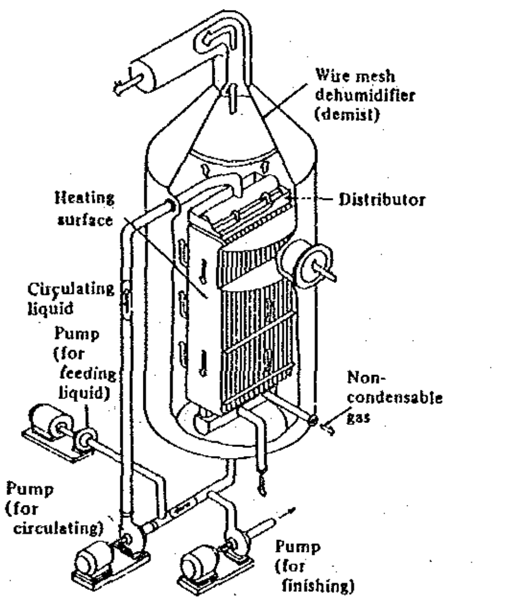
A : Non-condensable gas outlet (vent)
C : Condensate outlet (drain)
F : Dilute liquor inlet
L : Thick liquor
S : Inlet of steam for heating
V : Evaporated vapor outlet



Vertical short tube system
(inside tube: liquid)
(standard type)

Figure 4–2 External Heating System

Figure 4–3 Vertical Short Tube System



(f') Falling-film evaporator

Figure 4–4 Falling-Film Evaporator

4.2.3 Rational Use of Energy for Evaporators

(1) Use of latent heat of evaporating steam

It requires 100 kcal to heat 1 kg of aqueous solution whose specific heat is 1 kcal (kg·°C) to 100°C, while it takes 539 kcal to evaporate its water. Because latent heat of vaporization accounts for a large percentage, it is important to make effective use of the latent heat of vaporization of the generated vapor without directly condensing. Some methods are used for this purpose as shown in Figure 4–5.

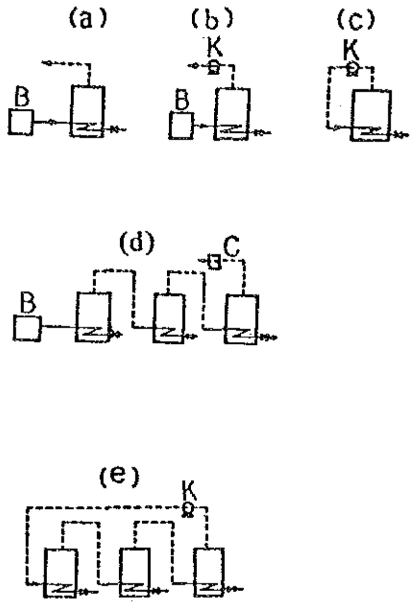


Figure 4–5 Classification of Evaporation Systems

(a) Vapor recovery mėthod

Generated vapor is directly used for other heating purpose. (a)

Vapor is compressed to raise the temperature and then is used for other purpose. (b)

(b) Vapor recompression method

Evaporating vapor is compressed to raise the temperature for its own heating purpose. (c)

A motor-driven blower or steam ejector is used to compress the vapor.

(c) Multi-effect evaporator (d)

If the second and subsequent evaporators in Figure 4-5 (d) are set to a lower internal pressure than the one upstream to lower the boiling point below the condensing temperature of the vapor generated in the evaporator immediately upstream, the vapor generated in the upstream evaporator can be used in the evaporator downstream.

If the number of evaporators is N, the amount of steam for heating will be theoretically 1/N in case only one evaporator is used. As N increases, thermal economy improves. Actually, however, equipment cost and operating expenses increases with N. Thus, there is an economically optimum N. If, for simplicity, steam expenses are assumed to be inversely proportionate to N and the fixed expenses to be directly proportionate to N, the optimum number of evaporators Nopt can be expressed by the following equation.

$$Nopt = \sqrt{P/K}$$

where P = Wy·Cs/Fe;

K = Mean steam economy (amount of water evaporated per kg of steam per evaporator: 0.85 to 0.9);

Wy = Annual amount of water evaporation (kg/year);

Cs = Steam unit cost ($/kg);

Fe = Fixed expense for evaporator ($/year).

(d) Heat pump method

Instead of the compressor used in the vapor recompression method, an absorbing type heat pump is used to raise the vapor temperature as the own heating source.

(e) Combination of the above

Combinating multi-effect evaporators with the vapor recompression method. (e)

The vapor generated in the final multi-effect evaporator or in the first multi-effect evaporator is partially compressed and added to the heated steam in the first evaporator.

In addition, there are other methods, including one which uses the heat possessed by generated vapor for preheating the original juice and another which passes the steam generated in the boiler through a turbine to generate drive power and use it as a heat source for vaporization. This drive power is used to generate electricity or drive the compressor.

In the following instance, the heat of generated vapor is recovered and used. In a sugar refinery, the heat of vapor about 60°C generated in the crystallizing evaporator is recovered by a heat exchanger installed between the vapor pipe of the crystallizing evaporator and barometric condenser to heat city water of about 18°C – 24°C to about 53°C, which is then added to the crystallizing evaporator or to clean the separation process. With a daily sugar treating capacity of 1,000 tons, this refinery uses about 1,430 tons of water daily, of which about 430 tons is added into the crystallizing evaporator daily. Hot water about 470 tons is obtained from heat recovery, which is more than enough to meet the above need. An investment in the equipment amounting to 18,000,000 yen can be recovered in 1.2 years, calculating the amount of heat recovered as hot water in terms of fuel oil. That is, as 1.5 percent of the annual consumption of fuel oil amounting to 500 kiloliters is saved, the annual saving amounts to 15,000,000 yen, calculated on the basis of the unit price of 30 yen per liter. This heat exchanger will have a function similar to a surface condenser, which also helps improve the performance of the vacuum unit.

(2) Evaporation load reduction

Most of the energy required for evaporation concentration is the latent heat that the evaporating solvent takes away with it. In concentrating fruit juice, for example, it is necessary to prevent entry of water into the material in and before the evaporation process and thus prevent increase of evaporation load.

Let's take, for example, the crystallizing evaporator in a sugar refinery. In the crystallization process, the mother liquor is evaporated while controlling its super saturation and adding sugar liquid. It is necessary for producing sugar of good crystals in that process not to generate false grains. If false grains occur, hot water must be injected to dissolve them. This requires extra evaporation energy. To dispense with the need for hot water injection, the process was analyzed by more than 10 steps of crystallization, and the best conditions were input to the memory of a microcomputer to be put to sequence control. This resulted in a fuel saving of 4.6 percent.

(3) Effect of scale

The heating tube walls become the hottest of all so that, if salt that produces scale in the solution exists, scale deposits on the heating surface, possibly increasing heat transfer resistance or causing blocking. Therefore, it is necessary to eliminate scale-producing substances beforehand and clean the heating tubes regularly.

(4) Air purging of steam heating chamber

If heating steam or solution contains air or other gas, the gas builds up in the heating chamber, blocking heat transfer and lowering heating temperature due to decreased steam partial pressure.

As a way of preventing it, an air vent valve is installed in the heating chamber, and is used to vent gas to an extent rather excessive at regular intervals. Theoretically, it is considered good to continue discharging the gas until its temperature reaches the temperature of the steam.

An air vent valve should be installed on the side diametrically opposite to the steam inlet in the direction of steam flow.

(5) Steam ejector condenser water

Steam ejectors are widely used for the purposes of maintaining the pressure inside evaporators and discharging air and other non-condensing gases. Drive steam is generally condensed by a barometric condenser, and the necessary amount of drive steam depends on the temperature of the cooling water used for that condenser. In other words, the lower the cooling water temperature, the smaller the amount of steam and the lower the steam pressure.

Suppose a steam pressure of 15 kg/cm^2 is necessary when the water temperature for the barometric condenser is 41°C, for example. If the water temperature falls to 35°C, a steam pressure of only 10.6 kg/cm^2 will be sufficient.

If saturated a water vapor pressures corresponding to barometric condenser water temperature are Pt_1 and Pt_2 and ejector drive steam pressure s P_1 and P_2,

$$\frac{P_1 + 1.033}{P_2 + 1.033} = \frac{Pt_1}{Pt_2}$$

(Units) Pt_1, Pt_2 : Torr

P_1, P_2 : kg/cm^2

(6) Steam ejector nozzle maintenance management

If the steam ejector nozzle grows larger (more than 10 percent of design value) in bore due to wear, pulsation occurs. It is necessary, therefore, to overhaul the barometric condensers and steam ejectors at least once every 2 years. If nozzle wear exceeds 5 percent of the steam ejector design value, the worn nozzle should be replaced with a new one. Nozzle degradation and air leakage can be detected early by measuring the time of reaching the required degree of vacuum at the start of the day's work and comparing it with the standard value.

(7) Comparison of steam ejector, water ejector, and wet type vacuum pump

If the final evaporator's evaporation temperature is about 45°C, the steam ejector can be changed to a water ejector. In this case, the required heat energy will decrease to 1/5.

A comparison of the wet type vacuum pump with the steam ejector shows a decrease of energy consumption to about 1/3. The relative economy of these devices depends on the price difference between fuel and electricity.

(8) Condensate recovery

The first evaporator uses the steam so that, if the heat exchanger is free of liquid leakage, the condensate can be recovered for use as boiler feed water. The second and third evaporators use the vapor generated upstream as a heat source, so juice carry-over may be considered. If each evaporator uses a plate heater, juice leakage from the packing is possible, and the condensate can be used only in case strict water quality requirements are absent.

(9) Heat insulation

In the case of multi-effect evaporators, steam is used as a heat source for the first effect evaporator, which should be heat-insulated because its operating temperature is high. Evaporation tempetature falls in the second, third, and subsequent evaporators in order, but heat insulation is advised if the surface temperature is about 70°C or more.

(10) Membrane separation

With the improvement of membrane performance in recent years, membrane separation has come to attract attention in point of energy conservation and quality. High-molecular impurity removal and clarification by means of an ultra filter (UF) and concentration by reverse osmosis (RO) are now used for juice production.

Clarification by UF offers advantages that there are no problems of quality deterioration by heating during enzyme treatment and disposal of filter material, and that the product juice can be stored for a long period of time because it has no undecomposed pectins.

Concentration by RO is limited to about Brix 25, though loss of vitamin C, amino acid, and fragrant components is small.

What is important is the separating performance that is suited to the type of material fruit to be processed and to the quality requirements. It is necessary to select a membrane that resists the heat or chemicals used for sterilizing in the part of the equipment that holds the juice, and to establish an effective cleaning method.

A report mentions an instance of concentrating apple juice to Brix 25 using a tubular module of acetic acid cellulose RO membrane. In this case, the equipment and piping are cleaned with water and 75°C caustic soda, while the module is cleaned with a chemical solution and hot water after cleaning the sponge ball.

4.3 Canning Industry (Tunas, Bonitos, Horse Mackerels, Cods, Sardines)

4.3.1 Summary

The republic of Argentina is blessed with rich fishing resourses, but fish consumption per capita is less than 1/10 that of meat. Demand for canned fish has not shown a significant recovery since it sharply fell in 1978.

Fish catches from the coastal water are limited to the summer season alone, and the country depends on imported fish for canning for the other half of the year. Canned fish export is in a difficult situation because of the high costs of the material and cans and high wages.

The fish canning industry consumes much thermal energy for cooking and sterilization. Boiler fuel is being changed from fuel oil to natural gas.

4.3.2 Production Process

The production process is shown in Figure 4–6.

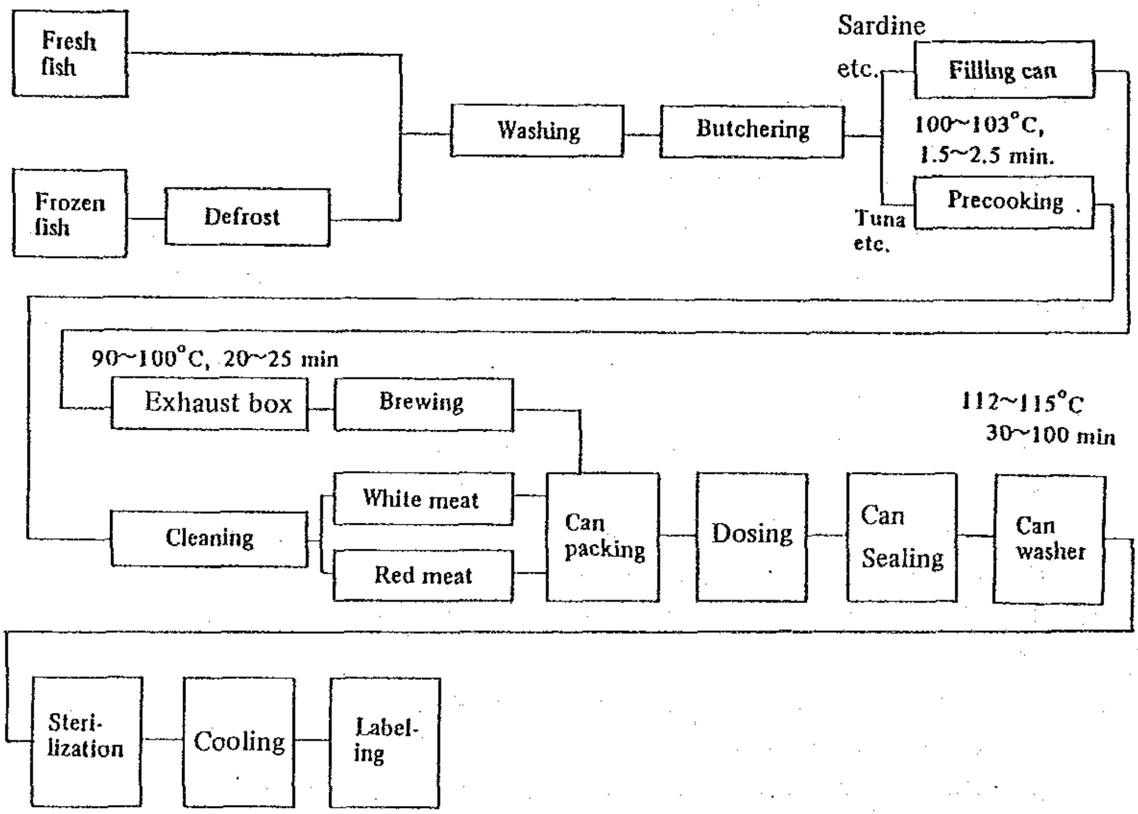


Figure 4–6

Material fish may be either fresh or frozen. If fresh fish is used, the first process is cleaning. If frozen fish is used, it must be defrosted first. Sardines and other small fishes are defrosted in a natural way, while large-sized fishes are defrosted by exposure to running water or immersion in water. In Japan, about 3.5 tons of water is used to defrost 1 ton of frozen fish.

Fish are washed by two methods: Washing by running water in a tank or by a shower.

After dessecting large fish, such as tunas and bonitos, they are placed in iron net cases, which are then carried by trucks into the cookers, where the fish are cooked by the steam directly injected into the cookers. Generally, cylindrical or square horizontal type or cylindrical vertical internal pressure vessels are used as cookers. Cooking temperature ranges from 100°C to 105°C and cooking time from 1.5 to 2.5 hours. Steam pressure is generally about 1 kg/cm^2. In some instances, cooking time is shortened by using a higher steam pressure of 2 to 3 kg/cm^2. Drains are mostly disposed of without recovering because of contamination.

Continuous cookers are used to cook large amounts of small fish, such as sardines. The continuous cooker is a trapezoidal, tunnel type steam heater with both sides open. It takes about 30 to 40 minutes for the fish to pass the continuous cooker, whose processing capacity is mostly from about 300 kg/hour to 500 kg/hour. Steam is injected at several points in the bottom of the net conveyor in the tunnel at a pressure of less than 1 kg/cm^2. Problems are liable to occur because, for one thing, exhaust loss in the exhaust duct tends to occur, for another, a large amount of heat is needed to raise the temperature of the large device, and for another, a large amount of heat is radiated from the large surface area.

After cooking, the bones are removed, the skins are peeled, and white meat is separated from red meat. The red meat and white meat are carried by separate conveyors to the canning process, where oil and salt are added before cans are sealed by seamer. The salt added is about 5% of the fish content, and the oil added is about 20% of the same. Generally, a vacuum seamer is used. In some cases, oil is heated to about 85°C and added before the seaming process, and the cans are made vacuum by natural cooling after the tightening.

Sealed cans have pieces of meat and oil adhering to their surfaces. Because these foreign objects not only adversely affect the product value but also have low heat conductivity and prevent heat transfer, the cans are cleaned using an alkaline detergent, defoaming agent, and hot water of about 80°C.

Cleaned cans are placed on trucks and inserted into the autoclaves, where steam is directly injected to heat and sterilize the contents of the cans. Similar to cookers, autoclaves are generally cylindrical or square horizontal, or cylindrical vertical internal pressure vessels. Heating temperature is about 110°C to 120°C, and heating time is generally about 60 to 90 minutes, varying depending on the dimensions and type of the can. Steam pressure is generally from about 1 to 1.5 kg/cm^2. In some cases, a higher pressure of about 3 kg/cm^2 is used to shorten the sterilizing time.

While steam is directly injected and inside air simultaneously discharged, both cookers and sterilizers will reach to the required heating temperature when all the air has been completely out. This is called come-up time, which generally requires 15 to 20 minutes. In the case of sterilizing in particular, not only the bacteria that adhere to the can contents but also the spores of heat-resistant bacteria must be killed. If air remains around the cans, the low conductivity of the air prevents the temperature to reach the required level, resulting in inadequately sterilized products. To reach the required temperature in a short time throughout the internal space of the autoclave while paying due attention to product quality is a factor as important as the shortening of the sterilizing process cycle for energy conservation. Drains are disposed of, instead of recovering, in many cases, but the trends are toward recovering drains. Heat insulation of autoclaves and the heat recovery of drains are also important factors for the effective utilization of energy.

The waste water treatment system of the cannery consumes much electric power, which cannot be disregarded for not only environmental effects but also energy conservation. It must not be forgotten to lower the load of the waste water treatment system by reducing the quantity of fresh water consumption through recirculation of used water as well as suppression of water demand.

If a cold storage is available, the production schedule can be easily adjusted by storing the material. This will also help raise the production efficiency of the factory. It is necessary to establish an efficient method of operating the refrigerators and to insulate them.

The fish cannery uses energy as shown in Table 4–1.

Steam is mostly used for cooking and sterilizing. The fuel used for the steam generating boiler is being changed from fuel oil to natural gas to suppress the energy expenditure.

Table 4–1

Purpose	Equipment	Energy source
Cooking	Cooker	Steam
	Exhaust box	Steam
Seasoning mix	Rice boiler	Steam
Sterilization	Autoclave	Steam
Degassing	Seamer	Steam & Electric power (vacuum pump)
Sealing	Seamer	Electric power
Refrigeration	Refrigerator	Electric power
Air compression	Compressor	Electric power
Waste water treatment	Lagoon pump	Electric power

Table 4–2 shows the results of a survey of energy consumption rates in Japan. Tunas and bonitos show a higher fuel consumption than sardines.

Electric power consumption rate increases if waste water treatment and cold storage are involved. High water consumption is another factor that increases the electric power consumption rate.

Table 4–2 Energy Consumption Rate of Marine Products Plant in Japan

Item	Output t	Fuel consumption rate (fuel oil)		Electric power consumption rate		Water consumption rate		Total energy Kcal/kg of product	Remarks
		Kl/t of product	Kl/t of raw material	Kwh/t of product	Kwh/ of war material	m^3/t of product	m^3/t of raw material		
Tuna, Bonito (Oil soaking, Boiling in water)	~ 500	0.010	0.180	78	128	20	32	1,151	Tuna
	1,000~2,000	0.075	0.062	94	77	13	10	823	Bonito
	2,000~3,000	0.086	0.069	174	121	190	132	1,002	Bonito
	"	0.075	0.050	94	63	13	8.4	572	Tuna
	"	0.128	0.106	47	43	–	–	1,311	Tuna, Bonito
	4,000~6,000	0.046	0.050	73	81	–	–	513	" "
	"	0.071	0.070	80	79	18	17	780	" "
	"	0.155	0.105	217	156	39	33	1,637	" "
	"	0.052	0.053	74	74	–	–	513	Tuna
	8,000~11,000	0.065	0.050	65	50	41	32	700	Tuna
		0.056	0.040	115	83	41	30	651	Tuna
	Average	0.074	0.076	101	89	47	35	878	
	Range	0.010~ 0.155	0.040~ 0.106	47~ 217	43~ 156	13~ 190	8.4~ 132	513~ 1,627	
Sardine, Mackerel, (Boiling in water, Boiling with tomato)	1,000~2,000	0.055	0.047	62	52	7.7	6.5	601	Mackerel
	"	0.051	0.015	99	29	14	4.2	595	Sardine
	2,000~3,000	0.052	0.044	100	84	15	6.5	600	Mackerel
	6,000~7,000	0.028	–	24	–	5.7	–	306	"
	"	0.080	0.060	82	63	14	11	843	Mackerel, Sardine, Bonito
	10,000~14,000	0.130	0.117	159	174	0.8	0.7	1,423	Mackerel Sardine
	"	0.052	0.048	99	24	14	9.9	521	Mackerel
	Average	0.064	0.055	89	71	10.2	6.5	699	
	Range	0.028~ 0.130	0.015~ 0.117	24~ 159	29~ 174	0.8~ 1.4	0.7~ 11	306~ 1,424	

4.3.3 Rational Use of Heat Energy

(1) Steam Pressure

Actual data on the use of steam at the fish canning factory surveyed in the Argentine Republic was approximately as shown in Table 4–3.

Table 4–3 Steaming Condition in Main Producing Processes

Item	Internal Temperature °C	Internal Pressure kg/cm² °C	Retention Time min	Supply Steam Pressure kg/cm² G
Cooker	100 ~ 105	1 ~ 1.5	120 ~ 150	5 ~ 8
	110 ~ 120	1 ~ 3.0	60 ~ 120	5 ~ 8

90% of the steam generated by the boiler is consumed by the cookers and sterilizers,

Using steam at excessive pressure will increase heat radiation from the vessels and pipings. If the pipings have a large enough diameter, heat radiation and blow loss can be reduced by lowering the pressure generated in the boiler.

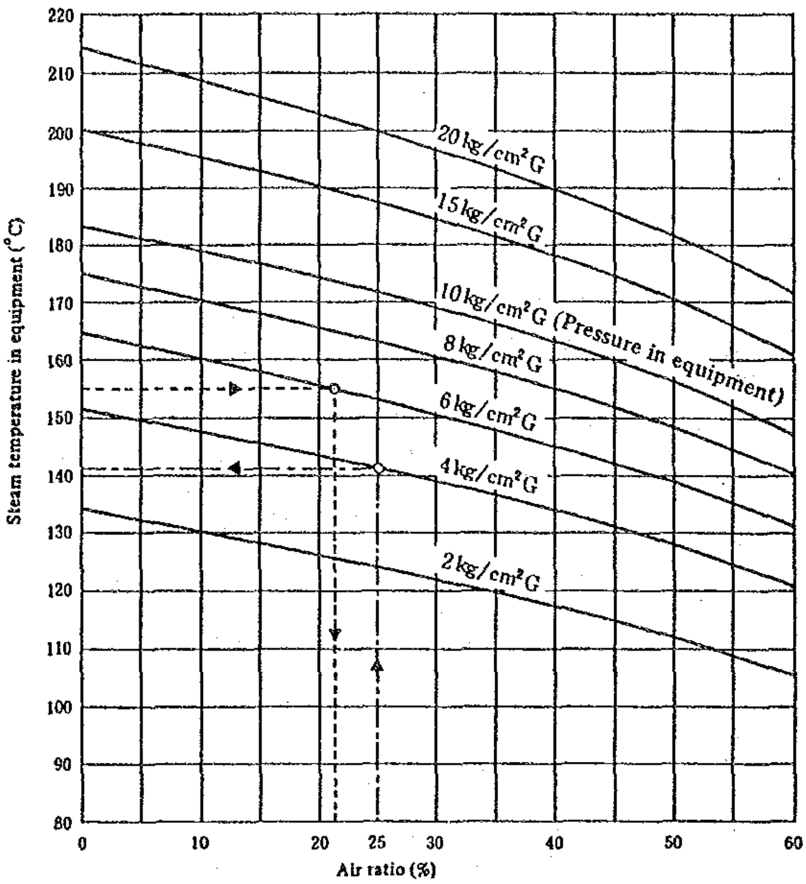
On the other hand, according to operation data on the canning industry of Japan, come-up time shortens and the operation rate of sterilizers increases as steam pressure rises. Find a point where maximum energy efficiency can be obtained on the whole according to the existing conditions of production and facilities.

(2) Air Venting

When processing a product with steam in a pressure vessel, all the air in the vessel must be discharged. Otherwise, the remaining air will generate a condition equivalent to a reduction of steam pressure so that the required temperature will not be reached, resulting in incomplete heating. Complete discharge of air is important for sterilizing food products. In many cases of steam heating with sterilizers, such trouble is prevented by discharging air almost to excess. To actively promote energy conservation for sterilizers, it is necessary to know exactly how air interferes with sterilizer operation.

(a) Ill Effects of Air

As steam is injected into an enclosed vessel, it mixes with inside air into a gas mixture. The temperature of this mixed gas is lower than that of pure steam according to Dalton's law of partial pressure. For example, an autoclave filled with saturated steam at an absolute pressure of 2.4 kg/cm² has a temperature of 125°C. If there is a gas mixture of steam and air at the volume ratio of 3 to 1 in the autoclave, the steam partial pressure will be 0.75 x 2.4 kg/cm² and the absolute pressure 1.8 kg/cm². The saturation temperature of steam whose absolute pressure is 1.8 kg/cm² is 116°C so that the internal temperature of the autoclave will be actually 9°C lower than the temperature corresponding to the pressure gauge reading of 1.4 kg/cm² G. This will result in incomplete heating. The relationship between the air mixture ratio and internal steam temperature is as shown in Figure 4–7.



How to use the graph

When the air ratio is 25% in the gage pressure of 4 kg/cm^2, draw perpendicularly a line from the point of 25% in the air ratio, get an intersection of the curve of 4 kg/cm^2 G, draw horizontally a line in a left direction from the intersection and obtain a steam temperature. The temperature is 141°C but the steam pressure is 2.75 kg/cm^2 in the steam chart. When the temperature inan equipment is 155°C and the pressure is 6 kg/cm^2 G, the air ratio is 21%.

Figure 4–7 Temperature Change Chart Due to Air Pressure in Steam Equipment

Part of the air in the autoclave will remain as a thin film covering the can surfaces, and prevent heat transfer. This cannot be solved by raising the pressure in the autoclave or lengthening the heating time.

(b) Steam Flow

An autoclave for sterilizing is filled with cans which block free flow of steam and air, causing turbulence. Therefore, it is necessary to feed steam as slowly as possible in such a way that it will uniformly spread in all the directions of the autoclave.

Whether steam should be injected from the top or the bottom of the autoclave is a matter of argument. Air stays lower than steam because it has higher specific gravity than steam; and air has lower temperature than steam. Theoretically, therefore, it is unreasonable to inject steam from the bottom of the autoclave. A test was conducted to determine its effect, using a plant shown in Figure 4–8. Two steam diffusing pipes were connected to the top, and the test was made at a steam pressure of 4 kg/cm^2 and at a temperature of 115°C for 60 minutes, controlling with an automatic valve. The quantity of steam used was found to be less than in the case of injecting steam from the bottom as shown below.

In the case of Single steam diffusing pipe: 97.3%

In the case of Two steam diffusing pipes: 93.2%

The conditions vary with the way of filling the autoclave with cans, and steam flow is complex. There is room for improvement by trying various methods.

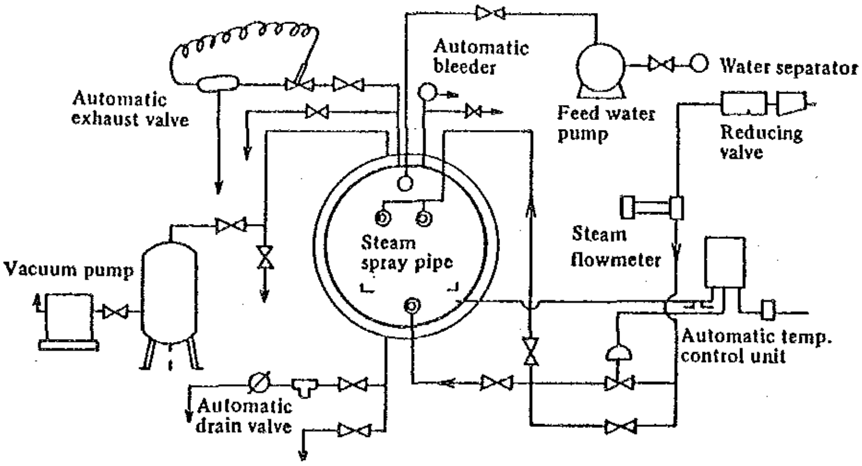


Figure 4–8

When venting air from the top by injecting steam from the bottom, it would be better to use two steam feed pipes about 2 inches in diameter at the bottom of the autoclave so that steam will be fed uniform at an appropriate speed, and make steam injection holes about 3 mm in diameter in these pipes slightly downward from the horizontal center so that steam will drive the air slowly upward without turbulence. In this case, at least two, or preferably three, air vent holes are necessary in the top of the autoclave to ensure laminar flow. More air vent holes are necessary for long-bodied autoclaves according to their body length.

The ideas presented above were derived from practical experiences in the past. In implementing actual improvement measures, carefully observe steam behavior and make modifications suitable to productivity, quality, and energy conservation.

(c) Automatic Air Venting

In many cases, the manual exhaust cocks are frequently operated to vent air. There is no problem at the start of operation, but it is difficult to determine whether all the air has been discharged. If the cock is closed too soon, air remains inside and adversely affects product quality. Anxiety of this drives to excessive discharge, which in turn results in steam loss.

If an automatic air venting device of thermo-sensing type which exactly senses air and controls it is employed, multiple effects can be expected as follows.

1 Steam can be saved

The device senses the mixture of air and steam in the exhaust gas and closes the autoclave upon discharge of all air, thus eliminating waste of steam.

2 The device shortens exhaust time and com-up time, and thus increases the operating rate of the autoclave.

3 The device sharply reduces the reject rate due to air trouble.

Select an automatic air venting device of high accuracy and large enough capacity for autoclaves. Cookers process fish at 90 to 100°C for 100 to 120 minutes, and dont need so severe cancern as sterilizers. But, mounting a small-sized automatic air vent valve on the cookers will be effective for saving steam.

Absolutely no errors are allowed in food products because even a slight defect can adversely affect the trust in the producer. Automation is significant not only for energy conservation but also for eliminating defects.

An automatic test was conducted using the equipment shown in Figure 4–8. A temperature indicator recorder was installed to determine the internal condition, and exhaust steam from the exhaust port, air vent, and drain cock was condensed and the amount of steam discharged from each of them was determined. The test results are shown in Table 4–4. It is clear that automation reduced steam consumption by more than about 10 percent.

Table 4–4 Discharge Steam and Drain Due to the Differences of Cooking Initial Temperature and Automatic and Manual Operation

Initial temp.	Control valve / Process	Exhaust gas		Air vent		Drain		Typical value	
		Automatic	Manual	Automatic	Manual	Automatic (Trap)	Manual (Valve)	Automatic	Manual
		(kg)	(kg)	(kg)	(kg)	(kg)	(kg)		
115°C 60 min. Initial temp. 20°C	Come-up process	3.07~ 4.92	2.26~ 2.49	0.02~ 0.06	0.19~ 0.95	74.97~ 96.5	80.00~ 88.08	123 kg	137 kg
	Sterilization process	0.75~ 3.08	0	0.05~ 0.90	2.54~ 12.34	18.20~ 42.7	34.32~ 49.50		
115°C 60 min. Initial temp. 30~ 40°C	Come-up process	2.39~ 4.38	2.07~ 3.14	0.02~ 0.06	0.18~ 0.82	54.9~ 72.95	67.59~ 75.03	104 kg	121 kg
	Sterilization process	0.65~ 1.98	0	0.07~ 0.1	2.53~ 12.25	22.18~ 48.15	32.42~ 46.57		
Equipment		Thermostat 1", Temp. control range 93~ 127°C	1 1/2"	Temp. sensitive system, bellows type 1/2"	1/8"	Float type steam trap 1"	1/2"	227	258
								$\frac{258-227}{258} \times 100 = 11.2\%$	

(3) Initial temperatûre of autocolave

According to the automation test results in Japan described above, fuel consumption can be reduced by about 15 percent by starting the autoclave at 30°C to 40°C instead of at 10°C to 20°C. (See Table 4-3-9.)

Sterilzied cans may be cooled in an autoclave filled with water in some cases, but this has the disadvantage of cooling the cans thermselves. It is necessary not to lower the temperature below the required cooling temperature.

(4) Autoclave heat insulation

Heat insulation of autoclaves is the most direct way of conserving energy. According to a test, covering an autoclave with rock wool 50 mm thick reduced steam consumption to about 88 percent of that of a non-insulated autoclave, and also shortened the come-up time. The measuring results and calculation results are shown in Table 4-3-10.

Table 4—5

Sterilization temp. (°C)	Heat insulation	Retort surface temp. (°C)	Heat radiation from retort surface ($Kcal/m^2 \cdot h$)		
			Radiation Qr	Convection Qc	Total
113	No	107	263.1	584.6	847.7
113	Yes	28	36.9	29.6	66.5
·115	No	109	271.7	601.4	873.1
115	Yes	29	41.9	34.3	76.2
120	No	113	289.5	635.4	924.9
120	Yes	30	46.6	39.1	85.7

Note 1) Room temp.: 20°C
2) ε : Radiation coefficient of no insulation (Painted with aluminium paint): 0.40
Radiation coefficient of insulation with glass wool: 0.90
Thickness of insulation: 50 mm

A hot device dissipates heat by radiation and convection. Quantity of heat dispation by radiation (Qr) per unit area and unit time can be calculated by the following equation.

$$Qr = 4.88 \epsilon \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right] \qquad (kcal/m^2 \cdot h)$$

where T_1 : Absolute temperature of the equipment surface (°K);
T_2 : Absolute room temperature (°K);
ϵ : Emissivity of the equipment surface.

Quantity of heat dissipation by convection (Qc) per unit area and unit time can be calculated by the following equation.

$$Qc = hc\ (T_1 - T_2) \qquad (kcal/m^2 \cdot h)$$

where hc: Heat transfer coefficient.

In case of vertical plane, $hc = 2.2\ (T_1 - T_2)^{0.25}$

In case of upper horizontal surface, $hc = 2.8\ (T_1 - T_2)^{0.25}$

$hc = 1.5\ (T_1 - T_2)^{0.25}$

(5) Steam heating and hot water heating of autoclave

In Japan and the United States, steam heating is mostly used, presumably because of high productivity. In other words, the higher the temperature the shorter will be the processing time. In Europe, however, hot waer heating is mostly used for sterilizing. Sterilization errors are fewer because, for one thing, automatic control is easy and, for another, air trouble can be eliminated more easily than in steam heating. Besides, the heat of hot water can be repeatedly used.

Steam heating and hot water heating have their own advantages and disadvantages, and it is desirable to make a comparative study of them as to sterilizing efficiency, quality, and energy consumption as well.

(6) Saving refrigerating power

(a) Reising refrigerator operation efficiency

The following are important to prevent increase of electric power consumption by refrigerators.

1 Clean the condenser heating surfaces.
Check the quality of cooling water and regularly clean the heating surfaces.

2 Keep the cooling water flow rate at the required level.
Periodically clean the strainers and nozzles so that they won't be clogged up.

3 Maintain the cooling water temperature.
Periodically check the cooling tower and packing and maintain proper water distribution.

4 Prevent entry of non-condensed gas.
Be careful to keep non-condensed gas out particularly during vacuum operation and overhaul.

5 Prevent cooler efficiency from lowering.
Be careful of frosting and cold air short pass.

6 Put the sufficient heating area for the cooler.

7 Make sure that the refrigerator capacity will not be too large.

8 Clean the refrigerant strainers.
Clean the refrigerator suction strainers, automatic valve protective strainers, etc. to prevent clogging up.

9 Check the refrigerant piping that its diameter is correct.
The refrigerant piping may often be left as it is when refrigerator facilities are expanded. In such a case, enough refrigerant may not be circulating.

10 Check the refrigerant if it is sufficient.

(b) Reducing refrigerating load of cold storage

1 Heat Q penetrating the wall can be expressed in kcal/h by the following equation.

$$Q = AK\Delta t$$

where $A\ (m^2)$: Outer wall area of the building;
$K\ (kcal/m^2 \cdot h \cdot °C)$: Coefficient of overall heat treansfer (dependent on type and thickness of heat insulation material);
$\Delta t\ (°C)$: Difference between room temperature and outer wall temperature.

It is important, therefore, to improve heat insulation to decrease the K. Carefully check the heat insulating material that it is not wet because if it contains water, it cannot effectively insulate heat. Replace it if wet.

2 Reduce loss due to ventilation
When the cold storage door is opened and closed, warm outside air enters the

cold storage, causing heat loss. If outside air 32°C with 70% humidity enters the cold storage to replace 1 m^3 of cold air, heat loss will amount to 40 kcal for a −30°C cold storage, or 35 kcal for a −20°C cold storage.

If the cooler is located near the door, the water vapor contained in outside air deposits on the cooling pipes as frost, causing efficiency to lower. It would be better to install an air curtain, or install a free door or curtain in the prechamber.

3 Reducing heat of objects entering cold storage

When vans and pallets are used to move material out of the cold storage, use them again as quickly as possible to move material into the cold storage.

The load of freezing 10°C fish meat to −20°C can be calculated as follows:

The load of freezing to −2°C: [(10 − (−2)] x 0.85 + 58 = 68 kcal/kg.

The load of cooling from −2°C to −20°C: [−2 − (−20)] x 0.47 = 8 kcal/kg.

As shown, the load of freezing at relatively high temperature is large. It is suggested, therefore, that material fish to be taken into the cold storage be at low temperature as possible.

4 Reducing fan generated heat

The electric energy applied to the cold storage fan enters the cold storage as heat amounting to 860 kcal per kWh. If the fan capacity is reduced, electricity can be directly saved and the refrigerating load to remove that heat can also be reduced.

Table 4–6 shows an example of actual measurement of refrigerating load ratio. As shown, the cooling fan has a high percentage (12.7%) of heat generation.

Table 4–6 Refrigeration Load Ratio in Refrigerating Equipment

Type of load	Load ratio %
1. Heat coming from wall	1.4
2. Cooling heat of building etc., veneer plate, floor concrete, heat insulator, cooler frame etc.	6.6
3. Cooling heat of refrigerating pan	0.9
4. Cooling of residual moisture and air in refrigerator	0.7
5. Cooling and refrigerating heat of products	77.7
6. Heat generated from cooler fan	12.7

Batch refrigeration: 15 hours. Temperature when fishes are put in it: 10°C.
Source: Maekawa Seisakusho Data.

Make sure that the fan is not running while the refrigerator is not in use.

5 Reducing loss due to lights

Be sure to switch off the lights and floor heater in the cold storage when they are not needed. Remove all such fixtures except the ones that are absolutely necessary.

6 Use the heat discharged by the refrigerator to defrost.

(c) Cold storage temperature and electric energy

Input to capacity ratio: 2.5%/day

Outside air: 40°C at ceiling; 30°C on outer walls; 20°C on floor

Outside air wet bulb temperature: 27°C

Heat insulating material: 225 mm thick at ceiling; 20 mm thick on outer walls; 175 mm thick on floor

Heat transfer coefficient: 0.025 kcal/(m² h°C)

The refrigerating load of the cold storage under the above conditions was calculated at inside temperatures of −20°C, −25°C, and −30°C as shown in Table 4–7.

Table 4–7

Temperature in refrigerator	−20°C	−25°C	−30°C
Heat coming from wall Kcal/h	43,818	48,291	52,764
Heat loss due to ventilation Kcal/h	21,945	23,826	25,080
Cooling heat of product in refrigerator Kcal/h	37,500	56,250	75,000
Heat generated from fan Kcal/h	19,800	26,400	33,000
Heat loss from lighting and others Kcal/h	1,785	1,785	1,785
Safety factor 10% Kcal/h	12,485	15,655	18,763
Total load Kcal/h	137,333	172,207	206,392
Refrigeration ton JRT	41.4	51.9	62.2
Load factor in −20°C: 100%	100%	125.4%	150.3%

Variation of electric energy (kW) per refrigerating ton of the refrigerator due to the evaporation temperature of refrigerant is shown in Table 4–8.

Table 4–8

condensation temperature +35°C, Fron 22

Refrigerant evaporation temp. °C	−28	−33	−38
Refrigerating capacity JRT	40.3	32.8	25.6
Required power kW	64.3	59.7	54.5
kW required to 1 JRT (kW/JRT)	1,596	1,843	2,129
kW/JRT ratio (as 100% the ratio in −28°C)	100%	115.5%	133.4%

As the inside temperature of the cold storage changes, the refrigerating load changes and electric energy per refrigerating ton of the refrigerator also changes accordingly. Table 4–9 shows the percentages of electric energy at different temperatures in the cold storage. As shown, there is a difference of twice the refrigerator power requirement between cold storage temperatures of –30°C and –20°C.

Table 4–9

Temperature in refrigerator °C	–20	–25	–30
Load factor	100	125.4	150.3
Refrigerator kW/JRT ratio	100	115.5	133.4
Required power ratio	100	144.8	200.5

Thus, good care must be taken not to lower the inside temperature more than necessary.

(d) Speeding up refrigeration

To speed up refrigeration, it is necessary to increase the velocity of cold air to fish to raise the heat transfer coefficient. There will be a difference of a few hours in freezing depending on air velocity. In one case, fish was not frozen until the inside temperature was below –40°C. In another, fish was well frozen even at –30°C. This is due to the difference in air velocity and the way in which fish is exposed to cold air. It is necessary to assure uniform circulation of cold air in the cold storage.

(7) Saving water

Use of much water not only requires electric power to convey water but increase electric power to dispose of it.

The first step to save water is to prevent wasteful use of water in each process. Observe the following for that purpose.

(a) Educate the employees to let them understand the importance of saving water.
(b) Install a flow meter in each main process and shown the reading in the workshops daily.
(c) Use automatic stop valves depending on the case.
(d) Try to reuse water. Build pits and reuse autoclave cooling water, sterilized can washing water, etc. that are not so dirty. This will not only reduce water consumption but also permit recovery of heat.

5. Textile

5. Textile

5.1 Characteristics of Energy Consumption

5.1.1 Manufacturing Process and Main Facilities

There are a wide variety of textile products, manufactured by different processes, which include the process to produce synthetic fibers from chemical materials, the spinning process to produce yarn from natural or synthetic fibers, the weaving process to produce woven fabrics from yarn, and the dyeing to dye yarn and woven fabrics. The materials are diverse, including natural fibers, such as cotton, silk, and wool, and man-made fibers, such as rayon and synthetic fibers. In the spinning process, many kinds of yarn are produced, varying in length, twist, and gauge.

There are also many weaving and finishing methods to give the woven textiles a different feel of their own, and there are diverse dyeing methods, including dip dyeing and printing.

Here, we will give a summary description of the general production processes without discussing expertise.

(1) Synthetic fibers

Synthetic fibers can be classified into two kinds: One includes rayon, acetate, etc. that are produced by chemically treating natural cellulose, and the other is synthetic produced by synthetic reaction from chemical materials. Synthetic fibers range widely from nylon to polyester, polyacrylnitrile, and polyvinyl alcohol.

Polyester, which is one of the most important synthetic fibers in the world, is produced by the process shown in Figure 5-1.

Terephtalic acid and ethylene gloycol are heated and polymerized. Because this polymer contains water-soluble unreacted substances, it is extruded into a string in water to solidify, cut into chips, and then cleaned using hot water. The chips are dried and sent to the spinning machine, where they are melted and extruded through the small hole in the spinneret. The polymer out of the spinneret is cooled in the air to solidify in fiber form, and then is wound as yarn. The yarn is stretched 3 to 4 times to rearrange the molecular orientation and increase the strength.

The unreacted substances that were extracted into the hot water are condensed and cleaned of impurities in the evaporation tower and distillation tower to be used again as material.

As described, the processes till the material enters the spinning machine are similar to those of the chemical industry, and employ fluid-handling equipment consisting of towers, tanks, pipes, and pumps, and solid-handling equipment consisting of a dryer, centrifugal separator, etc.

Because these sets of equipment handle organic compounds and must be kept free of local overheating, a jacket steam heating system is mainly used. Heating medium oil and electric heaters are also used in part of the processes. The utilities facilities include boilers and air conditioning chillers for the spinning process.

The utilities used in each of the processes are shown in Figure 5-1.

(2) Cotton and synthetic yarn spinning and weaving

The standard process of producing cotton yarn from raw cotton and synthetic fibers

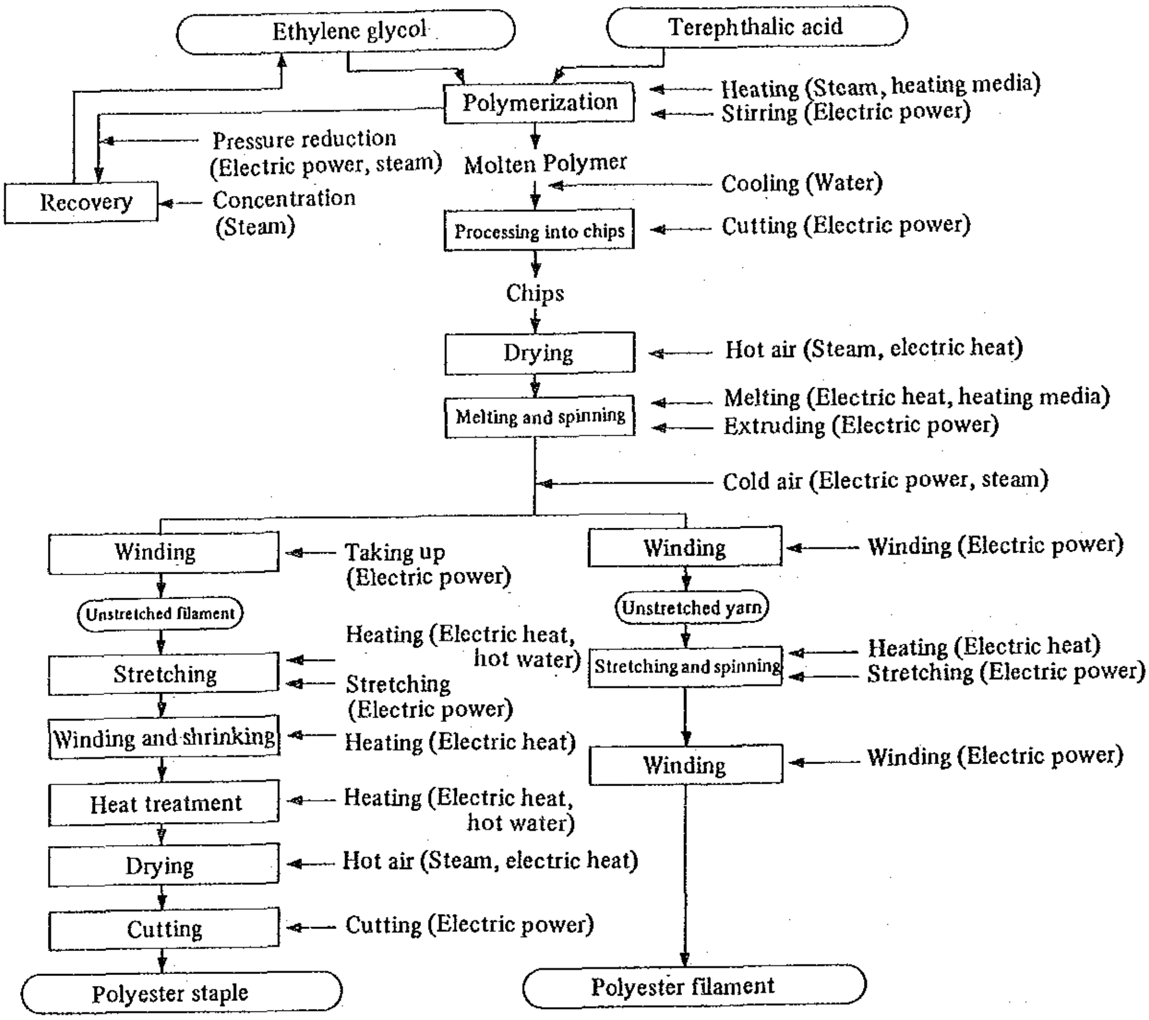


Figure 5-1 Polyester Production Process

is composed of the parts shown in Figure 5-2. Blended yarn of cotton and man-made fibers, such as rayon and acetate, can also be produced by a similar process.

Raw cotton is shipped in a firmly compressed state to facilitate transportation. So, first beat it with pinned rollers or a beater to loosen the cotton (see Figure 5-3), and remove foreign matter and short fibers from it.

The cotton from the beater still has small lumps and tangles, and the individual fibers are not stretched enough. Therefore, it is sent to the carding machine (see Figure 5-4) to further loosen and stretch the fibers, and remove short fibers. Only the long stretched fibers are gathered and arranged parallel to one another into string-like slivers of 2 to 3 cm in diameter.

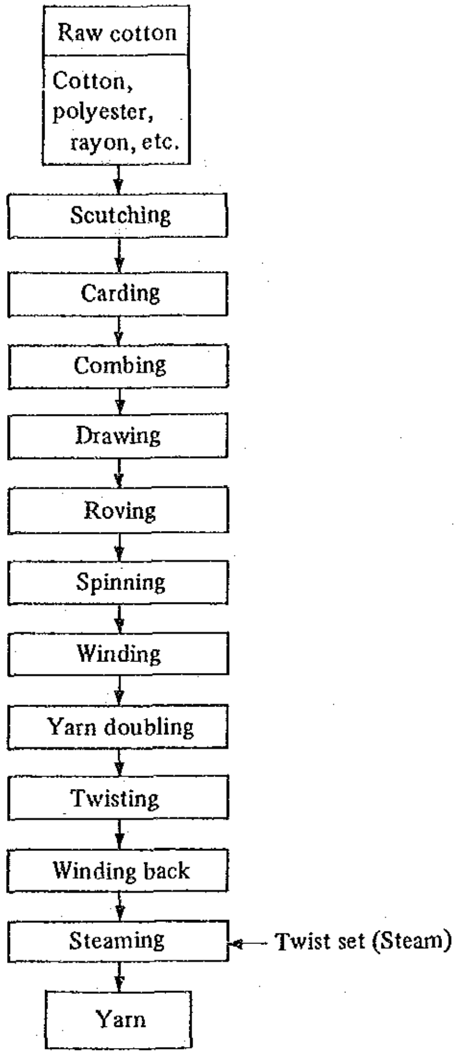


Fig 5-2 Spinning Process (Short Fibers)

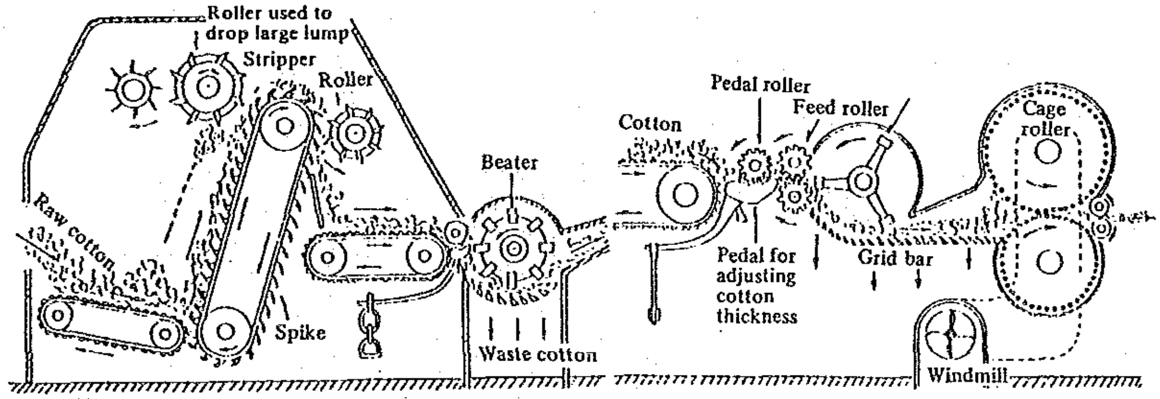


Fig 5-3 Blowing Machine and Beater

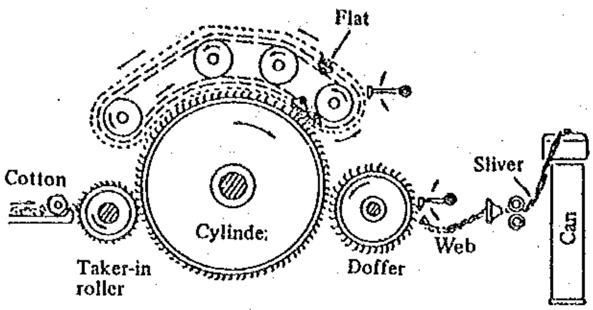


Fig 5-4 Carding Machine

In case of producing yarns of better quality or greater strength, the material is sent to the comber to obtain fibers of even length and remove short fibers and remaining foreign matter.

To make the slivers uniform in gauge, sliver bundles each consisting of several strands are sent to the drawing frame to stretch them to the original gauge. Generally, about bundles of 8 strands are stretched 8 times in length so that their unevenness in gauge will decrease to about 1/8. This is repeated a few times to further reduce the uneveness of sliver gauge.

The slivers now even in gauge enter the roving process, where the slivers are further stretched and slightly twisted into yarn. After repeating it once or twice, the yarn is sent to the spinning process.

Figure 5-5 shows an example of shipping machine. The yarn is sent from E through F and traveler B, which runs around ring A, to bobbin D, which winds the yarn around it. The bobbin rotates very fast, at about 10,000 revolutions per minute, while the traveler follows the bobbin at a slightly lower speed. Thus, the yarn is twisted.

The single yarn thus produced is used as it is, or twisted with another yarn or more.

The yarn then enters the winding process, where it is wound in the form of hank, cheese, or cone (see Figure 5-6) according to the applications. The wound yarn is then processed by a heat setter to prevent untwisting.

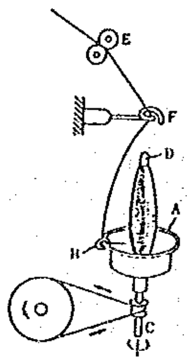


Fig 5-5 Ring Spinning Machine

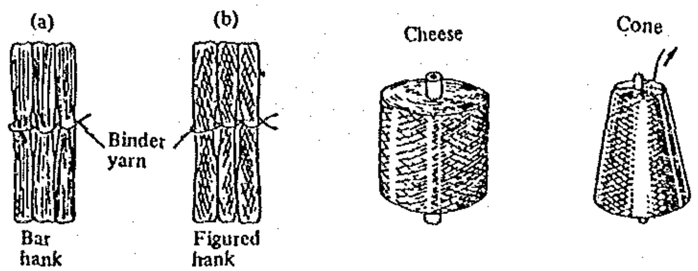


Fig 5-6 Wound Yarn

(3) Woven textiles

A woven textile is a fabric produced by weaving warp and weft crossing each other at right angles. A wide range of woven textiles are produced using different kinds of yarn and different methods of crossing them. (See Figure 5-7.)

Basically, the loom passes the weft through the warp grouped into the upper and lower parts, and tightens the woven yarn with a reed. This process is repeated by the loom.

Generally, the loom has a mechanism by which the weft is passed in both directions alternately using a shuttle. To raise production speed, the shuttle must be rapidly moved back and forth, braking it fast at one end and returning to the other end at high speed. This is why the loom consumes much energy and makes much noise.

A shuttleless loom that was recently developed overcomes these disadvantages and improves productivity. Instead of inserting a shuttle into the shed, air or water is injected into it with the weft running along the air or water jet.

The method that uses air current is called the air jet method, which is used for cotton or synthetic yarn. The method using water current is called the water jet method, which is used for synthetic filaments.

The warp is sized beforehand to prevent hairiness due to friction of one thread with another and to improve weaving performance.

The sizing machine is generally classified by type of drying. The thrasher sizing machine that feeds steam through the cylinder to dry sized yarn is constructed as shown in Figure 5-8.

There are also other types, including the hot air sizing machie and cylinder hot air sizing machine.

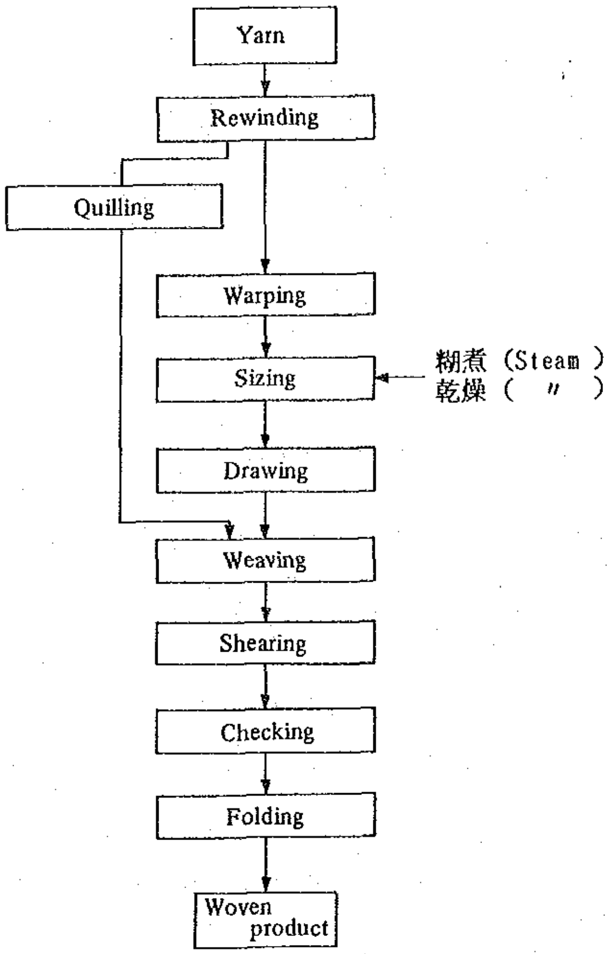
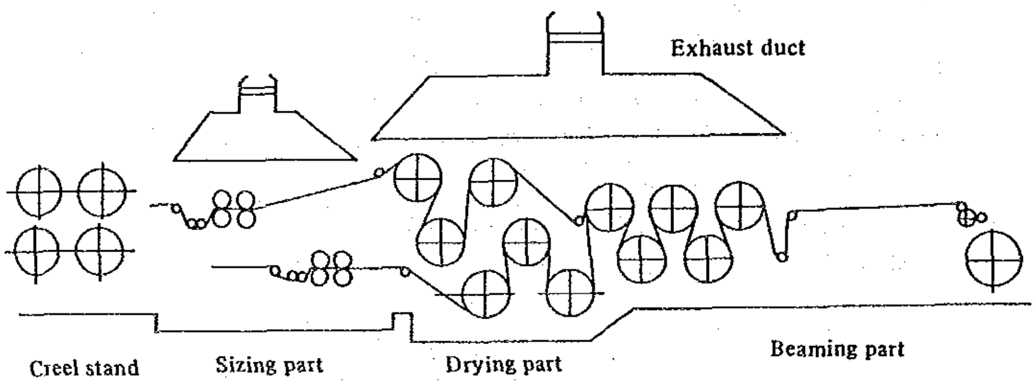


Fig 5-7 Weaving Process



1. Creel stand
2. Sizing part .... Steam used
3. Drying part .... Steam used
4. Beaming part

Fig 5-8 Construction of Sizing Machine

(4) Dyeing and finishing

There are two cases of dyeing: Dyeing yarn and dyeing woven textile. Fabrics are dyed by either dip dyeing or printing. Of these two methods, dip dyeing accounts for the greater part of production.

The dyeing process is connected to the preceding processes of scouring and bleaching and to the subsequent process of finishing.

A typical dyeing and finishing process for short-fiber fabrics is shown in Figure 5-9.

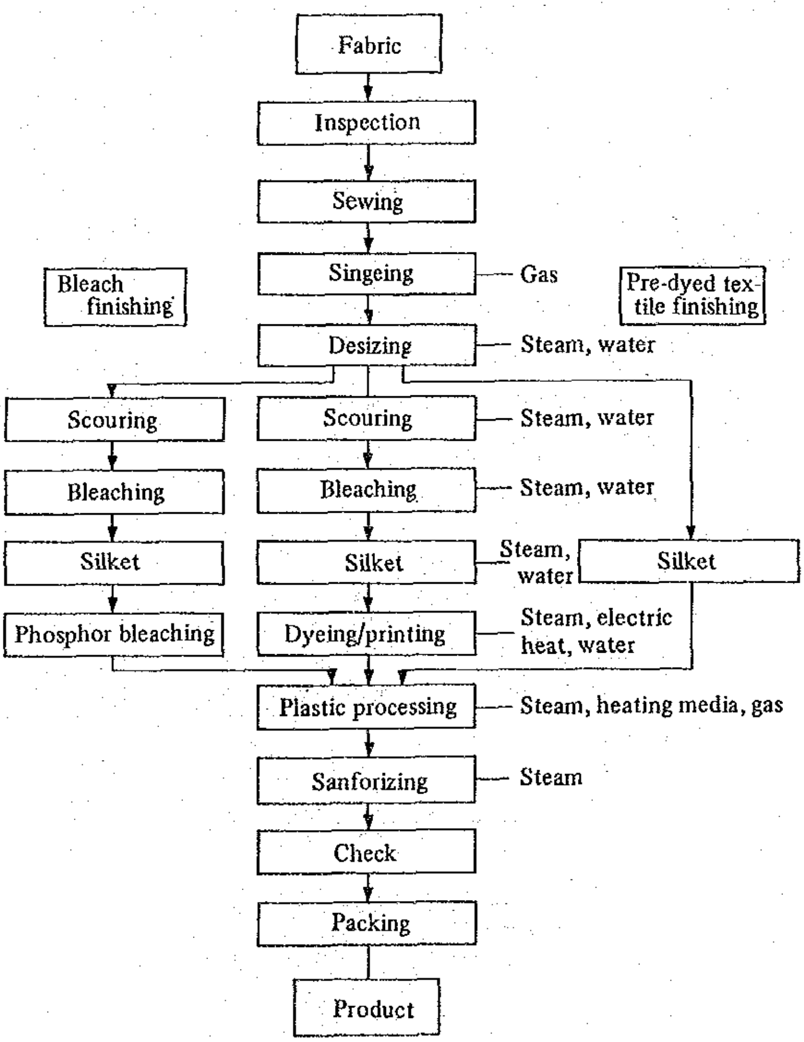


Fig 5-9 Dyeing and Finishing Process (Short-Fiber Textiles)

There are various types of dyeing depending on the kind of fiber and dyestuff. Basically, however, the following five functions are combined and repeated.

A) Adding: The dye and assistant are applied by dip dyeing or printing.

B) Washing: Impurities and excess dye and assistant are removed by washing with cold or hot water.

C) Dehydration: Moisture is removed by physical means, such as press, vacuum machine, and centrifugal machine.

D) Drying: Moisture is further removed by evaporation through conduction heat (cylinder dryer), convection heat (hot air dryer), radiation heat (infrared dryer), etc.

E) Fixing: Heat is applied to fix the dye, pigment, etc. on the fiber.

Dyeing fabrics involves, in addition to the above, the preparatory processes of singeing, desizing, scouring, bleaching, and heat setting, and the special finishing processes of non-shrink, wrinkle resistance, and waterproof treatment.

The cheese dyeing machine for yarn is a vertical cylindrical type with a steam coil for heating in the lower part of it. The yarn to be dyed is set in the carrier to be inserted into or removed from the dyeing machine at the top. The dye liquor is circulated by the pump, jetting it alternately to the outside and inside of the yarn to dye it.

The hank dyeing machine is a horizontal type with an open door in front. The hank hung on a hanger is exposed to a jet of dye liquor while the hank is rotated at specific intervals of times.

The cheese dyed in the carrier is dried in a vertical cylindrical dryer such as shown in Figure 5-10, while the hank is dried in a hanger type hot air dryer.

Various types of dyeing machines, such as the Wince machine shown in Figure 5-11, are used to dye woven textiles.

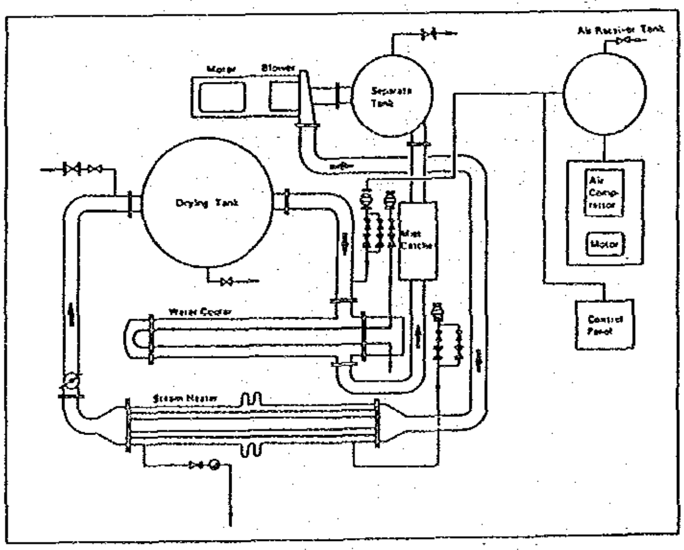
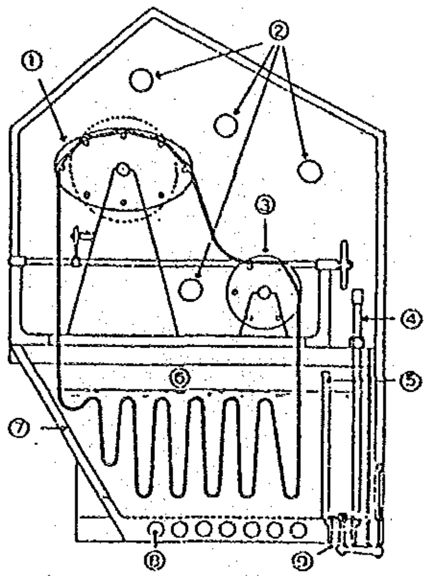


Fig 5-10 Cheese Drying Machine



1. Ellipse-shaped or circular Wins frame
2. Steam pipe
3. Guide roller
4. Perforated steam pipe
5. Perforated partition plate
6. Level of dyeing liquid
7. Stainless steel tank
8. Steam pipe
9. Drain valve

Fig 5-11 Internal Construction of Wince

(5) Woollen textiles

A typical production process from raw wool to woollen textile is shown in Figure 5-12.

Woolen yarn is classified into worsted yarn (count 20^S to 78^S) and woollen yarn count 3^S to 24^S).

Worsted yarn is produced by carding raw wool to remove short fibers, and spinning long fibers arranged parallel, and is relatively smooth on the surface. Woollen yarn is produced with fibers not arranged parallel but crossing, and is hairy on the surface. Relatively short raw wool and waste wool from the carding process are used for producing woollen yarn.

Worsted yarn is used for weaving relatively thin and medium-thick serge, poral, and tropical, while woollen yarn is woven into thick fabrics including flannel, cashmere, tweed, and blakets.

The worsted spinning process without top making is basically similar to the cotton spinning process, but differs in the sliving part in the pre-spinning process because it handles long fibers.

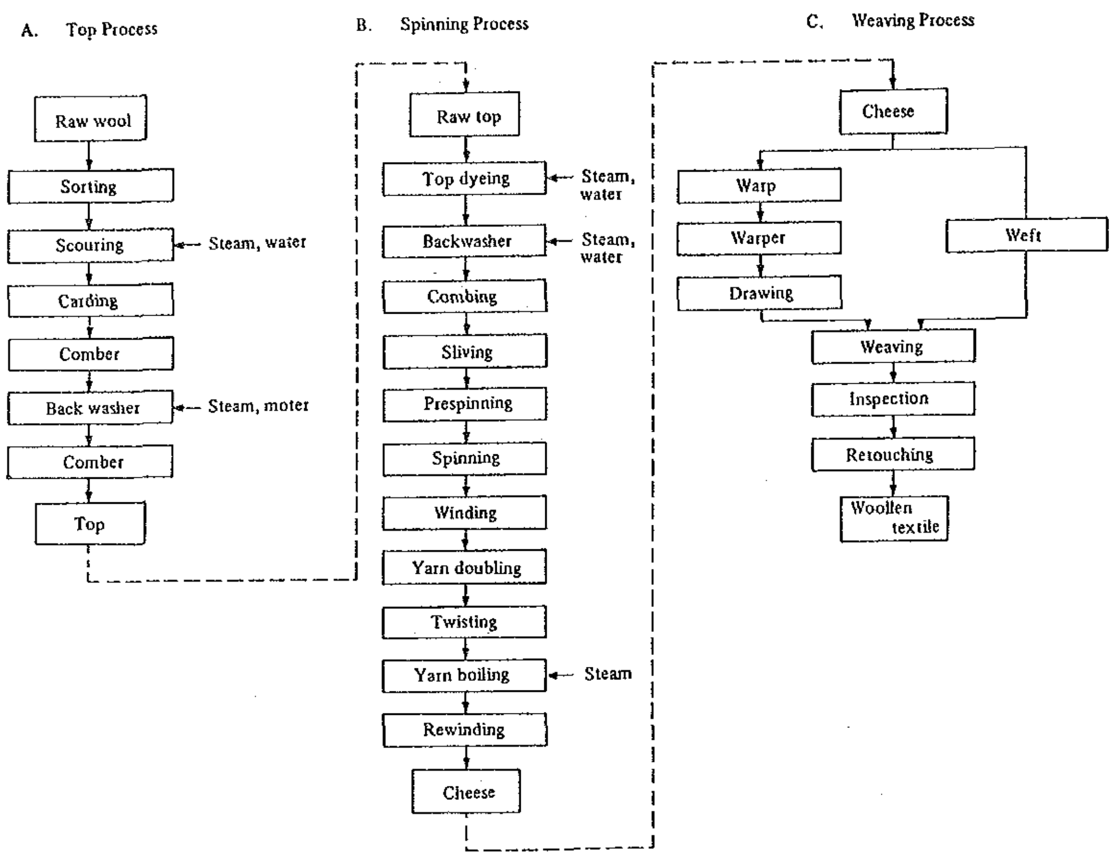


Fig 5-12 **Carding, Spinning and Weaving Processes**

A typical woollen textile finishing process is shown in Figure 5-13.

The basic difference between woollen textiles and cotton or synthetic textiles is that woollen textiles are required a special kind of quality called feeling. Woollen textiles are produced in a wide variety of small lots, and are finished mostly by a batch system.

5.1.2 Energy Consumption

(1) Synthetic fibers

The kinds of energy used in the polyester production process are shown in the process diagram of Figure 5-1.

In producing synthetic fibers, monomers are polymerized into macro-molecules as material. The polymerization process consumes much energy for heating, stirring, and pressure reduction to polymerize the monomers; cooling, washing, and drying the macro-molecules produced, and recovering unreacted monomers. Steam, used a heat source, is generated by a back-pressure extraction trubine driven by an independent generator set, and is used for many purposes: for heating in the production process; for driving the boiler forced draft fans and feed water pumps; for quenching yarn; driving the turbo refrigerator for air conditioning the spinning room; and as a heat source for absorption refrigerating machines. That is, steam is used for these different purposes according to different levels of pressure.