8.3 Rationalization of Energy Utilization

8.3.1 Chemical Fibers

As one of the features in energy utilization by manufacturers of chemical fibers, the private power generation rate is more than 60 %. Electric power is partially used for heating as well as for dynamic power. The extraction and/or back pressure steam from the turbine for in-house power generation is used for heating and air-conditioning in manufacturing processes.

Basic actions taken by chemical fiber manufacturers to reduce energy intensity are as follows:

(1) Actions for energy conservation in manufacturing processes

a. Adoption of the method of direct polymerization from TPA

Omission of the raw material process

b. Continuation of the polymerization process

Improvement of heating/cooling repetition

c. Continuation from the polymerization process to the spinning process (Direct spinning method)

Omission of the chipping process, drying process, and re-melting process

d. Direct connection of spinning and drawing (spin-draw)

Since the spinned thread is directly led to the drawing process, the winding process in spinning is omitted. Therefore, it contributes to energy conservation and power conservation.

e. Changing the heat source of the heat medium boiler

For heating and heat insulation in the polymerization process, a heat medium such as Dowtherm or ThermS has been used with electricity as the heat source. Recently, to attain energy conservation through improving the thermal efficiency, it is now being replaced by boilers using heavy oil, etc. as fuel.

f. Enhancement of heat insulation

Traditional heat insulation specifications were economical ones when the energy cost was low but they are inadequate in this age of high energy cost. Heat insulation specifications and the construction level are being reviewed, and every effort to enhance heat insulation is made at such opportunity as regular check of facilities.

g. Review of air-conditioning conditions

The temperature/humidity condition of the cooling air in the spinning process and the temperature condition in the winding room, drawing room, etc. are re-examined to reduce the air-conditioning load.

(2) Energy conservation measures for supplementary manufacturing facilities

a. Air-conditioning facility

The air-conditioning facility is provided to maintain the temperature/humidity condition for the thread cooling air or room temperature in the spinning and winding processes. In recent years, the capacity of the air-conditioning facility tends to be excessive, since the temperature/humidity condition is reviewed as a result of promotion of energy conservation activities and some machines are out of service or dismantled along with reduction of the production scale.

The following actions are being taken for energy conservation of air-conditioning facilities.

① Air-conditioning facilities are integrated or abolished and the fan rotational speed is changed to obtain a proper capacity.

② Freezing load reduction is implemented by introducing the outer air.

③ Use of cold water for cooling is changed to the use of well water.

b. Vacuum facility

The reaction process under vacuum in the polymerization process requires a vacuum generator. Generally, a steam ejector is often used as the vacuum generator. Since reviewing the process conditions results in energy conservation, the existing vacuum generator is replaced with the energy conservation type upon renewal.

c. Recovery facility

Energy conservation measures for the process for recovery of the raw material monomer from the distilled material in the polymerization process or from the chip scouring liquor include the following:

① The double-effect evaporator is modified into the triple-effect one. Figure 8.16 shows its flow.

② By reviewing the vacuum condition and reducing the degree of vacuum, the steam ejector driving steam pressure can be made lower.

Figure 8.17 shows an example of changing the steam pressure from 10 kg/cm² (G) to 3 kg/cm²(G).

In this field, development of the separating method with the reverse osmosis membrane not using the heat energy is expected.

Figure 8.16 Triple-effect Utilization of Recovery Double-effect Evaporator

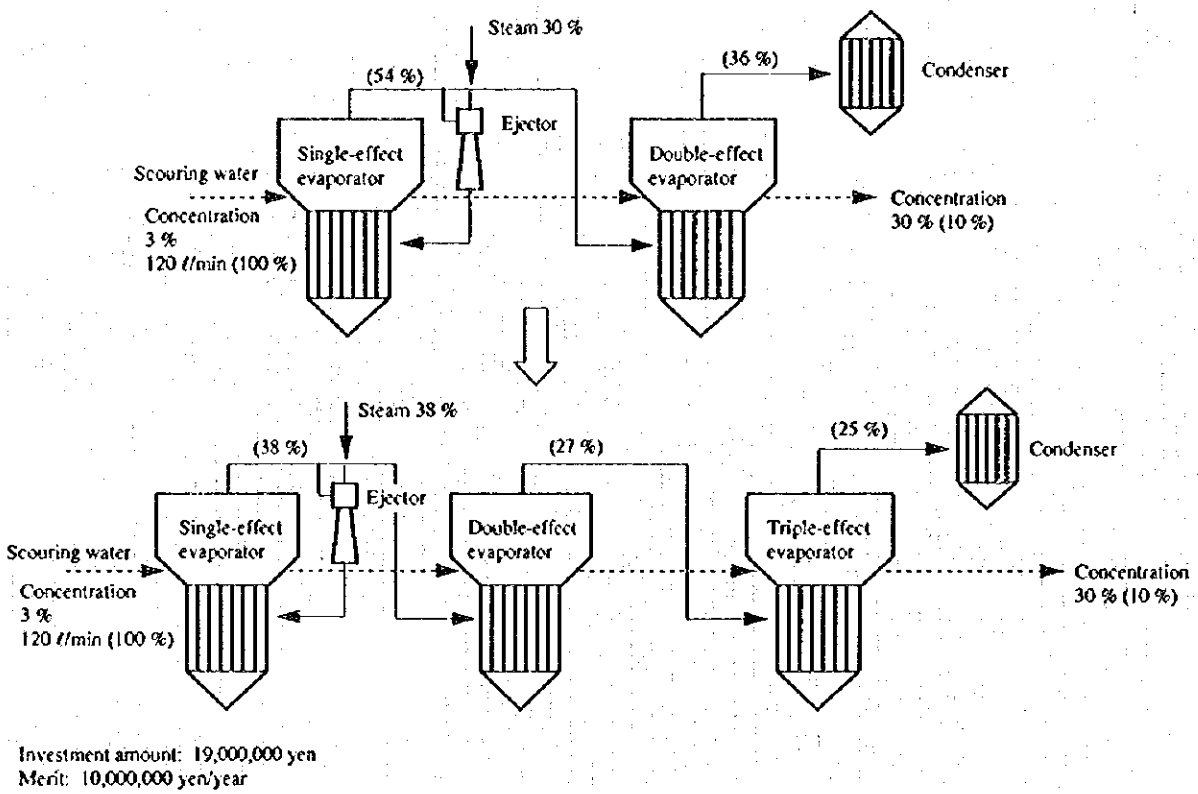
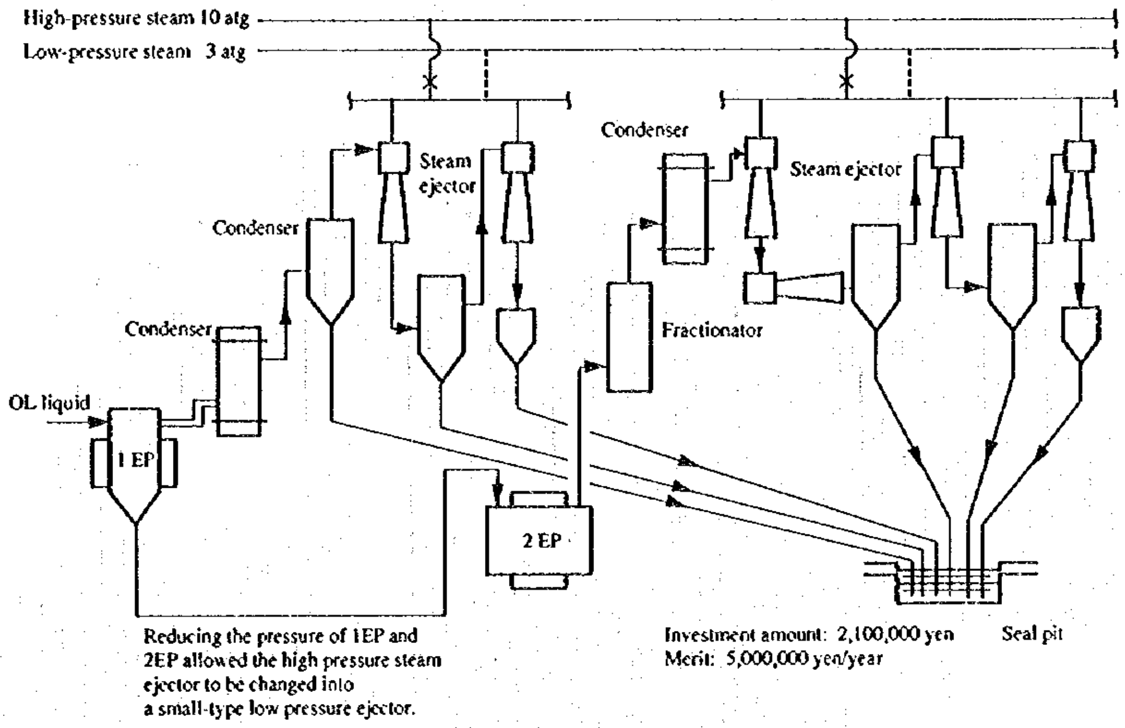


Figure 8.17 An Example of Energy Conservation by Reducing the Steam Ejector Pressure



(3) Energy conservation measures for motor facilities

a. In-house power generation facility

In a chemical fiber plant, steam is used for many purposes such as heating, drying, vacuum, air-conditioning facilities, and so on. Thus, there are many plants having a large-capacity boiler facility. On the other hand, manufacturing processes are made continuous and many of them are accompanied by chemical reaction. Therefore, the time schedule for these processes must be strictly controlled. Under such circumstances, slow-down of the processes due to power failure, etc. give a fatal damage to the product quality. To prevent this problem, factories often have the in-house power generation facility using the steam to secure the electric power for security. In the factories having such a power generation facility, the power generation unit price is lower than the purchased power unit price because steam used in the processes is utilized again. In factories having an allowance in the power generation facility because the volume of steam in use has reduced as a result of energy conservation, increasing the electric power generation is one of the energy conservation measures. Including this, cases of energy conservation in this field are as follows:

① Improvement of boiler combustion efficiency

Burner control

② Prevention of heat loss

Air ratio control, optimization of the steam piping line and size, steam trap control, prevention of steam leakage, enhancement of heat insulation, reduction of the continuously blown volume by water quality control enhancement

③ Switching from electric heating to steam heating

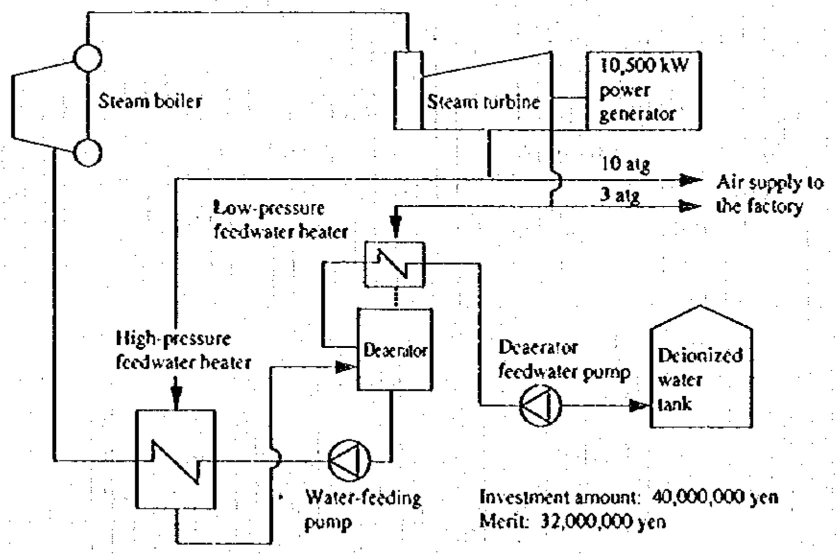
④ Use of the steam-turbine pump motor

⑤ Replacing the turbo freezer with a suction type freezer

⑥ Reducing the pressure for feeding air in the factory and increasing the generated power amount

⑦ Increasing the generated power amount by installing a high-pressure supplied water heater (Figure 8.18 shows the flow.)

Figure 8.18 Installation Example of a High-pressure Feedwater Heater



b. Freezing facility

To manufacture cold water for low-temperature cooling in the processes and as cooling water for the air-conditioning facility, most factories have a freezing facility (i.e. turbo freezer, suction type freezer, water cooler, pumps, etc.). Normally, two or more facilities are running.

Energy conservation measures in this field are as follows:

① Installation of or modification into a double-effect freezer

② Efficient operation by controlling the number of freezers

Normally, factories that have repeated expansion have also added freezing facilities according to the line of manufacturing facilities and these freezing facilities are often grouped. These facilities are reviewed to implement the most efficient running method.

③ Use of river water in the winter season

Normally, the cold water temperature is around 7 °C, so river water or cooling water from the cooling tower can often be used in the winter season. By using such water for the cooling water circulation system, a large energy conservation effect can be obtained.

c. Compressed air facility

Compressed air is used for substitution, metering, operation, and other miscellaneous purposes in the processes. The air is fed after it is divided into a few pressure groups.

① Use at a proper pressure

The pressure of air from the pressure line higher than necessary should not be reduced. By reducing the running pressure of the air compressor, electric power consumption is reduced.

② Air compressors are run most efficiently by controlling the number of air compressors.

d. Water facility

The pump facility often has a sufficient capacity. The delivery pressure is likely to be higher and the capacity is likely to be excessive. Special attention should be paid to serial use or parallel use. Also, it is important to review the existing facility. Although the amount of energy conservation achieved by each facility is small, a significant effect can be expected in total because there are many pump facilities.

Table 8.3 shows an example of reviewing the pump capacity.

Table 8.3 Example of Changing Pump Capacities

	Current Situation		After Improvement		Cost Reduction (Thousand yen/year)
Drain	m³/min mAq kW	(Actual load)	m³/min mAq kW	(Estimated load)	
Discharge pump	4.0 × 12 × 11	(10.3)	4.0 × 5 × 5.5	(4.7)	5.6 × 8,760 × 14 = 678
Cooling tower pump	1.6 × 18.5 × 11	(8.0)	0.7 × 10 × 2.2	(2.2)	5.8 × 8,760 × 14 = 711
Raw water pump	1.6 × 18.5 × 11	(18.85)	3.0 × 5 × 5.5	(3.5)	15.55 × 8,760 × 14 = 1,883
Water supply					
New clean water pump	17 × 10.8 × 45	(38.9)	17 × 5 × 22	(19.8)	19.1 × 8,760 × 14 = 2,342
Old clean water pump	7 × 12 × 19	(15.2)	7 × 5 × 11	(8.2)	7.0 × 8,760 × 14 = 858
Rayon temperature control					
Humidification pump	3.15 × 17 × 15	(13)	2 × 20 × 11	(9.5)	3.5 × 8,760 × 14 = 429
Auxiliary humidifying pump	1.5 × 20 × 15	(12)	0.8 × 20 × 7.5	(7.5)	4.5 × 8,760 × 14 = 552

Investment amount 8,400,000 yen Annual cost reduction 60.85 kW 7,460,000 yen

Practical actions for energy conservation are as follows:

① Cutting the pump impeller

② Switching to a pump with a proper capacity

③ Intermittent running

(4) Energy conservation measures for electrical facilities

a. Power receiving/distributing facility

By attempting to prevent electric power loss, energy conservation is implemented.

① Unification of the power receiving/transforming converters and re-distribution of load

② Installation of capacitors to improve the power factor

b. Electrical components

By increasing the efficiency of electrical components, energy conservation is implemented.

① Adoption of high-efficiency motors

② Replacing with a facility with a proper capacity to increase the motor efficiency

③ Achieving high efficiency by controlling the rotational speed against load fluctuation of large fans, pumps, etc. As an example of controlling the rotational speed, fan control by an inverter or omega clutch is available.

c. Lighting

Proper lighting should be provided at places requiring lighting.

① Proper illuminance

② Turning off the unnecessary lamps (providing a tumbler switch for each lamp)

③ Dividing the lighting line (turning off the lamps near windows)

(5) Energy conservation measures by waste heat recovery

So far, how to reduce the use of energy has been discussed, but it is difficult to make effective use of all energy. Thus, some waste heat will be generated, however efficiently energy may be used. The last issue in discussion of energy conservation concerns how well this waste heat should be recovered and reused. This is a very elementary subject but it may be most important. Recovery and reuse of waste energy is discussed below by source.

a. Recovery and reuse of the steam condensate

For heat recovery from the steam condensate, basically the utilization status of the facility using steam should be thoroughly checked. If the amount of condensate generated in this current status is believed without doubt and an action is planned, the action will become useless when a problem is found later at the location generating condensate. Therefore, care must be taken particularly to the leakage from the trap and bypass valve.

Then, drain recovery may have to be examined in consideration of utilization of the flush steam. A flow should be organized so that drain will be recovered by pressure and the flush steam can be utilized.

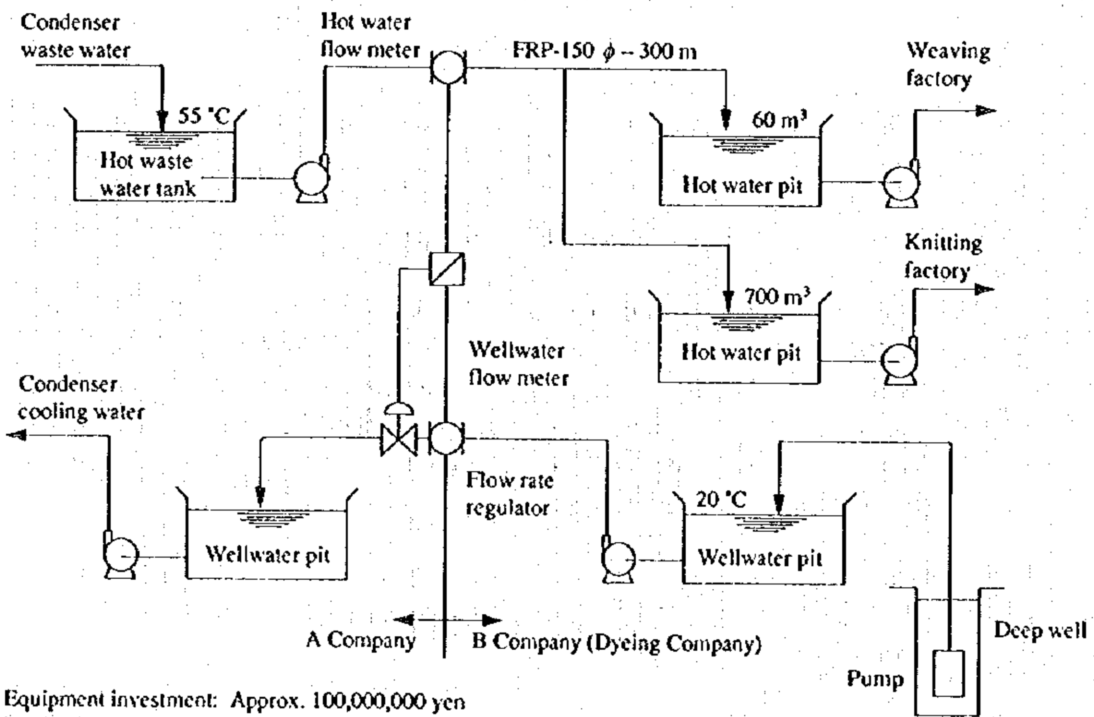
Recovery of condensate via a heat exchanger should be avoided as long as drain quality poses no problem because the recovery efficiency will be extremely low.

b. Recovery of waste hot water heat

There are many types of waste hot water. The temperature and water quality vary depending on the component cooling water, waste water for cleansing, or other purposes. The temperature is mostly as low as 30 to 50 °C.

The most important thing in efficient use of waste hot water is a continuous effort to examine a combination of the waste hot water generated and the consumer to reuse the recovered hot water. Utilization should be considered in inter-process, and inter-factory terms, and still more broadly from inter-company viewpoints. Figure 8.19 shows an example of effective use of waste hot water between adjoining companies. Company A that requires low-temperature cooling water and requires a measure for draining waste hot water and Company B that requires a large amount of fuel cost for manufacturing hot water and has a sufficient amount of pumped well water exchange hot water and cold water to mutually share the merit of saving the fuel cost.

Figure 8.19 Cold/Hot Water Exchanging Flow Sheet



Equipment investment: Approx. 100,000,000 yen
Merit: Approx. 10,000,000 yen/month

For utilization of low-temperature (40 to 50 °C) waste water, the heat pump utilization techniques have recently been developed. Examination on use of these techniques may be effective.

c. Heat recovery from waste gas

As the types of waste gas, waste gas from the product dryer, combustion waste gas from the heat medium boiler, and so on are available.

For utilization of waste gas from the dryer, heat exchange between the exhaust air and supplied air is performed by using a heat pump, achieving satisfactory results. The heat pump is used for heat recovery from the low-temperature waste gas (70 °C) from the rayon cake dryer and from the waste gas (125 °C) from the vinylon sliver dryer.

Also, the use of the heat pump is considered for exhaust gas recovery from the heat setter in the dyeing plant. In this case, however, a washable heat exchanger should be used, because the exhaust gas may contain tar.

Since the exhaust gas from the heat medium boiler is at a high temperature, the recovery merit is large, but corrosion by sulfur in the exhaust gas and the recovered heat utilization method should be thoroughly examined.

Finally, hot exhaust from the fan room, boiler room, dryer room, etc. is effectively used as the air for boiler combustion.

Additionally, exhaust heat from the industrial waste incinerator is utilized positively.

Also, power generation using reaction waste gas or reaction waste heat is often implemented, bringing about satisfactory results.

Table 8.4 lists the future energy conservation measires in production processes.

Table 8.4 Energy Conservation Measures to be Taken Mainly for Production Processes

Equipment Name	Specific Points for Energy Conservation	Estimated Energy Conservation Effect
High-speed spinning equipment	To melt and spin synthetic fibers such as nylon, polyester long fibers, etc., drawing and winding are performed in one process by the use of high-speed spinning method. At the same time, the yarn winding number is increased to produce drawn yarn and semi-drawn yarn. (Energy required for power and heating can be remarkably reduced.)	Energy conservation rate: 58 %
Continuous polymerization spinning equipment	The molten polymer obtained by continuously polymerizing the raw polymer for nylon and polyester fibers is directly fed to the spinning machine. (Energy for heating is drastically reduced.)	Energy conservation rate: 43 %
Re-utilization of steam Vacuum evaporator	Coagulating medium and solvent monomer are concentrated and recovered by fractional distillation of the spun yarn coagulating medium or the monomer-containing water by means of steam. This equipment consists of 3 or more linked vacuum evaporators. (Energy for concentration recovery is drastically removed.)	Energy conservation rate: 46 %
Class 2 absorbtion type heat pump method Heat source equipment	A large quantity of hot waste water from the production process of chemical fibers, etc. is utilized as heat source for the drive to generate reusable high-temperature water or steam. (Energy required for heating is remarkably reduced.)	Energy conservation rate: 50 %

Table 8.5 lists the items to be reviewed in energy conservation technology development.

Table 8.5 Energy Conservation Technologies to be Developed

	Technology
1.	Introduction and promotion of cogeneration (heat recovery and power generation system)
2.	Advanced (High-level) technology for utilization of coal and oil cokes
3.	Heat pump
4.	Film utilization technology
5.	Fuel battery
6.	Utilization of solar energy
7.	High-efficiency gas turbine technology
8.	High-efficiency combustion technology
9.	High-efficiency combined power generation technology
10.	Utilization of far infrared rays
11.	Utilization of LNG and LPG
12.	Biomass energy

8.3.2 Spinning

(1) Basic measures

Figure 8.20 shows the points to be checked before taking various kinds of energy conservation measures.

Figure 8.20 Check Points in First Step

Motor performance check

- Measure motor power, and adjust or replace defective motors.
- Reduce the differences among the motors.

Reducing the motor base load

- Adjust belt and tape tensions.
- Correct the engagement of gearwheels and center the motor bases.
- Optimize cleaning, oiling, and maintenance intervals, and perform them thoroughly.

Study of economical speed

a. Motor performance check

The power of the motor of each machine should be measured, and troubles should be checked for. If any faulty machine is found, it should be re-adjusted or replaced depending on the fault. Thus consideration should be given to minimize the unevenness of the performance of each machine. In replacing a motor, the introduction of a high efficiency motor should be taken into account.

b. Reducing the motor load

Each motor should be surely centered through proper maintenance. Further, the tension of belts and tapes, means for driving each part, should be correctly adjusted and the engagement of gearwheels should be corrected. Moreover, the intervals of periodical cleaning, lubricating and maintenance should be optimized and thoroughly performed. Try to keep the motor under control through the practices mentioned above. On the other hand, it is also important to introduce bearings into the driving parts and smooth their rotation.

c. Study of economical speed

The increase of the production machine speed will exponentially increase the energy consumption. It is advisable to find the number of units in operation and revolution most economical based on a production, and establish them as operation standards.

Then, Table 8.6 shows an example of energy conservation measure for each process.

Incorporating systematic energy conservation action into the daily management allows a substantial result to be achieved.

Table 8.6 Example of Energy Conservation Measures for Individual Processes (1/3)

Process	Measure	Description (Example)	Remarks
Scutching	1. Optimizing condenser fan speed	• 1,200 rpm → 1,000 rpm	• Be careful of blow of fibers to cage surface and duct blocking.
	2. Reducing operating speed of dust collector fan	• Down about 10 %	• About 10 % seems to be the limit, considering the effects on dust collection, etc.
	3. Stopping scutching fans	• Fans that can be substituted by duct collector fans are stopped.	• This means cannot be taken if indoor environment changes due to fan stoppage. • This measure may be taken if other fans have extra capacity to compensate for suction fan stoppage.
	4. Total stoppage of scutching machines	• Scutching machines are totally stopped only in emergencies. Instead of this conventional practice, stop all scutching machines in ordinary cases where their stoppage is necessary.	• Reduce the number of processes if possible.
Carding	1. Reducing operating speed of cylinder	• Use driving pulley of smaller diameter.	• Consider effects on quality.
	2. Use of ball bearing in place of doffer metal	• Use ball bearings in place of plain bearings.	• Effective for not only power saving but also oil saving and labor saving.
	3. Intermittent operation of cotton and dust collectors	• Change constant suction of flat strips to intermittent suction.	• Power can be saved by stopping constant suction equipment. • Power can be saved by reduced carrier air rate incidental to reduced volume of return.
	4. Intermittent operation of blow cleaners	• Operate suction blow cleaners intermittently.	
	5. Reducing operating speed of main blower for dust collector	• Stop dust suction at taker-in.	• Indoor cleanliness remains hardly changed.
Combing	1. Stopping creels of predrawing machine	• Stopping creel rollers	• Power saving effect is not so much, but creels no longer need maintenance.
	2. Reducing operating speed of pneumatic fan for lap former	• 2,240 rpm → 1,640 rpm	• Static pneumatic pressure above a certain level is unnecessary depending on the cleanliness of roller parts.
	3. Reducing pressure of compressor for auto lap changer	• Auto lap changer's perssure is 6.5 kg/cm^2. Compressor (primary) pressure is reduced from 9 kg/cm^2 to 7 kg/cm^2.	• Reduce required air volume by enforcing proper maintenace of auto lap changer (preventing air leaks; centering various parts).

Table 8.6 Example of Energy Conservation Measures for Individual Processes (2/3)

Process	Measure	Description (Example)	Remarks
Combing	4. Reducing operating speed of comber cylinder brush	• 1,240 rpm → 780 rpm	• Cylinder needles are hardly blocked in uni-combing. Brush operating speed (rpm) shoud be about 5 times that of cylinder.
	5. Interlocking operation of comber fans	• Interlock machine motors and fan motors so that fans stop when machines are stopped.	• Interlocked operation will not cause sliver trouble at start/stop of machines.
	6. Reducing operating speed of comber suction fan	• 1,970 rpm → 1,600 rpm • 40 mmAq → 32 mmAq	• Because of sliver joining, static pressure of 25 to 30 mm Aq is sufficient for perforated roller. Determine operating speed of suction fan depending on cleanliness of draw part.
	7. Reducing operating speed of comber exhaust fan	• Down 20 % to 40 %	• Underground duct suction has excess capacity because of dust collection and recovery equipment. • Spinning is hardly affected even though individual machines air flow rate is reduced.
Roving	1. Driving upper and lower Ermen's clearers with back roller	• Upper and lower Ermen's clearers are driven with chain from back roller.	• No problem arises from driving clearers with back roller.
	2. Interlocking pneumatic motors with machine motors	• Interlock pneumatic motors with machine motors so that pneumatic motors stop when machine motors are stopped.	• It is not necessary to keep pneumatic motors operating at all times.
Spinning	1. Using bearings for draft rollers	• Use bearings for bottom and top rollers.	• Consider this measure for not only saving power but also quality and maintenance.
	2. Changing spindle tape	• Replace with elastic spindle tape.	• Tape slip will decrease by half, and variation rate will also sharply improve to make thread quality more constant. Power saving effect is great.
	3. Using narrowing spindle tape	• Elastic tape: 13 mm → 11 mm	• Take slip ratio into consideration.
	4. Reducing spindle tape tension	• 1.9 → 1.5 lb/4 sp	• Take slip ratio into consideration.
	5. Using spindle wrap of smaller diameter	• 23.8 → 20.2 mm	• Take this measure when spindle insert is renewed.
	6. Using tin pulley of lighter weight	• Tin roller → Lightweight tin pulley or bakelite tin pulley	• Take this measure when old tin roller must be replaced.
	7. Pneumatic impeller cut	• Cut impeller for pneumatic fan.	• After cutting impeller to smaller diameter, adjust balance. Otherwise, vibration occurs.

Table 8.6 Example of Energy Conservation Measures for Individual Processes (3/3)

Process	Measure	Description (Example)	Remarks
Spinning	8. Interlocking pneumatic with main body		• Effective also for reducing thread breakage at start.
	9. Intermittent operation of overhead cleaner	• Operate at half-hour interval instead of continuous operation.	
	10. Changing drive belt	• V-belt → Cog belt	
	11. Removing auto doffer clip		
	12. Changing open end rotor drive belt		
	13. Improving power factor	• Use low-voltage condenser.	
	14. Using high-efficiency motors	• Replace existing motors with high-efficiency motor for energy conservation.	
Winding	1. Changing drive belt	• V-belt → Plain belt (elastic spindle tape)	
	2. Reducing area of blower opening	• Reduce blower suction port to lower static pressure.	• Pulley down not possible because motors and fans are directly connected.
	3. Integrating blowers	• Auto corner: Integrate 6 blowers. • Couple to automatic cop feeder blower motors. • Use centralized exhaust system, and newly employ motors specially designed for low-pressure fans. • Individual blowers → Large blower.	• If exhaust air from each blower flows into room, room temperature rises. This measure is taken to prevent it.
Air conditioning	1. Reducing operating speed of air conditioning fans		• Drill shaft hole in motor pulleys on hand.
	2. Reducing operating speed of prespinning carrier fan	• 2,590 → 1,735 m^3/min	
	3. Reducing operating speed of spinning carrier fan	• 360 → 325 mmϕ	• Use pulleys on hand.
	4. Reducing size of finish spray blower		

(2) Energy conservation measures for individual processes

a. Blowing

The blowing process is composed of a linkage of many machines having different purposes. In many cases, individual machines are provided with a fan for collecting dust and use air to transport material fiber. The power consumption of the blower systems is measured, and, when air is throttled by dampers, the number of revolutions of the blower is decreased to control the discharge pressure and the air flow of each system .

For the prevention of troubles during operation, it is advisable to reduce the number of revolutions of the blower by approx. 10 %, then observe the condition of operation, and further, reduce the number of revolutions by stages with an increment of 5 %.

b. Carding

An energy conservation measure must cover carding machines because of their large number. The rotary body of a carding machine is heavier than that of other production machines.

Introducing bearings will reduce the power consumption of the old type carding machines. The new type machines are provided with a separate dust collector, and the automation of dust collection contributes to the saving of labor, and the improvement of quality and working environment. However, the blowers for dust collection do not deliver their full power yet, and the efficiency of the blowers is low in general.

Grouping or centralizing the separate dust collectors will conserve energy.

c. Drawing and roving

The new type drawing machines and roving machines are provided with a large pneumatic dust collector. Reducing the outside diameter of the impellers of blower (impeller cut) is one of the common energy conservation measures.

The configuration of the roving machines is similar to that of the ring frames mentioned below. The energy conservation measures for the machines can be considered to be in accordance with that for the ring frames.

d. Energy conservation measures for ring frame

① Introducing bearings into draft part

With the shift from the conventional roller weight to the top arm, the power consumption is reduced by introducing bearings.

② Retrofitting spindle part

The width of the spindle tape is reduced and the material is replaced with elastic one. The friction loss with air is thereby reduced. Slipping is prevented by the employment of elastic material.

The routine control is tightened: For example, the amount of lubricant to the spindle supports is reduced.

The diameter of the spindle wheel has a tendency to be smaller; however, this increases the cost of retrofitting. Therefore, this should be considered together with increasing the number of revolutions.

③ The pneumatic waste suction apparatus associated with the ring frame has been made larger in capacity with the improvement of productivity. However, there is a trend that the capacity of the pneumatic waste suction equipment blower is reduced by reviewing the economical operation speed of ring frames and tightening the routine control against duct clogging.

For the existing blowers, cutting the outside diameter of the impellers will bring about a considerable energy conservation effect. The centralized system, mentioned in the section of carding, is also introduced .

④ It may be another energy conservation measure to make intermittent the operation of the ring frame traveling cleaners for removing flies, or to increase the coverage of the traveling cleaners.

⑤ When an aged main motor is replaced, a high efficiency motor is introduced.

e. Winder

Winders were modernized earlier than machines of any other processes, and many high performance winders have been introduced.

For these high performance winders, however, their blowers for yarn collectors consume a considerably large quantity of power. For an energy conservation measure, a system is widely employed which groups five to ten units of yarn collectors and centralizes their suction lines.

In this case the specifications of a blower selected will determine the effect of energy conservation.

f. Air conditioning (refer to the volume of electricity.)

① Reviewing the air conditioning load

Approx. 30 % of power for direct production is consumed for air conditioning.

The air condition in a spinning process influences the quality of yarn and the productivity, and individual factories have established their own conditions. However, it is necessary to review these conditions as required with the advance in technology.

Table 8.7 shows an example of temperature and humidity standards.

Table 8.7 Standard Humidity by Fiber Materials and Processes

Process	Cotton	Worsted	Synthetic Fiber
Blending and scutching	45 ~ 60 %	– %	– %
Carding	45 ~ 55	65 ~ 70	55 ~ 65
Combing and gilling	55 ~ 65	60 ~ 70	
Drawing	50 ~ 60	50 ~ 60	
Prespinning	50 ~ 60	50 ~ 60	
Spinning	50 ~ 65	50 ~ 55	60 ~ 65
Winding	60 ~ 70	50 ~ 60	60 ~ 70
Twisting	60 ~ 70		
Warping and reaching	60 ~ 70	50 ~ 60	
Weaving	70 ~ 85		

Note 1: Temperature: 24 – 29 °C
2: The conditions of the carding process is as per the Bradford sytem.
[Sorce: Text. World]

In a factory in Japan they varied the temperature and humidity by stages and checked the quality of yarn wisps and the working environment each time, and thereby found the limit within which no problem will be caused. They, who used to apply consistent conditions throughout all seasons, established new conditions for each season based on the findings, and achieved the reduction of 14 % of refrigerating load and 16 % of humidifying heating steam.

Enhancing the thermal insulation of the building and heating equipment leads to the reduction of load.

Moreover, it reduces the cooling load and heating load by efficiently utilizing fresh air in mild seasons.

② Changing spray nozzles

When directly cooling air using cold water sprays, enlarging the spray nozzles and reducing the number of them will reduce the original pressure. This reduces the power of pumps and may reduce the number of pumps as well in some cases.

In a factory in Japan, for example, they used to use 15,400 nozzles of 4 mm in diameter and replaced them with 212 nozzles of 44 mm in diameter. This reduced the spray pressure of 3 kg/cm³ to 2 kg/cm³, saving approx. 470,000 kWh of electric power per year.

The air conditioning systems called a carrier in spinning and weaving mills, directly sprays cold water (L) in air (G), and transports the resultant cooled air into the building as supply air. In many cases the operation is controlled, as the ratio of the weight of L to that of G is 1:1. In this case, properly maintaining spray water nozzles may reduce the weight ratio of L/G down to 0.7 or so; in outdoor air using seasons, that is, mild seasons and winter, L/G may be further reduced to 0.3 or so.

③ Introducing a high efficiency refrigerating machine

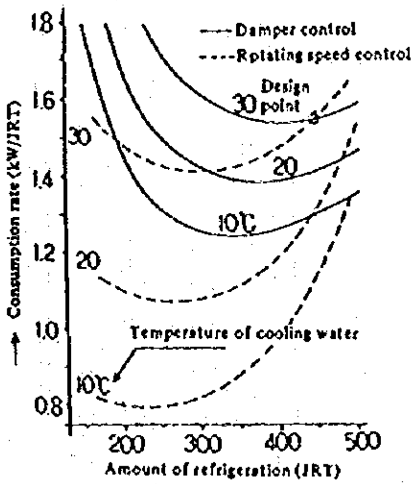
An aged refrigerating machine does not deliver its full performance.

In a factory in Japan, refrigerating machines of a design intensity of 1.28 kW/JRT (Note: 1 JRT=79,690 kcal/d) had been degraded and the intensity fell to 1.41 kW/JRT; so, they replaced them with high efficiency refrigerating machines of an intensity of 0.91 kW/JRT, saving 750 kW.

④ Controlling number of revolutions of a refrigerating machine

In case the load is largely fluctuated in a factory using turbocompressors, the control of the number of units or revolutions is effective. Figure 8.21 shows an example of the reduction of the power consumption.

Figure 8.21 Characteristic Comparison of Capacity Adjustment



⑤ Saving the carrier power

Measures for saving the carrier power include the control of the rotation number of fan-pump, change of pulley diameter, reduction in the impeller diameter, exchange to small-sized high-efficient fan-pump, etc.

(3) Case study of energy conservation measures for the spinning process

Assumption:

Assuming that the process conditions are constant for all the individual processes, the energy conservation effect in each process was calculated.

Figure 8.22 shows an energy conservation measure taken for each process and the effects.

Figure 8.22 Example of Energy Conservation Measure under Constant Process Conditions (Power consumption for direct production: 520 kWh/400 lbs)

Prespinning
- Replacing bale opener and hopper bale breaker ..... Δ 1.78 kWh/400 lbs
- Reducing operating speed of dust collector fans ..... Δ 0.86 kWh/400 lbs
- Interlocking comber fans ..... Δ 1.41 kWh/400 lbs

Subtotal: Δ 4.05 kwh/400 lbs (0.8 %)

Spinning
- Using smaller-diameter spindle wharve ..... Δ 13.28 kWh/400 lbs
- Using elastic tape ..... Δ 13.28 kWh/400 lbs
- Tin pulley (bakelite) ..... Δ 9.83 kWh/400 lbs
- Cutting pneumafil impeller ..... Δ 3.47 kWh/400 lbs
- Intermittent operation of overhead cleaners or arranging them in series ..... Δ 10.35 kWh/400 lbs
- Using high-efficiency motors ..... Δ 10.09 kWh/400 lbs

Subtotal: Δ 60.30 kWh/400 lbs (11.6%)

Winding
- Intergrating blowers ..... Δ 18.25 kWh/400 lbs (3.5 %)

Total: Δ 82.60 kWh/400 lbs (15.9 %)

It turns out from this case study that the energy conservation measures had the greatest effect in the winding and spinning processes. Figure 8.23 shows the power consumption per bale (400 Lbs) for each process; Figure 8.24 is the Pareto's diagram of the required power for each process.

Figure 8.23 Required Power per Bale

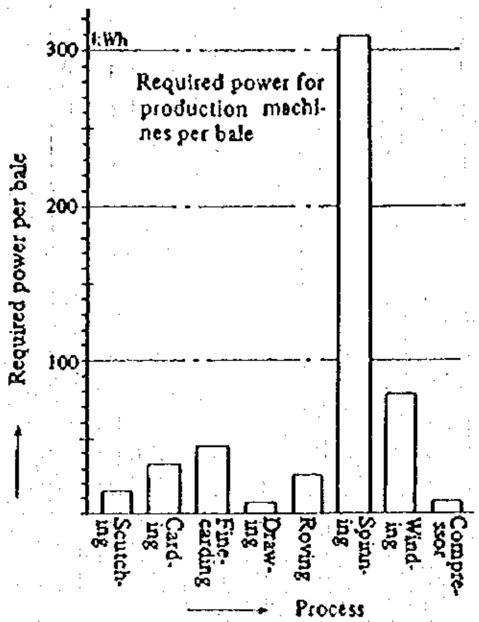
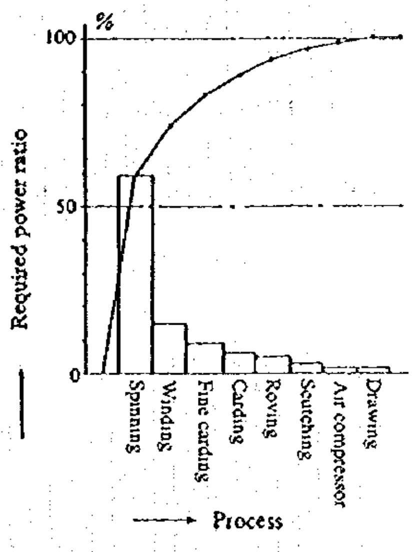


Figure 8.24 Pareto's Diagram of Required Power (%)



(4) Challenges in energy conservation

Listed below are considerations for future energy conservation in the spinning process:

① Review the process design conditions (e.g. number of revolutions).

② Review the size and unit quantity of individual packages.

③ Consider the flat belt material and replace the V-belts with cog belts.

④ Develop an energy conservation type rubber roller.

⑤ Introduce ball bearings into the skewer metal.

⑥ Make the shafts lubrication-free.

⑦ Thoroughly control idle spindles (using computers).

⑧ Improve the operation efficiency to shorten the operation time.

⑨ Reduce the diameter of the pneumatic fan impellers.

⑩ Centralize the air compressors.

⑪ Centralize the dust collector fan for machine.

⑫ Change the use of compressed air for cleaning.

⑬ Shorten the time of the dust and cotton collector intermittent operation.

⑭ Recover and reuse the waste heat from the spinning machines.

⑮ Introduce high efficiency spinning machines (winders and twisting machines).

8.3.3 Weaving (Including wool fabric)

(1) Works before implementing energy conservation measures

A larger number of production machines with a smaller motor capacity per unit are installed in the weaving process than in the spinning process. Accordingly, the weaving process is characterized by the difficulty of implementation of efficient energy conservation measures.

It is necessary to thoroughly implement basic measures as in the spinning process.

(2) Energy conservation measures for individual processes

a. Preparation process

The preparation process consists of the rewinding, weft winding, warping, sizing, and reaching. The utilities supplied to the process include electric power, steam, water, and compressed air.

1) The electric energy is used as power for driving production machines. The energy is also consumed by the following:

① Dust collector suction blowers for collecting dust and cotton

② Compressed air for removing yarn waste and flies

- The power consumption of a blower for collecting dust is in proportion with the third power of the number of revolutions of the blower. If you can manage to reduce the required air quantity and the number of revolutions of a blower by 10 % by reducing the area of its suction opening and reviewing the interval of cleaning its filter, it saves electric power by 23 %.

- Reducing compressed air pressure for cleaning

Reducing the discharge pressure of the air compressors will save electric power.

If you reduce the air pressure of 7 kg/cm^{2}G to 5 kg/cm^{2}G, it saves electric power by approx. 14 %.

If the existing nozzles for cleaning, many of which are self-made, are replaced with ones of gun type that can be opened/closed with a lever, it will have a great sufficiency of saving.

2) Sizing machine

① Enhancing thermal insulation

Provide the tanks, headers and piping with complete thermal insulation.

② Mounting a hood

A hood helps to maintain temperature around the cylinders and promptly remove vaporized moisture.

③ Squeezing at a high pressure

There is a case where increasing the squeeze pressure after sizing from 350 kg to 1,500 kg reduced the amount of moisture to be vaporized by 33 %.

④ Changing the type of size

Changing the type of size enables preparing the size and sizing at low temperature. There is a case where reducing the preparation temperature from 130 °C to 80 °C saved steam by 13 %.

⑤ Increasing the number of yarns sized at a time

Increasing the number of yarns sized at a time reduces the speed but contributes to energy conservation after all.

⑥ Improving the heat transfer property of cylinder

Adjust the siphons and locate the traps so that condensate in the cylinders will be smoothly removed.

⑦ Recovering condensate

Refer to the volume of boiler steam.

⑧ Controlling exhaust from hot air drier

The thermal efficiency of the hot air drier is lower than that of the cylinder drier. Therefore, the amount of exhaust air and the drying temperature are controlled to prevent overdrying.

b. Weaving

1) Almost all of the weaving machines are shuttle driving type machines called loom, and a large number of them are installed.

   Electric energy is consumed for the rotation and reciprocation of looms, and this is different from cases of the other production machines.

   The basis of energy conservation measures for the weaving process is proper maintenance.

2) Energy conservation measures for weaving process

   ① Reduce the suction area of the yarn waste suction blowers and prevent yarn waste clogging.

   ② Employ energy conservation drive belts for power transmission.

   The shift to the cog belt will reduce the power consumption by 4 %.

   ③ Correct the belt tension.

   ④ Control the lubrication to individual parts of the machines (proper amount of lubricant, early repair of leakage)

   ⑤ When renewing a drive motor, employ a high efficiency one (It is estimated that the difference in price between a standard type and a high efficiency type will be paid in one or two years).

   ⑥ Control the compressed air for cleaning in accordance with the description in the section of "Preparation Process".

   ⑦ Air conditioning equipment

   Some types of weaving yarn require a high humidity of 70 to 80 % RH. The air washing system together with indoor direct humidifying system is in common use. Increasing the rate of indoor direct humidification enables the reduction of the air feed amount, and the reduction of the number of revolutions of blowers reduces the power consumption.

⑧ New type loom

Compared with the shuttle type loom, the air jet loom and the water jet loom are of energy conservation type. However, these new type looms require compressed air, pressure water, electric heating cutters and driers in addition to fundamental driving power. Accordingly, energy conservation measures for these peripheral devices are required.

For the air jet loom, it is required to set a driving air pressure according to types of products; for the water jet loom, it is necessary to efficiently vaporize the moisture content in the ground fabric .

⑨ Introducing a production monitoring system

This is to reduce the machine interruption loss due to end breakage and thereby improve the working ratio. There is a case where the working ratio was improved by 10 % or more.

⑩ Maintain machinery

- Prevent the idle running of the motors.
- Correct the belt tension.
- Correct the amount of lubrication.

The implementation of these basic items is indispensable.

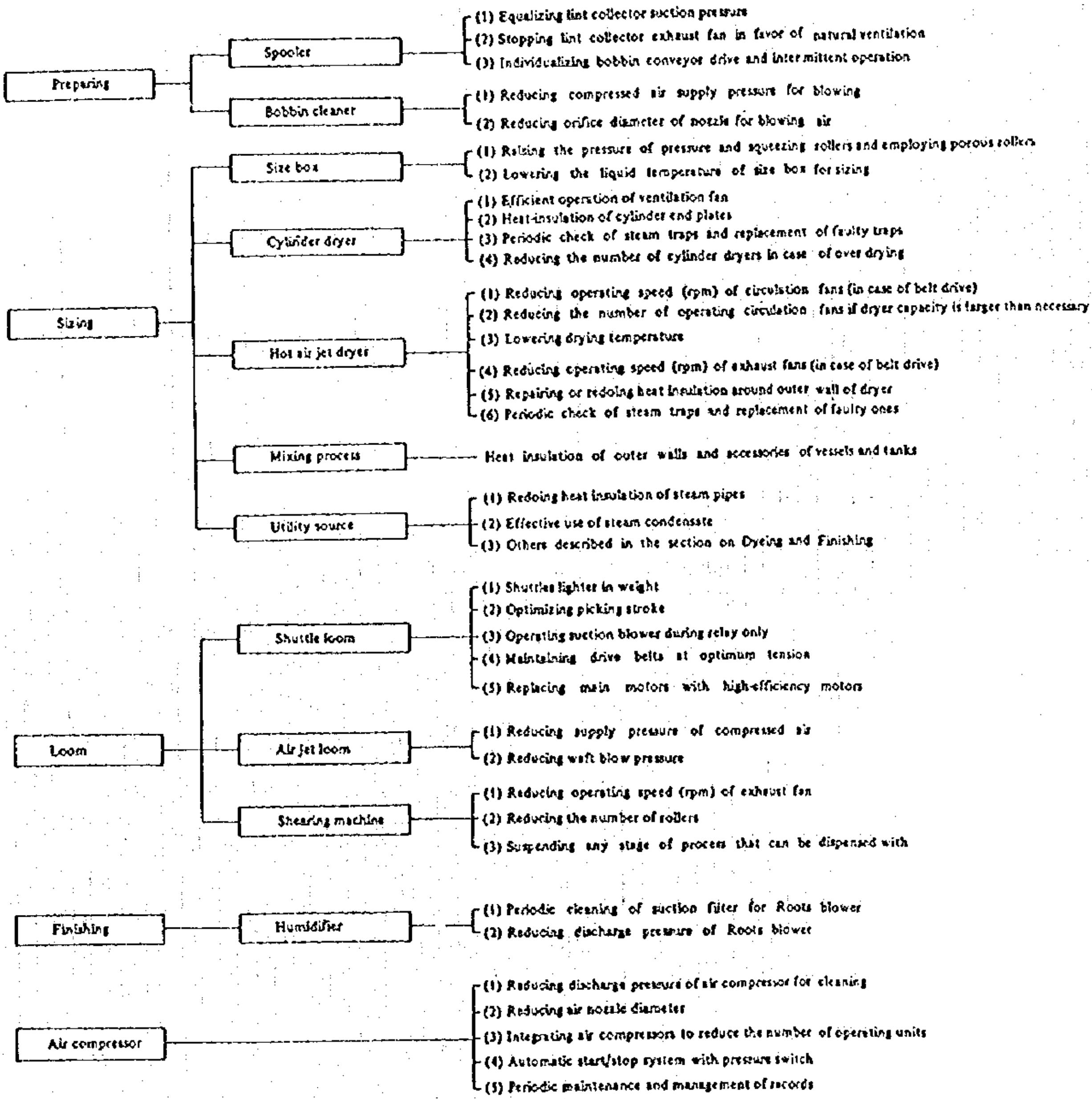
c. Finishing

Shearing is one of the finishing processes in which a large quantity of electric power is consumed. Especially, the dust collectors occupy a large portion of the power consumption.

This process is the final one in the manufacture, and care should be taken to prevent troubles from occurring in quality.

Figure 8.25 shows the energy conservation measures for individual processes.

Figure 8.25 Items of Study for Energy Conservation in Individual Processes (for weaving)



8.3.4 Dyeing and Finishing

(1) Reducing the bath ratio

The dyeing industry consumes a large quantity of water, and hot water is often used. Therefore, saving water leads to saving thermal energy.

The quantity (L) of water used to dye 1 kg of fabric is called bath ratio, which largely varies depending on dyeing methods and types of dyeing machines.

The following measures are taken in the dyeing process:

a. The bath ratio is lower in hank dyeing than in cheese dyeing; that of the former is 25 to 35, and that of the latter is 8 to 15.

b. Even in cheese dyeing, changing the winding density and the spindle arrangement reduces the bath ratio.

c. If dye is distributed evenly in the form of foam or mist, the bath ratio is reduced to 3 or below. The foam dyeing applies to plain solid dyeing: Dye is bubbled using air into fine uniform foam, and applied to fabrics.

d. For blended yarn fabric, changing the two bath dyeing to the one bath dyeing is effective in the reduction of the bath ratio and the shortening of the dyeing time. A variety of low bath ratio dyeing machines has been developed.

   The low bath ratio type dyeing machine rotates a fabric at a high speed of 200 m/min or above or vibrates it, and thus ensures the sufficient contact between them. This method achieves a bath ratio of 1 :11, whereas the bath ratio of ordinary type dyeing machines is 1:20 to 30. Table 8.8 and 8.9 show the performance of the low bath ratio type dyeing machine and that of conventional ones.

Table 8.8 Example of Performance Comparison

	Length of Work	Amount of Liquid	Weight of Fabric	Amount of Steam	Amount of Steam per m	Amount of Steam per kg of Fabric
Conventional	300 m	4,000 ℓ	514 g/m²	1,473 kg	4.91 kg/m	9.54 (100)
Low bath ratio type	500 m	2,000 ℓ	409 g/m²	440 kg	0.88 kg/m	2.15 (23)

Table 8.9 Example of Power Consumption Comparison

	Electric Power		Load Factor		Dyeing Time Each Time		Electric Energy Each Time		Length of Work		Electric Energy per m
Conventional	24 kW	×	0.8	×	2.5	=	48	+	300 m	=	0.16 kWh/m (100)
Low bath ratio type	16.5 kW	×	0.8	×	2.5	=	33	+	500 m	=	0.066 kWh/m (41)

Moreover, a system has been developed which reduces the required energy to 1/10 or less using rapid heating by microwaves.

(2) Reducing the amount of cleaning water

Various efficient cleaning machines have been developed. The principles of these machines are as follows:

a. Increase the number of times of contact between fabrics and water.

b. Feed water in a flow counter to that of fabrics.

c. Provide fabrics and water with vibration.

The efficient cleaning machine uses these principles to enhance the cleaning effect. There is a case where the amount of water and steam was reduced to 1/10 and the power consumption was reduced to 1/4 compared with those of conventional machines.

(3) Shortening the dyeing time

For polyester dyeing, a technique has been developed which maximizes the temperature rise to the extent that dyeing is not influenced and makes level dyeing unnecessary.

(4) Reducing processing temperature

Try to reduce the bleaching and dyeing temperature by changing liquor. For water washing, it should be considered whether the temperature can be further reduced.

(5) Saving drying energy

a. Dyeing is a process which repeats dipping into liquor and drying many times. For some types of fabric, the drying process is omitted; fabrics are only squeezed and forwarded to the next process (Wet on Wet method). In some cases, for example, a technique to uniformly apply finishing agent to a wet cloth was developed, and the drying process after the dyeing process was omitted. It has been reported that this achieved the energy conservation of 8 % or more. Refer to <Case 1>.

b. Before drying, sufficient dehydration is performed using a mangle to save thermal energy. Rubber coated rolls of an appropriate hardness are used; the rolls are so adjusted that the linear pressure will be even in the direction of width. More efficient equipment include ones using a non woven fabric roll and vacuum type which sucks through slits. The hydration by blowing air at a high speed is also effective.

   25 to 50 % of moisture content is removed. Therefore, there is a case where the drying speed was doubled and the drying cost was reduced by 17 %.

c. When dried too much, fibers, when left in air, absorb moisture to the equilibrium moisture content. Therefore, overdrying more than specified in Table 8.10 will result in the loss of energy.

Table 8.10 Norms for Exit Moisture Percentage (20 °C/65 % RH)

Material	Exit Moisture Percentage (%)
Cotton	7.0
Polyester	0.4
Nylon	4.5
Viscose	12.5
Wool	16.0
Polyester-cotton blend (2:1)	2.5
Polyester-wool blend (2:1)	5.5

Source: F. C. Harbert, International Dyer, Vol. 142, No. 2, (1972), p. 102.

d. The hot air drier circulates hot air, and accordingly, raises the drying temperature, leading to energy conservation. Periodically measure the moisture content in exhaust air, and adjust the relieving amount based on the measurement result. In case flammable solvent is contained, care should be taken for the prevention of explosion.

   For the drying of wool fabrics, consideration should be given to the introduction of automatic control of the drying temperature and the exhaust air humidity for the prevention of overdrying as well as for the purpose of quality control.

e. With respect to thermal efficiency, the cylinder (slasher type) drier is more advantageous than the hot air drier. For efficiently utilizing cylinder driers, it is important to inspect and maintain the internal siphon pipe and the steam trap for extracting condensate from inside cylinders.

f. In applying liquor, such as waterproofing agent, to a fabric, minimizing the amount of application using a mesh roll will save drying energy.

(6) Preventing loss of heat

a. Many dyeing machines and washing machines are provided with no thermal insulation. This is because the conventional fiber or porous thermal insulation materials absorb moisture easily and to use them in a high humidity atmosphere, such as a dyeing factory, a larger cost is required. However, a closed cell type water repellent plastic foam was recently developed, and it has been used together with chloroprene adhesive. Polypropylene and hard urethane can be used at a temperature of up to 120 °C; intermediate pressure polyethylene foam is applicable at 100 °C or below.

Simpler methods have been implemented. For example, there is a case where thermal insulation material was just wrapped with vinyl sheets attached like skirts for preventing water and steam was thereby saved by 20 % or so.

b. Hot water storage tank

Provide the hot water storage tanks with thermal insulation as well, and place a cover or a floating cover to prevent the loss of heat from the surface.

c. Provide the outer wall of the driers with thermal insulation, and lessen the openings as much as possible.

(7) Recovering waste heat

Table 3.11 shows an example of analyses of the thermal energy consumption in dyeing factories. It turns out from the table that a large part of heat is lost through waste liquor. For this reason there are a lot of cases where heat of dyeing waste liquor is transferred to supply water or hot waste water is used for counter-current multi-stage washing.

Table 8.11 Thermal Energy Consumption State
(Intermediate Scale Dyeing Factory)

Item	Percentage (%)
Product heating	16.6
Product drying	17.2
Waste liquor loss	24.9
Heat release from equipment	12.3
Exhaust loss	9.3
Idling	3.7
Evaporation from liquid surface	4.7
Unrecovered condensate	4.1
Loss during condensate recovery	0.6
Others	6.6
Total	100.0

<Case 1>

(1) Employment of wet on wet finishing for knitted fabric dyeing

a. General description of factory

- Products : Dyeing of circular knitted fabric of polyester/cotton (blended yarn fabric, union cloth), cotton and so on.
- Number of employees: 205
- Energy consumption : 11,025 kL calculated in terms of crude petroleum

(2) Selection of energy conservation measure

Among the dyeing processes (refer to Figure 8.26) for knitted fabric, the drying process, which used the largest quantity (13.7 %) of energy among all the processes, was omitted to reduce the energy consumption and the time when work is in process for the improvement of the productivity.

Since wet fabrics soaked with dye are processed in the finishing process, the technique is called wet on wet.

Figure 8.26 Finishing of Knit

Process / Feeder	Mercerizing • Scouring	Coloring	Drying	Finishing	Inspection • Shipping
Processing capacity (m/min)	30~60	(100,000m/day)	50	40	
Energy consumption rate	12.0	59.7	13.7	14.0	100%

(3) Problems and energy conservation measures taken

a. Problems in directly feeding wet fabric to finishing process

① For fabrics soaked with dye, difference is produced in moisture content between upper and lower fabrics with the passage of time, and this results in the uneven fixation of finishing agent in the finishing process.

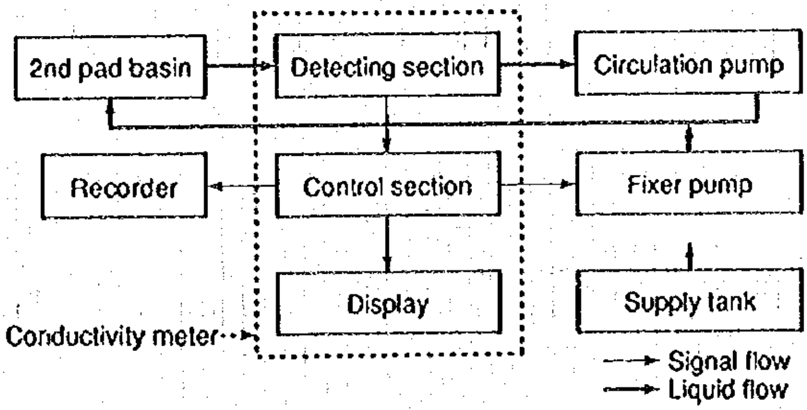
② Finishing agent in the liquor baths is diluted with the passage of time by moisture carried by fabrics.

b. Countermeasures

① Uneven fixation of finishing agent: Two stage padding system

② Variation in concentration of solution in liquor baths: Automatic control of concentration of solution in liquor baths (Refer to Figure 8.27.)

Figure 8.27 Agent Concentration Control



③ Measurement of finishing agent concentration → The alternative characteristic of inorganic electrolyte solution concentration is used.

It was verified through measurement that the relationship between the concentration of the finishing agent added to 10 % inorganic electrolyte solution (Na_2SO_4, NaCl) and the conductivity is proportional.

(4) Effects of measures (assuming that the wet on wet method is applied to 50 % of the whole facility)

a. Saved energy (comparison of the energy consumption before and after the implementation of the wet on wet method)

Fuel: 28,560 L/month (3.8 % reduced), Electric power: 30,167kWh/month (3.6 % reduced)

b. Improvement of overall process capability by the reduction of time when work is in process

357 hrs per month was saved and the productivity was improved.

c. Drier operation

Before implementation: 24 hrs × 2 units

After implementation : 18 hrs × 1 unit

d. Effect of investment (investment payback year)

Cost of improvement : U.S.$200,000

Energy conservation effect: U.S.$250,000/year

Investment payback : 0.8 year

<Case 2>

In a knit dyeing factory, waste water from the dyeing machines at 60 °C or above is passed through two spiral heat exchangers to obtain hot water at 50 to 60 °C, which is used for the next dyeing cycle.

Heat was recovered from waste water of 100 m³/d out of 200 m³/d, and the quantity of hot water obtained was also 100 m³/d.

Cost of installation : U.S.$100,000

Ratio of fuel oil saved: 25 %

Investment payback : 2.2 years

<Case 3>

The following measures were implemented in a polyester and rayon yarn dyeing factory with 40 employees.

(1) Condensate in the dyeing machines and the driers was recovered for boiler water supply, and the supply water temperature was raised to 80 °C.

(2) Cooling water for the high pressure dyeing machines was recovered into the hot water baths.

(3) Dyeing waste water at 57 °C or above was detected with temperature sensors, separated, and passed through heat exchangers; hot water of 170 m^3/d at 60 °C on average was recovered.

In addition, dyes, auxiliaries and dyeing methods were improved so that dyeing could be performed at least 60 °C.

Cost of installation : U.S.$210,000 in total

Breakdown : U.S.$180,000 for the relocation, piping, and thermal insulation of dyeing machines, condensate recovery pumps, hot water tanks, U.S.$30,000 for heat exchangers and pumps

Improvement of fuel oil intensity: 45 % (from 0.85 L/kg to 0.47 L/kg)

Reduction of fuel cost : U.S.$270,000/year

Investment payback : 1 year or less

<Case 4>

A factory dedicated to yarn dyeing with 12 employees. For energy conservation, condensate was recovered, and heat was recovered from dyeing waste liquor. Condensate is produced from dyeing machines and driers, but there is a fear that dye solution may be contained therein. So condensate is not mixed directly into boiler supply water, but heat is transferred to boiler supply water through heat exchangers. For heat exchangers, the plate type which is easy to clean was employed, and stainless steel (304) material was used in case of acid liquor mixing in (Refer to Figure 8.28).

Dyeing waste liquor of 10 to 15 m³/h is produced at 50 to 100 °C. The waste liquor is passed through vortex type filters to remove cellulose sludge, and subsequently, used in the plate type heat exchangers (stainless steel) for preheating water from 30 °C to 48 °C. The heat exchangers are provided with piping capable of back wash, and automatic operation is possible by setting the temperature and flow rate.

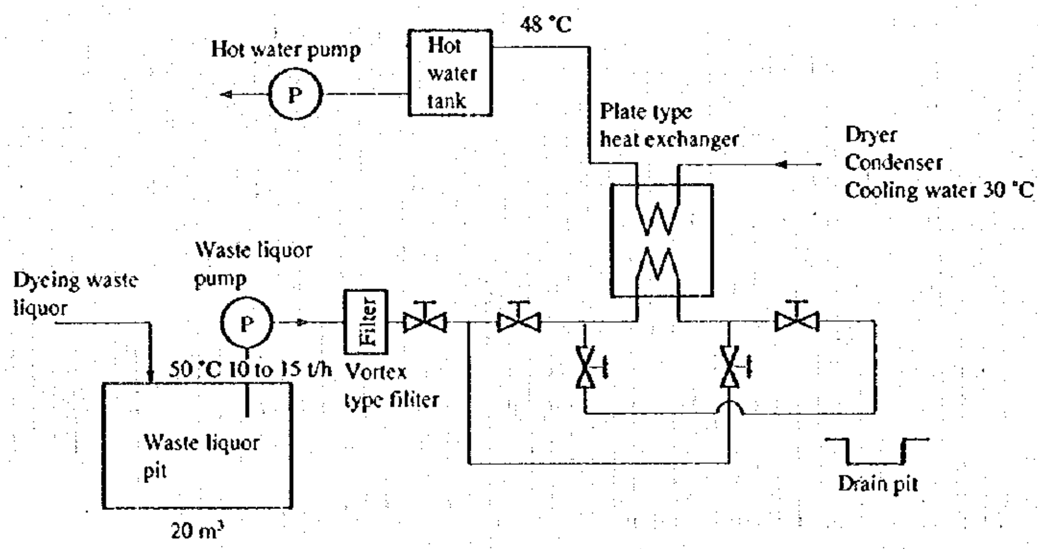
Cost of installation : Approx. U.S.$120,000 for two heat exchangers, pumps, tanks and piping.

Reduction of fuel consumption: 22 %

Saved cost : U.S.$38,000/year

Investment payback : Approx. 3 years.

Figure 8.28 Dyeing Waste Liquor Recovery Equipment



<Case 5>

Heat recovery from hot waste water discharged from the dyeing and the bleaching processes to service water by heat exchangers had been executed. It was found that the introduction of the absorption type heat pump would enable heat recovery from lower temperature waste water. In addition, low-temperature waste heat, which used to be emitted outdoor through refrigerating machines and cooling towers, was recovered and utilized as hot water.

Figure 8.29 is the flow sheet.

Cost of installation : Approx. U.S.$250,000

Energy conservation effect: As per Table 8.12

Figure 8.29 Flow Sheet of Heat Pump System

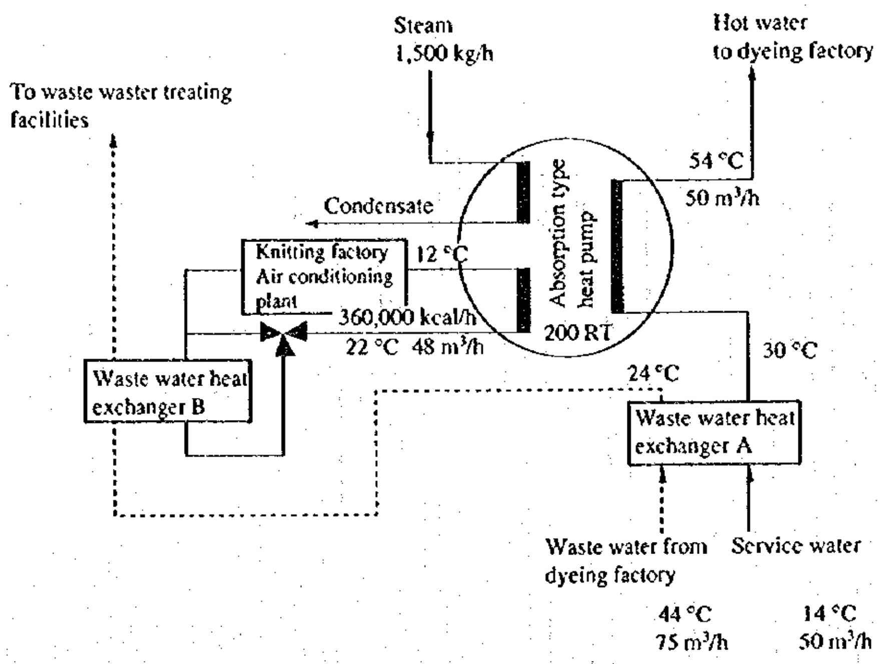


Table 8.12 Energy Conservation Effect

Fuel oil saving	170 kL/year	About 70,000 US$/year
Reduction in contract demand by stop of refrigerator	170 kW	About 30,000 US$/year
Reduction in refrigeration electric energy	200 thousand kWh	About 20,000 US$/year
Total		120,000 US$/year

There is a case where heat of exhausted air from hot air driers is recovered and used for air supply using rotary heat exchangers.

<Case 6> Cogeneration system

There are many methods for power generation, of which a cogeneration system is, in many cases, employed in spinning, weaving and dyeing plants.

The cogeneration system means a system which generates electric power using a gas turbine, a diesel engine, etc., while utilizing the generated waste heat to cope with heat demand such as steam, hot water supply. This system is also called "combined supply of heat and power".

A proper combination of power demand and heat demand allows an approximately 80 % overall heat efficiency to be obtained. Hence, there are an increasing number of cases where this cogeneration system is introduced.

Figure 8.30 shows the conceptual diagram of this system, and Figure 8.31 shows the energy component ratio.

Figure 8.30 Conceptual Diagram of a Cogeneration System (Example)

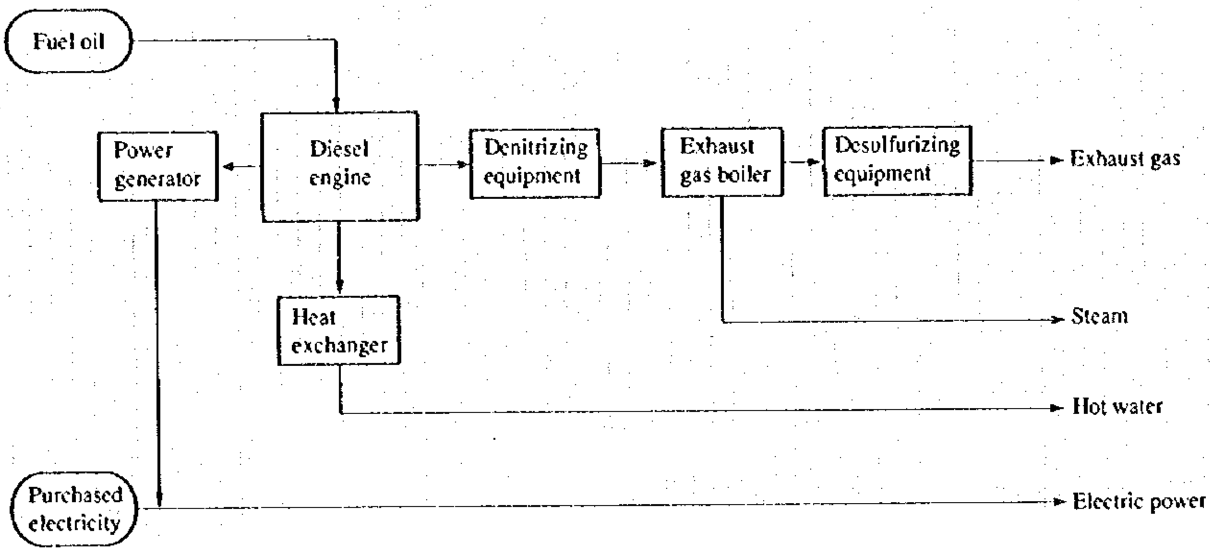
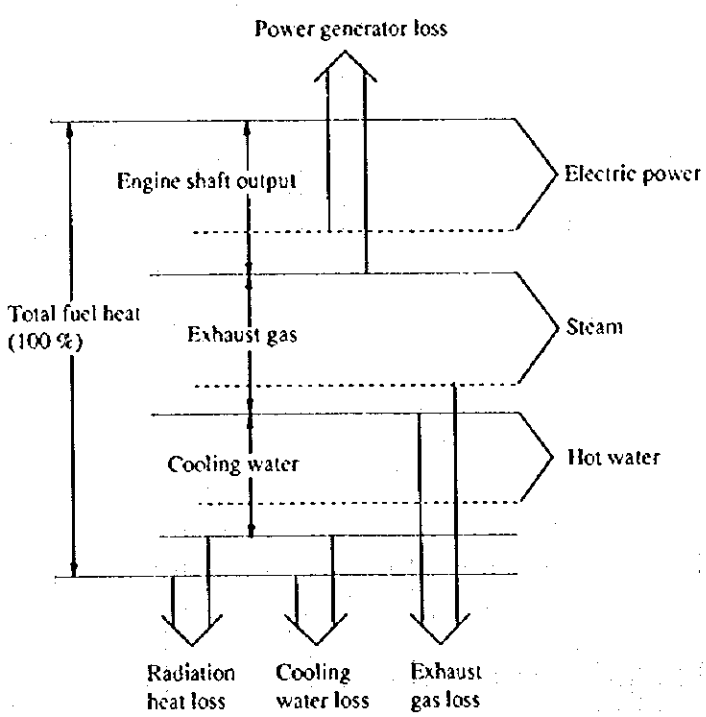


Figure 8.31 Energy Component Ratio by Diesel Engine (Example)



Energy	Conventional	Cogeneration system
Electric power	40 %	37 %
Steam	–	16 %
Hot water	–	25 %
Total	40 %	78 %

9. ENERGY CONSERVATION IN THE FOOD INDUSTRY

9. ENERGY CONSERVATION IN THE FOOD INDUSTRY

9.1 Energy Conservation at the Vegetable Oil Industry

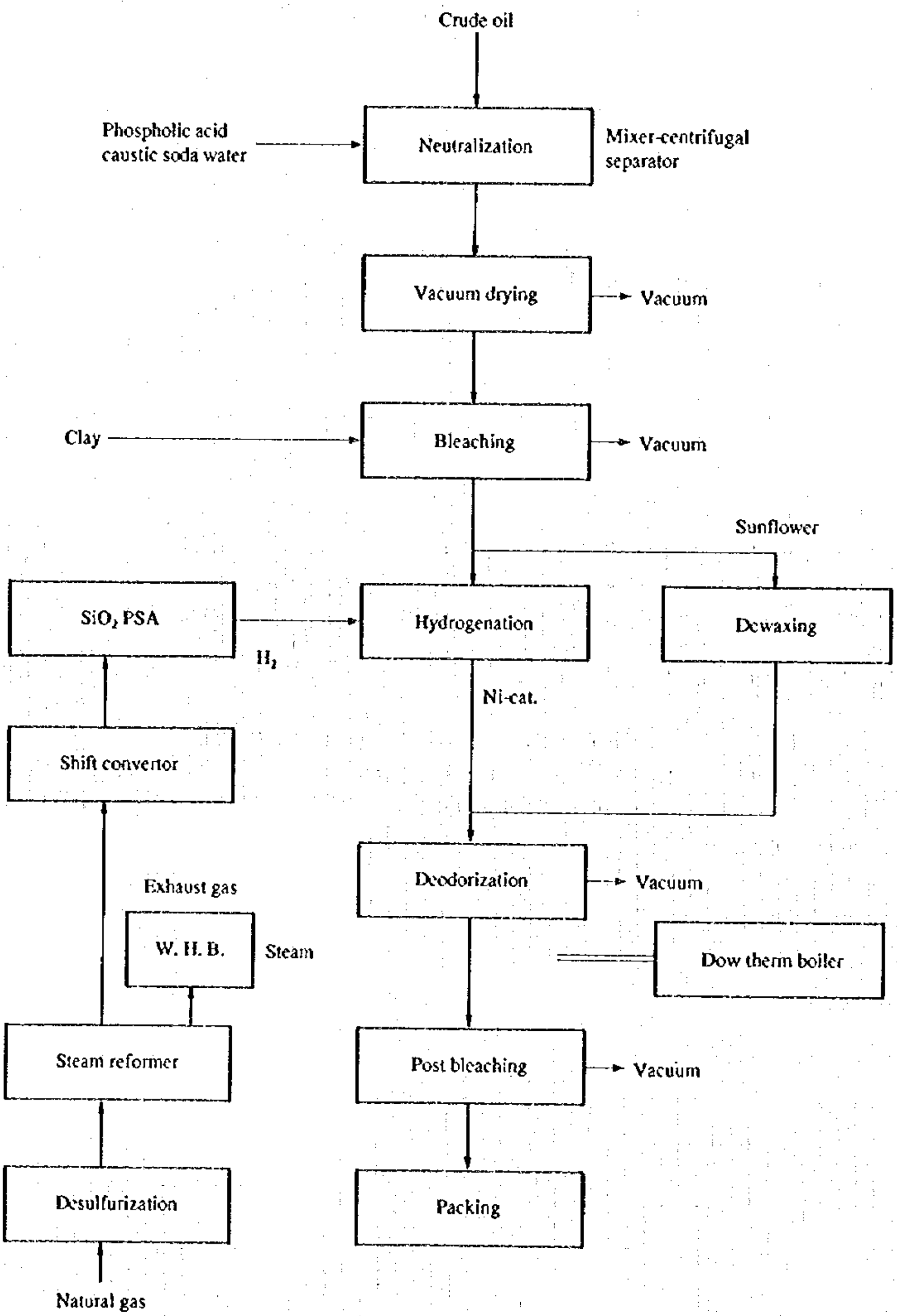
9.1.1 Production Process

Edible oils can be broadly classified into two types; vegetable oils and animal fats. The plant covered by our study project is a vegetable oil manufacturing plant. The seeds of soybean, rape, sunflower and palm are often used as materials of the edible oils throughout the world. The sunflower seeds contain 40 to 45 % oil; they contain much linoleic acid and oleic acid in particular. The sunflower is grown in the former Soviet Union, Australia, East Europe and the United States. Except that the vegetable oils are partly taken by the expression process, they are extracted from the seeds containing oil of 20 % or less directly by hexane (extraction method). When more oil is contained in the seeds, generally, the expression process is used first; then extraction method is used after oil has been reduced (prepress and solvent expression).

Oils taken by these methods contain a great deal of impurities, and cannot be used as edible oils as it is, and a variety of impurities such as free fatty acid, coloring matter, wax, odorant components must be removed in the refining process. Figure 9.1.1 shows the sunflower seed oil manufacturing process. Defatted meal is generated as by-products in the vegetable oil manufacturing plant, and the generated amount is greater than that of the oil. Defatted meal is often used as feeds containing much protein, so factories are required to produce high-quality defatted meal.

The production process differs slightly according to the quality of materials or oil and meal required, technical standards and method, but it roughly consists of the oil extraction process to extract oil from the material seeds and the refining process to make the extracted raw oil suitable for food.

Figure 9.1.1 Process Flow for Oil Refining



(1) Oil extraction process

a. Pre-processing

The raw material, from which foreign matters have been removed, is heated. This heating process which consolidates protein of cellular walls is important to obtain the high-quality raw oil through improving operability and enhancing the oil extraction rate by making the extraction solvent flow smoother and making the raw material composition strong and hard enough not to be destroyed.

b. Expression (Squeezing)

Expression is a method that has been used long and applies a high pressure physically to raw materials such as rape seed, safflower, and sesame containing much oil. Generally, a continuous squeezing machine, called the expeller, is used to squeeze 1/3 to 1/4 of oil contained in the raw material.

c. Extraction

For a raw material such as soy bean containing relatively less oil, oil can not be obtained as desired by squeezing it alone. Therefore, the material is crushed flat to increase the surface area and oil is efficiently eluated with a solvent, hexane. In the extraction machine (using countercurrent extraction) that moves hexane against the transfer direction of the flat crushed material, the raw material is dipped into hexane and the residual oil is reduced to approximately 1 % or less within a few hours. For a large machine, its standard capability is 1,500 to 2,000 tons/day. The hexane solution that has extracted oil is called the micella, whose oil content is 25 to 30 %. The micella is first condensed in a distiller and then a stripper (blows in vapour under vacuum) almost completely removes hexane to produce the raw oil. Hexane is recovered and reused.

d. Expression/extraction method

After expression described above, the residual oil content is 10 to 20 %, which is recovered by extraction. These expression and extraction are called the expression/ extraction method.

(2) Refining process

Since the raw oil contains phospholipid, free fatty acid, trace metal, and pigments as well as its unique odorant matter, it is not suitable for food. Refining removes these unnecessary matters while retaining useful contents such as tocopherol as much as possible.

a. Degumming

Among the matters contained in the raw oil, phospholipid is useful for several purposes and the residual phospholipid in the oil results in coloring or bubbling when oil is heated. Therefore, phospholipid should first be removed. Then, lecithin is recovered separately from this phospholipid.

The process that removes mainly this phospholipid is called degumming, which gives warm water or water vapour to the raw oil to hydrate phospholipid, and then separates the gum content from the oil with a centrifugal separator. The content of phospholipid (such as lecithin) in soy bean oil is 2 to 3 %, but after the degumming process, it will be approximately 0.5 % or less.

b. Neutralization (Alkali Refining)

The neutralization (alkali refining) process is intended mainly to eliminate free fatty acid (FFA) from the oil. The amount of FFA is represented as acid value (AV). The value provides a guideline to check the quality of the material seed or the adequacy of oil expression process. This process removes the oil soluble phospholipid, protein, coloring matter, and water content which could not be removed in the degumming process. FFA can be also removed by the deodorization process. The amount of FFA can be expressed in the following equation:

FFA (%) = AV/2

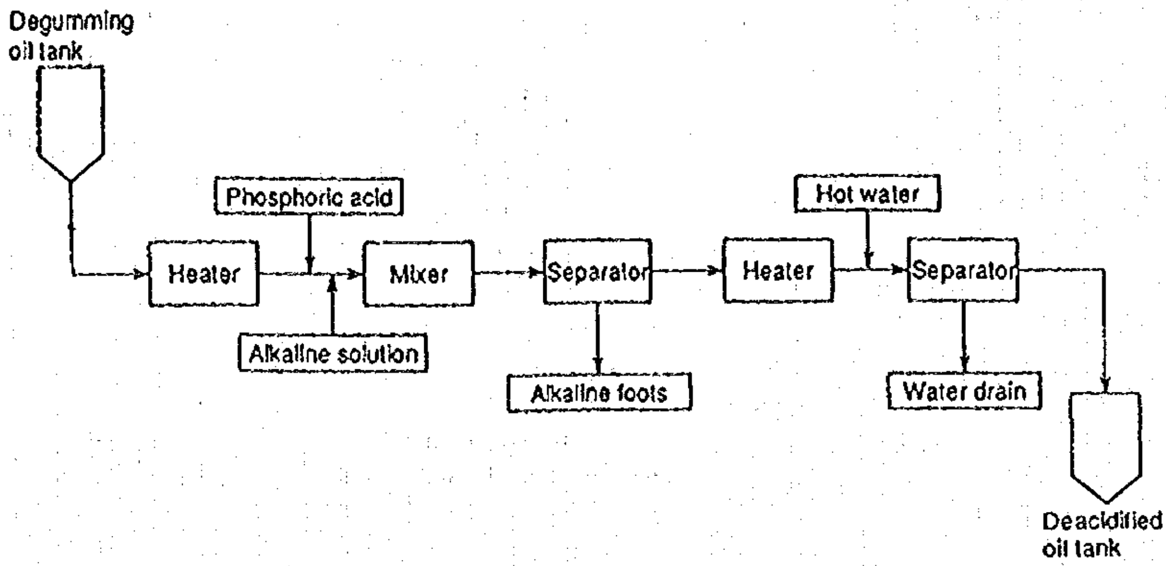
The representative process is the neutralization process where alkali aqueous solution is mixed with oil sufficiently to be made into contact with each other and FFA is separated from the oil in the form of alkali foots. Alkali refining generally uses caustic soda aqueous solution of 10 to 24 °Be (6.55 to 17.7 %).

The following shows an example of the batch type neutralization process for cotton seed meal: Degummed oil is heated to 50 °C, and caustic soda aqueous solution of 18 °Be (12%) is added 100 % of the neutralization equivalent in excess. Then it is stirred for 20 to 30 minutes. Stop stirring when breaking has occurred, and add 10 % water preheated to 50 °C. Settle it for about one hour. After removing the alkali foots from the lower layer, add 10 % alkali aqueous solution of 0.4 % concentration to oil; then wash it at 100 °C. After removing the lower layer, wash it again with alkali water of 95 °C, and wash it finally with 8 to 10 % boiling water two or three times. The entire process requires 10 to 12 hours.

According to the batch type neutralization, the contact time for alkali aqueous solution and oil is 10 to 60 minutes, and 1 to 10 hours are required for separation of alkali foots. Furthermore, sedimentated alkali foots contain much neutral oil, indicating a great loss of oil. The continuous alkali refining process provides a method of preventing the loss of neutral oil by reduction of treatment time and separation of the alkali foots by centrifugal separator.

The following describes an example of short mix process of Alfa-Laval Inc. as a representative case of the continuous neutralization process. Caustic soda aqueous solution is used as alkali aqueous solution. Figure 9.1.2 illustrates the flow sheet of the Continuous Neutralization Process.

Figure 9.1.2 Continuous Neutralization Process



The amount of alkali aqueous solution can be expressed in the following equation:

Amount of alkali aqueous solution to be used (%) =

$$\frac{\text{FFA (\%)} \times \text{Factor} \times \text{Excess}}{\text{Concentration of alkali aqueous solution (\%)}} \times 100$$

The factor can be calculated in the following equation:

Factor = Caustic soda molecular weight/oleic acid molecular weight
= 40/282
= 0.142

Excess is normally 0.1 to 0.13 % in the case of soybeans. Add about 0.1 % phosphate to the degummed oil pre-heated to 75 to 82 °C, and add a specified volume of alkali aqueous solution to the mixture oil; then make them contact with each other after mixing carefully with the line mixer or paddle mixer. During the short-term contact, hydration of oil soluble phospholipid, neutralization of FFA and reaction with coloring component take place. Alkali foots generated by using the enclosed type rotary disk centrifugal separator (6,000 rpm) is separated from the neutral oil. The back pressure at the outlet of the oil from the centrifugal separator is adjusted to shift the separation zone for heavy liquid and light liquid inside the centrifugal separator. Increase of the back pressure will reduce the amount of soap remaining in oil, and will increase the amount of the neutral oil enclosed in the alkali foots, resulting in greater alkali refining loss. On the contrary, reduction of the back pressure will reduce the alkali refining loss, but will increase the amount of soap content in oil. Normally, adjustment is made so that the soap content in the neutralized oil will be below 300 ppm. Of the refining loss, the neutralization loss accounts for the greatest percentage, 65 %. Neutralized oil is fed to the washing process. After the oil is heated up to about 90 °C by the heat exchanger, it is mixed with 10 to 20 % hot water of 95 °C and is made to contact; then it is separated by the centrifugal separator. Figure 9.1.3 illustrates the centrifugal separator. About 90 % of soap remaining in the neutralized oil shifts to the washing water side.

Theoretical loss in the alkali refining process is called "Wesson loss", and can be calculated in the following equation:

$$\text{Wesson loss (\%)} = AV/2 + \text{phospholipid (\%)} + \text{water content (\%)}$$

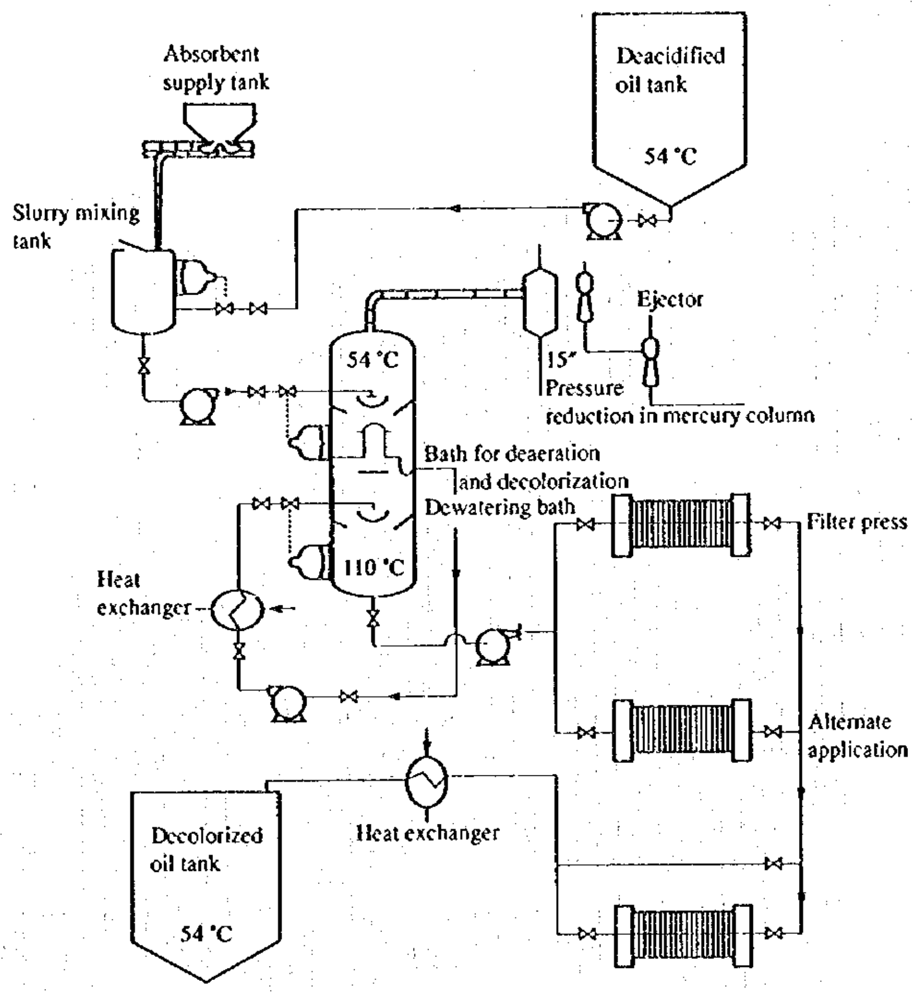
If FFA, phospholipid and water content can be removed completely in the alkali refining process, the alkali refining loss will become equal to Wesson loss.

c. Decolorization

Decolorization under the normal pressure accelerate oil oxidation and deteriorates the decolorization effect of the activated clay, so decolorization is performed under the reduced pressure in recent years. To minimize contact with air and to ensure effective operation, continuous vacuum decolorization process is often adopted.

The following describes an example of the continuous vacuum decolorization process, and Figure 9.1.3 illustrates the flowchart.

Figure 9.1.3 Continuous Vacuum Decolorization Process



0.3 to 2.0 % activated clay is added to neutralized oil which has been pre-heated to 54 °C, to be made into slurry. It is then led to the deaeration tank on the upper stage of the decolorization tower whose pressure is reduced to 380 Torr, and is dehydrated and deaerated. Then it is heated by the heat exchanger and is maintained at 110 °C under the reduced pressure for seven minutes. After that, it is separated from the clay. The horizontal or vertical pressure type leaf filter accommodated in the enclosed vessel is generally used as the filter, in addition to the filter press.

The waste clay separated from the oil and fat is discarded or is washed by elution by such solvent as hexane, in order to recover the oil adsorbed by the waste clay.

About 10 to 100 ppm of soap content is normally in the oil after neutralization, and promotes deterioration during heating. Chlorophyll and pheophytin much contained in rape seeds and immature seeds promote oxidation of oil, and their elimination will contribute to stabilization of the oil. Tocopherol, carotene and phospholipid working as natural antioxidant, however, are also removed by adsorption.

Clay is a mineral mainly comprising montomorillonite ($Al_4Si_8O_{20}(OH)_4 \cdot nH_2O$) which is formed of volcanic ashes exposed to efflorescence for a long time and is produced by thermochemical reaction through geothermal energy. Adsorption is increased as more aluminum ion is replaced by hydrogen. Adsorption will be deteriorated when water content is excessive or insufficient; water content of 8 to 16% is said to be appropriate.

The amount of the activated clay to be used should be 0.3 to 2.0 %. A greater amount of clay is required as more coloring matter and products decomposed by oxidation are contained.

d. Dewaxing

This process is generally performed after decoloring and before deodorizing. If oil contains solid-state grease when mayonnaise is made and stored by freezing, mayonnaise emulsion is broken (i.e. freeze breaking). Therefore, the original purpose of this process was to eliminate the low-temperature hardened grease. This process is also performed to prevent oil from becoming cloudy with wax at a low temperature.

In any case, oil is gradually cooled down and the contents that harden at a low temperature are fully precipitated and then removed by filtering.

e. Hydrogenation (hardening)

To manufacture solid-state grease such as margarine, solid-state grease should be used or liquid-state oil should be consolidated. This method is used to consolidate oil.

Since fatty acid composing liquid-state oil such as vegetable oil or fish oil is non-saturated (i.e. partially lacks hydrogen), inserting hydrogen into this part through chemical reaction is referred to as hydrogenation. As a catalyst, Ni is mainly used and reaction is promoted by adding hydrogen, applying a pressure and a temperature, and stirring. Controlling the degree of reaction properly allows you to obtain the hydrogenated oil with the desired hardness. Since the oil becomes hardened and at the same time comes closer to saturation, it becomes more resistant to oxidization, which might be one of the purposes.

f. Deodorization

After decolorization and hydrogenation, oil still contains various odorant components contents and other volatile matters. Therefore, the decolored oil is maintained at a temperature of 240 °C or higher and steam is blown into it under vacuum to evaporate odorant content along with water vapour. This process is referred to as deodorization.

To increase oil stability against oxidization, tocopherol as a natural anti-oxidization contained in oil is left as much as possible and a small amount of citric acid that works with tocopherol is added for finishing. In addition, silicon resin is normally added to give stability against heating and the debubbling property.

To heat to a high temperature of 240 °C or higher, a heat medium (particularly Dowtherm) was previously used. However, even a very small amount of the heat medium contained in the product affects health of human body seriously; therefore high-pressure steam is used presently in Japan.

The steam jetting device such as ejector and booster is used for vacuum generation. A high degree of vacuum below 6 Torr is normally used.

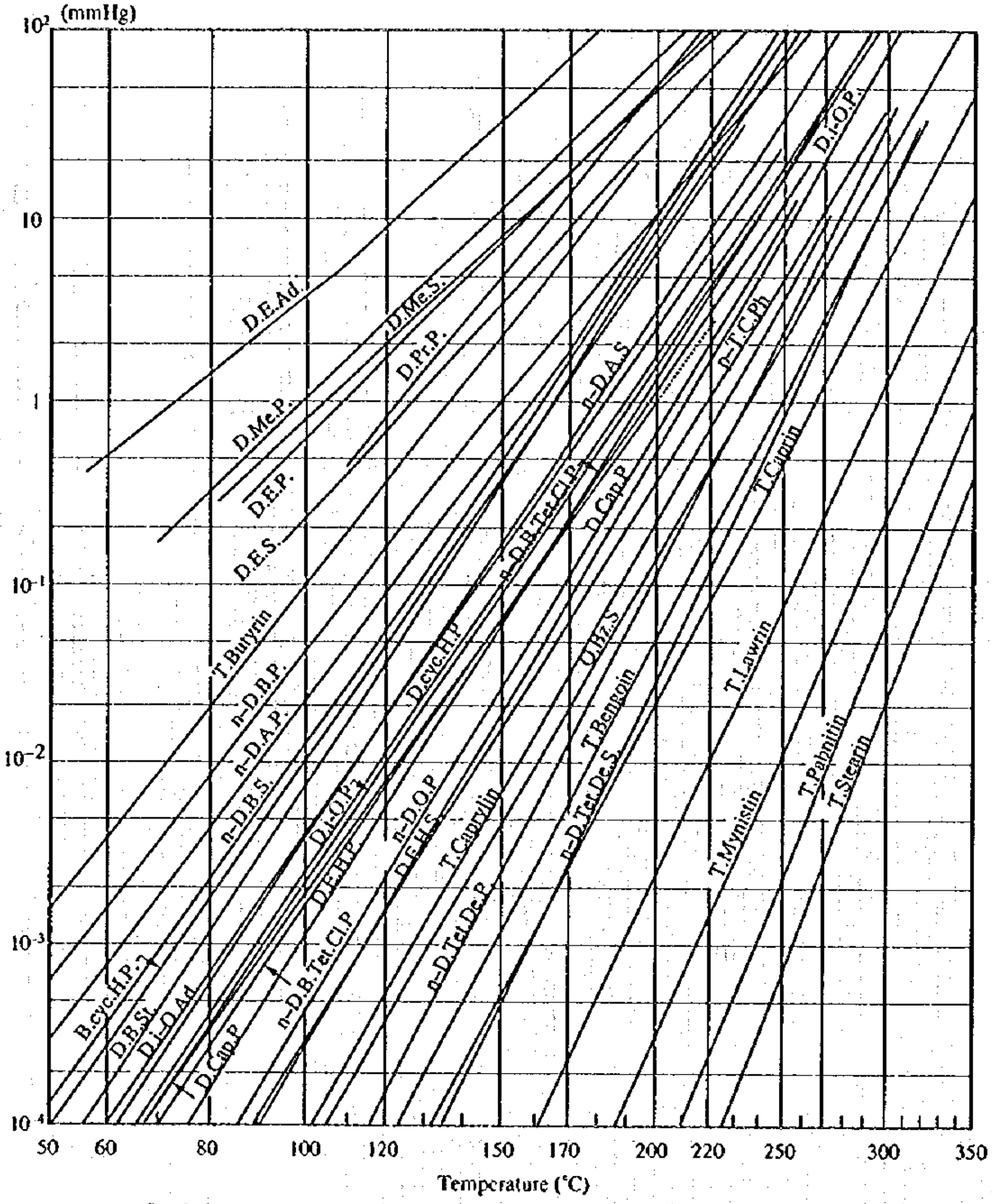
Deodorization uses the principle of steam distillation method where steam is blown into the oil heated to a high temperature under a high degree of vacuum to distill the volatile matters. The lower the absolute pressure of the system, the lower will be the heating temperature, though the situation may depend on the amount of the steam to be blown inside. Table 9.1.1 shows the vapor pressure of the palmitin acid and oleic acid which are representative free fat acids contained in the oil.

Figure 9.1.4 and Figure 9.1.5 show vapor pressure for esters and that for hydrocarbon, chlorinated hydrocarbon and organic silicon compounds respectively.

Table 9.1.1 Vapor Pressure of Fatty Acid

mmHg	Palmitin acid (°C)	Oleic acid (°C)
1	153.6	176.5
5	188.1	208.5
10	205.8	223.0
20	223.8	240.0
40	244.4	257.2

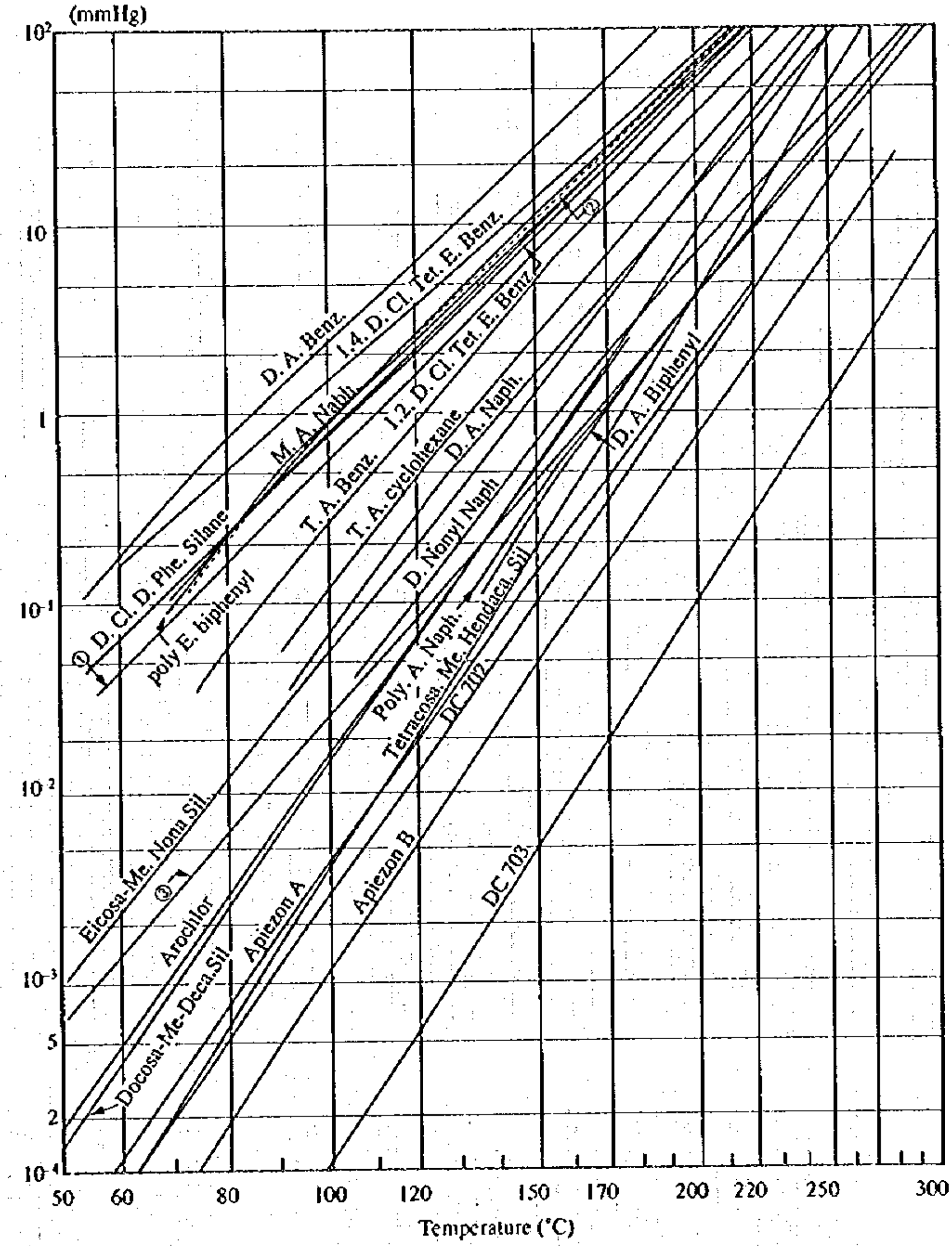
Figure 9.1.4 Vapor Pressure of Organic Compounds (Esters)



Symbols:

A.	Amyl	D.	Di	P.	Phthalate
Ad.	Adipate	E.	Ethyl	Ph.	Phosphate
B.	Butyl	H.	Hexyl	S.	Sebacate
Bg.	Benzyl	i–	iso-	St.	Stearate
C.	Cresyl	Me.	Methyl	T.	Tri
Cap.	Capryl	n–	normal	Tet.	Tetra
cyc.	cyclo	O.	Octyl		

Figure 9.1.5 Vapor Pressure of Organic Compounds
(Hydrocarbon, chlorinated hydrocarbon and organic silicon compounds)



A.	Amyl	E.	Ethyl
Benz.	Benzene	Naph.	Naphthalene
Cl.	Chloro	Sil.	Siloxane
D.	Di	T	Tri
M.	Mono	Phe	Phenyl

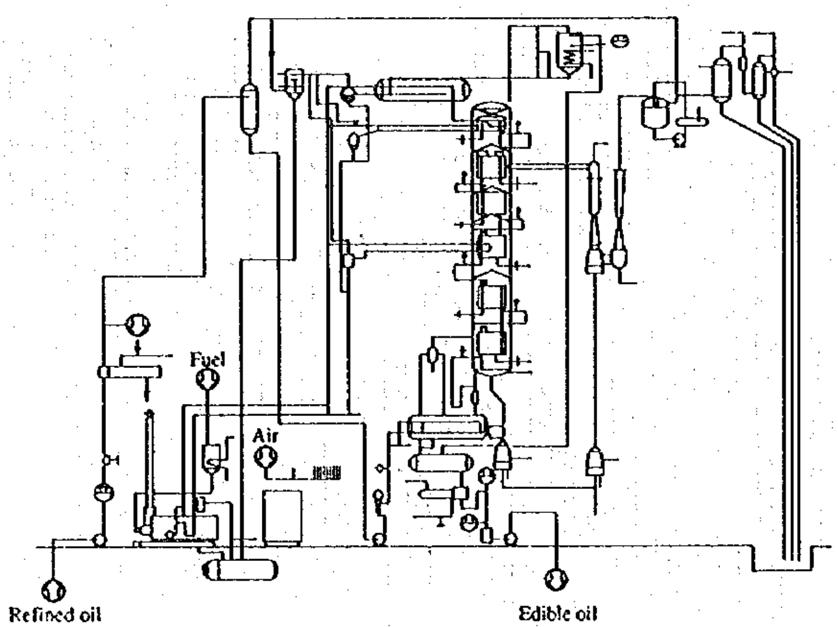
② Chlor. Me. D. phe. Silane   Broken line: Dodecyl Benz.
③ D. Phe. Silicon D. isothio cyanate

The blown-in steam serves to stir the oil during deodorization to facilitate evaporation of volatile matters. The amount of the steam to be used is 1 to 4 % in the case of the continuous and semi-continuous processes, and is 20 to 30 % in the case of the batch process.

Deodorization temperature is usually 230 to 250 °C and the degree of vacuum is 3 to 6 Torr for the continuous and semi-continuous processes. In the batch process, both the temperature and degree of vacuum are lower than those in the case of the continuous and semi-continuous processes, though they may depend on the type of the oil.

Figure 9.1.6 illustrates the flowchart of the continuous process according to the Gardner method.

Figure 9.1.6 Continuous Deodorization Process



In the process of Gardner method, 5 to 6 trays are suspended in one vertical cylindrical vacuum tower (shell). Inside the shell, almost constant vacuum is maintained by the operating of the ejector and booster, and the dewaxed oil is fed inside, passing from the first tray to the next one downward sequentially. In the 5-stage tray structure, each tray is assigned with different functions; deaeration for the first tray, heating for the second tray, deodorization for the third and fourth trays and cooling for the fifth tray.

In the case of the continuous process, oil is fed continuously to the first tray and is fed to the next lower tray after it has overfilled the first one, so the inter-stage valve is not provided. Energy intensity differs according to the water content of the material, ambient temperature, required product quality as well as according to the process.

The following shows the energy intensity of continuous and semicontinuous deodorizers in Japan:

Energy intensity in Japanese deodorization process

Steam : 80 to 120 kg/t (product oil, in tons)
Electricity: 30 to 50 kWh/t (product oil, in tons)

9.1.2 Rationalization in Energy Use

Before taking rationalization measures for energy use, it is necessary to check the amount of energy currently used. In the case of steam, it is possible to get steam consumption by the orifice for direct steam, and by measuring the amount of drain generated for indirect steam. It is possible to get it by calculating the heat balance.

After that, in the case of direct steam, try to reduce the amount of steam to be used, with consideration given to the position of steam blowing, nozzle shape, steam pressure, material contact time and use of exhaust gas. In the case of indirect steam, study the steam pressure, reuse of the condensate and replacement of steam by alternative heat sources and such related matters. In the continuous process, the temperature is raised or lowered in order to ensure treatment under the optimum conditions, so it is needed to study the possibility of mutual heat exchange.

(1) Heat recovery in the deodorizer

The amount of heat recovered by the deodorizer is the largest in the refining process. However, attention much be directed to quality, safety, operation, and maintenance because this heat recovery system deals with the final product.

Heat recovery by the deodorizer means basically heat exchange between the feed oil at the inlet and the high-temperature product oil at the outlet. However, how waste heat (if present) should be utilized must be considered. Therefore, heat recovery in the deodorizer should be considered as a part of the entire factory's heat recovery system as with other heat recoveries.

For the heat recovery method, the method employed by each manufacturer or working examples announced are described. These methods can be used in a combination.

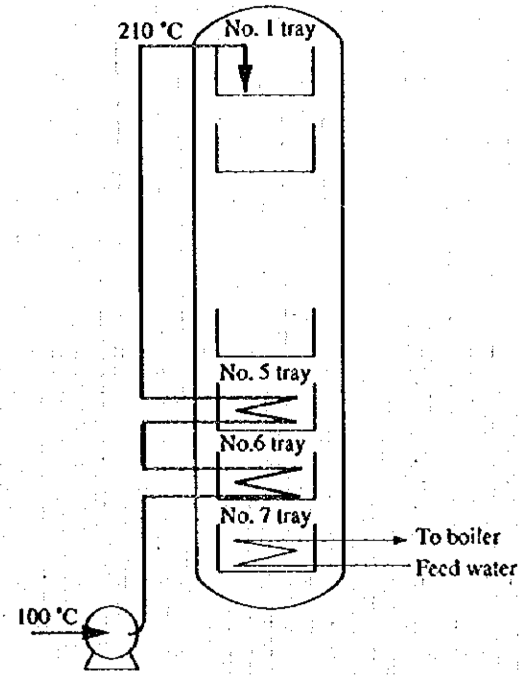
Generally, heat recovery methods are divided into 1. Oil-to-oil direct heat exchange and 2. Indirect heat exchange using an intermediate medium.

The simplified flow, method, and the recovered heat amount of these heat exchanges are described below.

a. Oil-to-oil direct heat exchange

1) Heat recovery using the coil in the tray (Figure 9.1.7)

Figure 9.1.7 Heat Recovery by Coil in the Tray



Two oil-to-oil heat exchange trays are installed in the deodorizing tower for heat recovery. For the cooling tray, heat recovery is performed by using water supplied to the boiler as the cooling water.

The feed oil at 100 °C flows through the coil in the No. 6 tray, so oil heat in the No. 6 tray is transferred to the feed oil, which is preheated to 140 °C. This preheated oil flows through the coil in the No. 5 tray and heated in the same way. As a result, the feed oil is heated up to 210 °C and fed to the No. 1 tray.

On the other hand, the deodorized oil is pre-cooled by the No. 5 and 6 trays and comes down to the No. 7 cooling tray.

The No. 7 cooling tray uses the water supplied to the boiler for cooling and then the heated water is used.

What must be taken into account with this heat recovery system is that the cleansing method should be examined carefully because the coil inner surface may generate dirt on a long-term basis.

Also, it is necessary to degas the feed oil before it comes to the heat exchange trays.

Exchanged heat amount:

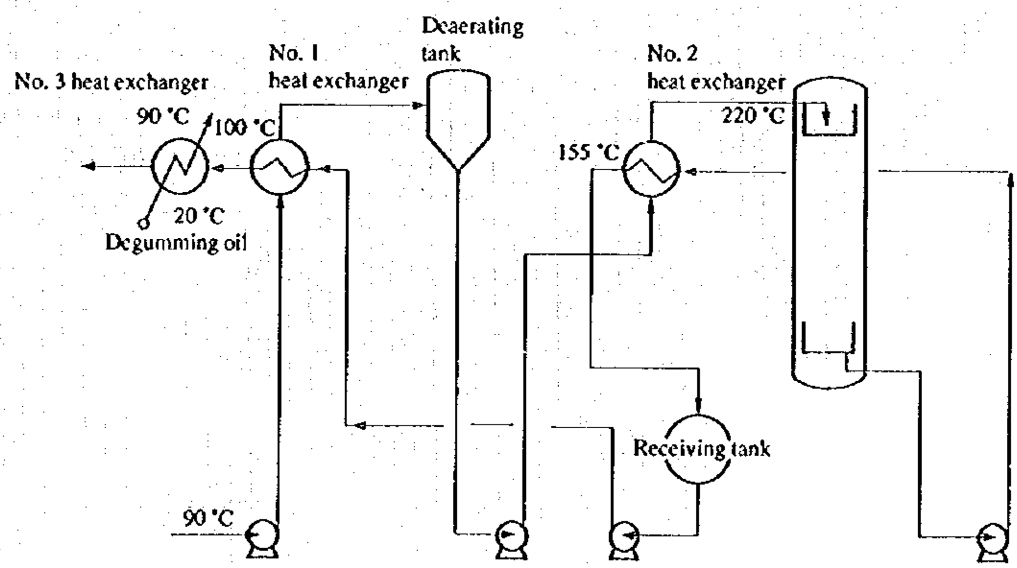
Feed oil : 100 °C → 210 °C — 65,000 kcal/t-oil
Hot water: 30 °C → 60 °C — 36,000 kcal/t-oil

Steam saved:

Feed oil heating	: (medium-pressure steam 10 kg/cm² (G))	— 66 kg/t-oil
	: (high-pressure steam 66 kg/cm² (G))	— 87 kg/t-oil
Feedwater heating:		— 73 kg/t-oil

2) Heat recovery by external heat exchangers (Figure 9.1.8)

Figure 9.1.8 Heat Recovery by External Heat Exchangers (1)



This system performs heat recovery by using three heat exchangers.

The feed oil at 90 °C enters the No. 1 heat exchanger, where heat exchange with the product oil is performed. The feed oil is heated up to 130 °C and then goes in the degassing tank.

This degassed oil goes in the No. 2 heat exchanger, where heat exchange with the product oil is performed again. Then, the feed oil is heated up to 220 °C.

On the other hand, the deodorized high-temperature oil enters the No. 2 heat exchanger while being extracted continuously from the bottom tray. Then the oil is cooled down to approximately 155 °C, entering the receiving tank.

Then, the oil, which goes in the No. 1 heat exchanger, is cooled down to 110 °C, enters the No. 3 heat exchanger, and then cooled down to 30 to 50 °C which is the desired final product temperature.

What must be taken into account with this heat recovery system is the quality aspect and how to remove dirt from the heat transfer surface on the heat exchanger.

Calories exchanged:

Feed oil : 90 °C → 220 °C — 72,000 kcal/t-oil
Degummed oil: 20 °C → 90 °C — 33,000 kcal/t-oil

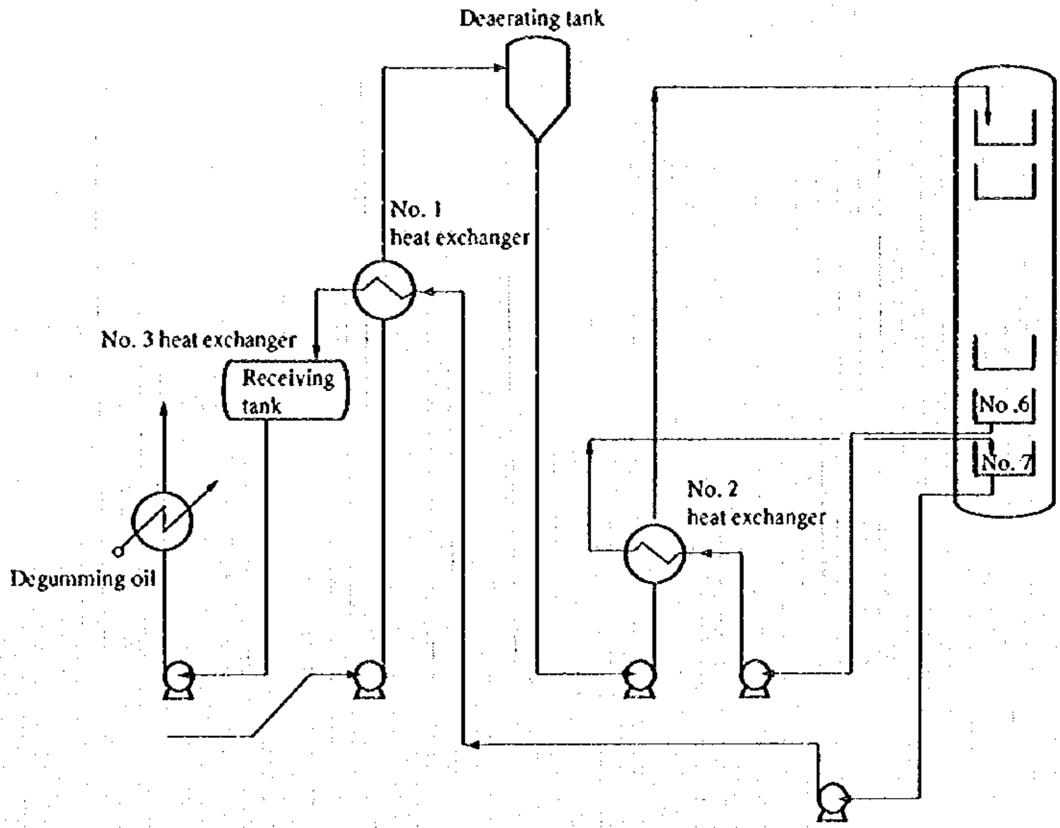
Steam saved:

Feed oil heating: (medium-pressure steam 10 kg/cm^2 (G)) — 75 kg/t-oil
: (high-pressure steam 60 kg/cm^2 (G)) — 95 kg/t-oil
Degummed oil heating:
(medium-pressure steam 10 kg/cm^2 (G)) — 69 kg/t-oil

The method described below is considered as a variant of the system described above. (See Figure 9.1.9.) This method performs extraction from the deodorizing tower with the No. 6 tray, and then returns the oil from the No. 2 heat exchanger to the tray in the deodorizing tower.

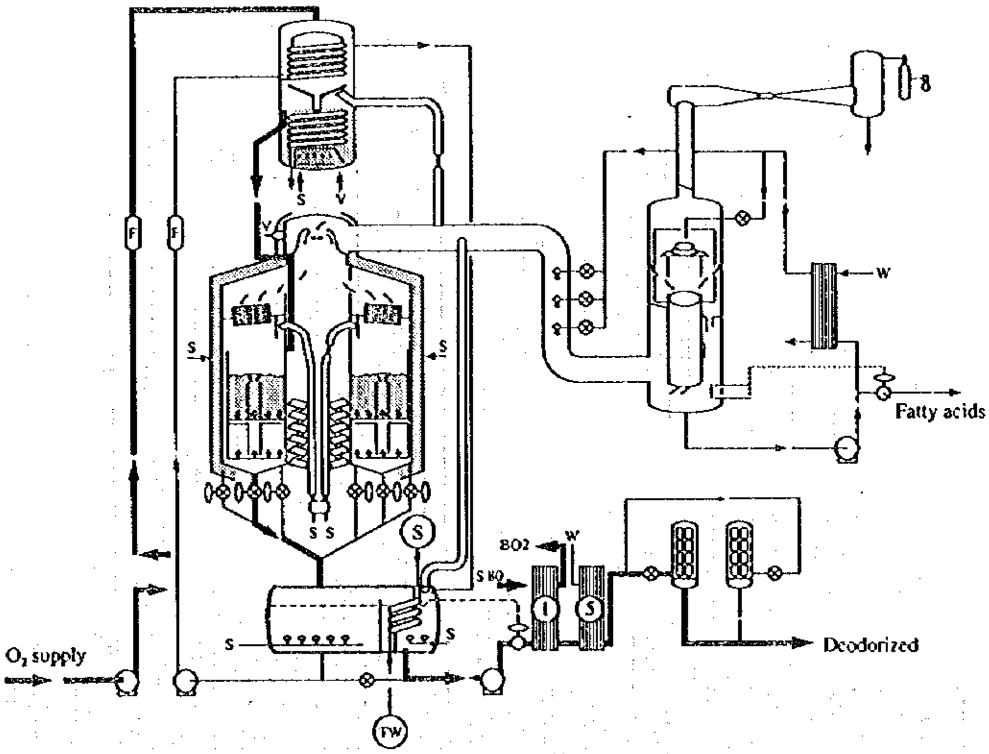
What must be taken into account and the heat recovery volume are same as those of the method described above.

Figure 9.1.9 Heat Recovery by External Heat Exchangers (2)



3) Heat recovery by Desmet method (Figure 9.1.10)

Figure 9.1.10 Heat Recovery by Desmet Method (Continuous Type)



This system performs heat recovery by using two heat exchangers, one of which is also used as a degassing tank.

The feed oil at 50 °C goes in the heat exchanger ①, where heat-exchange with the deodorized product oil is performed. Then, the feed oil is preheated and enters the degassing tank ②. In this degassing tank, the oil in a film state drops onto the heat exchange oil. During this period, heat exchange and degassing are performed and the oil is heated up to 210 °C.

On the other hand, the deodorized product drops to the left of the receiving tank ④. This oil flows through the coil in the degassing tank, is heat-exchanged with the feed oil, cooled, and then fed to the right of the receiving tank ④. This tank contains the coil used to cool down the oil.

Water contained in this coil is heat-exchanged with the oil and evaporated. This results in generating steam of 1.5 kg/cm² (G), which can be used as the steam to be blown into the deodorizing tower. To supply this water, the steam drain in the process is used.

As described above, the pre-cooled product oil is heat-exchanged with the feed oil and cooled in the heat exchanger ① to obtain the desired temperature in the final cooler.

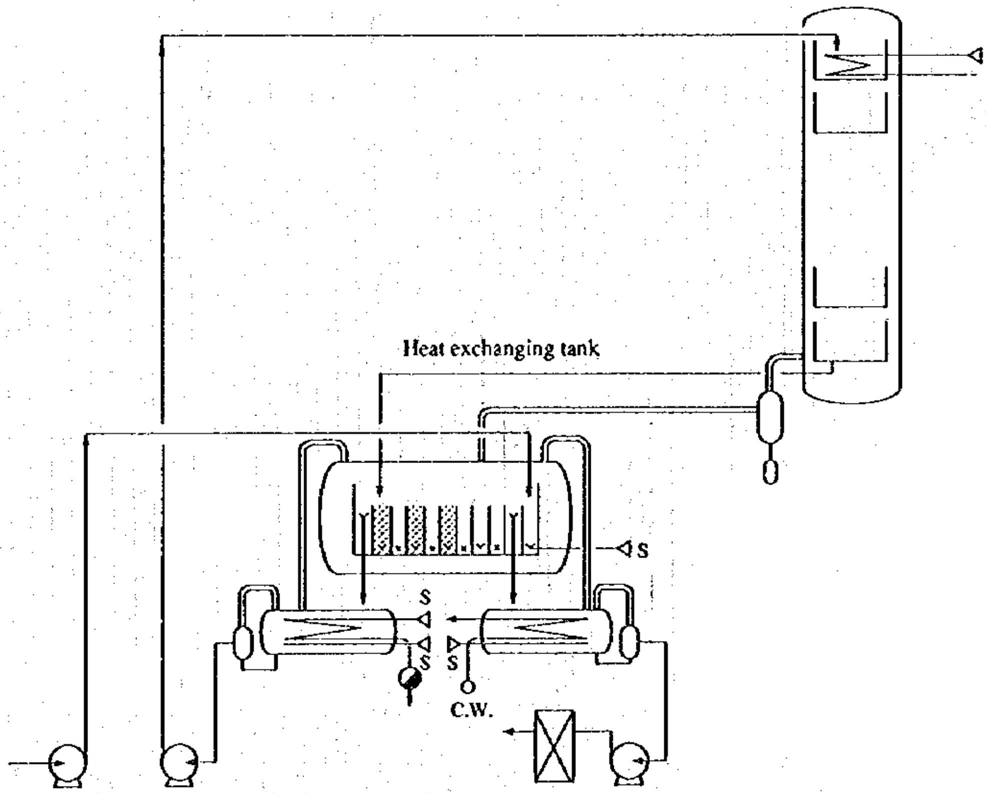
The degassing/heating tank ② and the receiving tank ④ blow in raw steam under the same vacuum as in the deodorizing tower.

Energy conservation effects achieved by this system are as follows:

	Heat recovery facility	
	Provided	Not provided
Calories required for heating	35,900 kcal/t-oil	119,500 kcal/t-oil
Raw steam	--	17 kg
Deodorizing temperature: 255 °C		

4) Heat recovery by the heat exchanging tank (Figure 9.1.11)

Figure 9.1.11 Heat Recovery by Heat Exchanging Tank



This system is so configured as to make the deodorized oil and feed oil flow as the counter current to each other via the heat exchanging wall and blow steam to each other. It is of such shape that the heat exchanging tray is contained in the shell.

The feed oil at 70 °C is heated up to 225 °C by heat exchange and the product oil at 250 °C is cooled down to 100 °C.

One of the advantages of this system is that calories exchanged are large. Care should be taken so that the feed oil and product will never be mixed in the heat exchange tank.

Calories exchanged:

Feed oil: 70 °C → 225 °C — 86,000 kcal/t-oil

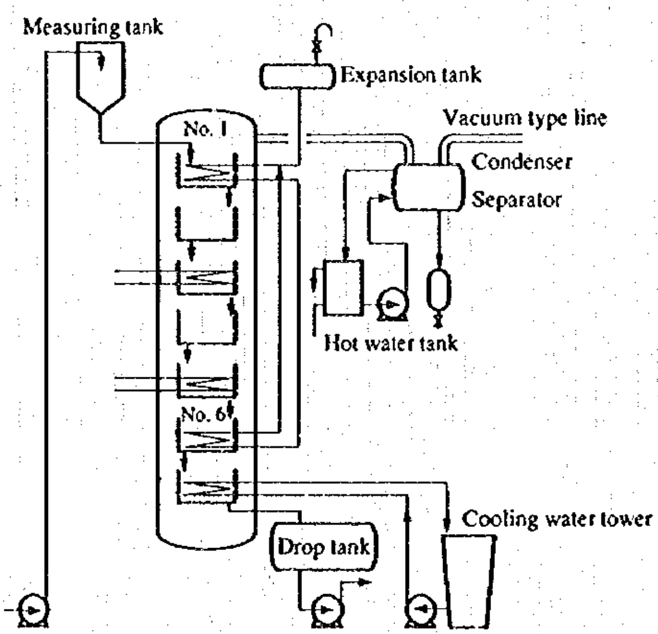
Steam saved:

Feed oil heating: (medium-pressure steam 10 kg/cm^2 (G)) — 87 kg/t-oil
Feed oil heating: (high-pressure steam 60 kg/cm^2 (G)) — 116 kg/t-oil

b. Indirect heat exchange

1) Heat recovery by hot water circulation (Figure 9.1.12)

Figure 9.1.12 Heat Recovery by Hot Water Circulation



Coils of the No. 1 tray and No. 6 tray are connected via piping and closed.

Since hot oil (normally at 250 °C) that completed deodorizing at the trays up to No. 5 tray drops onto the No. 6 tray, the heat is transferred to water in the coil. When hot water flows through the coil in the No. 1 tray, heat is transferred from the hot water to the cold oil (at approximately 90 °C) dropping from the measuring tank. Oil in the No. 1 tray is thus preheated.

Water cooled down as a result of giving heat to oil returns to the No. 6 tray, receives heat from the hot oil, and then returns it to the No. 1 tray to preheat oil.

As described above, hot water in the coil is naturally circulated between the No. 1 tray and No. 6 tray. Therefore, the preheating steam is not required.

Since this method uses water as a medium and the operating method is unchanged, it does not affect the quality.

Calories exchanged:

Feed oil: 90 °C → 170 °C — 42,000 kcal/t-oil

Steam saved:

(Medium-pressure steam 10 kg/cm² (G)) — 85 kg/t-oil

2) Heat recovery by steam/hot water circulation

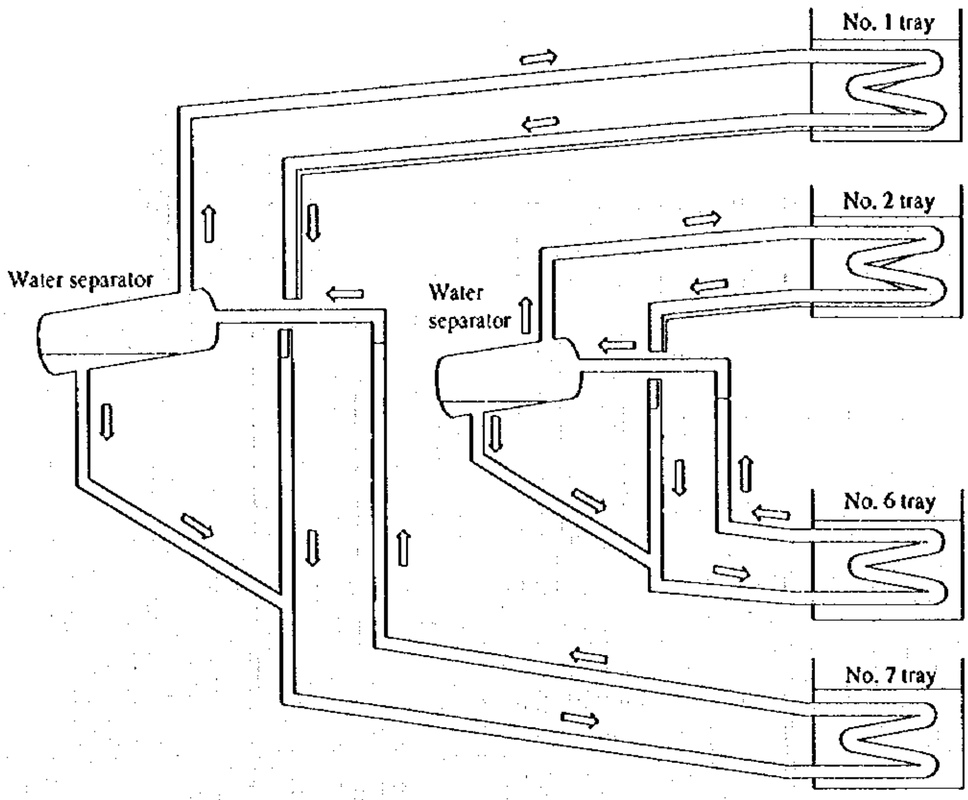
This concept is same as that of hot water circulation in 1) described above. Steam is generated in the coils of the No. 6 and No. 7 trays. Heat of this steam is transferred in the coils of the No. 1 and No. 2 trays. After condensation, drain water flows into the coils of the No. 6 and No. 7 trays.

In these processes, oil in the No. 1 and No. 2 trays is heated, while oil in the No. 6 and No. 7 trays is cooled.

This system eliminates the expansion tank only in the flow sheet shown above and there is no other change. The feed oil at 70 °C is preheated up to approximately 200 °C.

Figure 9.1.13 shows the heat recovery equipment.

Figure 9.1.13 Heat Recovery Equipment



(2) Vacuum retaining measure

What occupies the largest percentage in steam intensity in the refining process is the steam used for the vacuum generating equipment in the deodorizing tower.

To maintain the proper quality, it is necessary to set and keep a proper vacuum degree in the deodorizing tower. Doing this greatly contributes to energy conservation.

For operation of the vacuum equipment, care must be taken to the following:

- Air leakage around the deodorizing tower should be reduced.

  Vacuum degree reduction and time should be measured each time operation is stopped. Leak and the leak amount should be checked. If any leak is found, repair should be made immediately.

- Load applied to the booster should be reduced.

  Heating and degassing should be performed before feeding to the deodorizing tower.

This load is applied not to the booster but to the barometric condenser onward.

The suitable steam volume should be obtained.

- Load to the booster should be continuous.

Feeding to the deodorizing tower should be continuous.

- The driving steam pressure should be kept constant.

Fluctuation in the steam pressure greatly affects the performance of the booster that runs in the low vacuum area, thus making the vacuum degree unstable.

- The cooling water volume and temperature for the barometric condenser should be kept constant.

To reduce the driving steam volume while attaining a stable vacuum degree, the water temperature in the barometric condenser should be as low as possible. The steam volume can further be reduced by selecting nozzles for the summer and winter seasons.

Table 9.1.2 shows the relationship between the ejector steam volume and water temperature.

Table 9.1.2 Relationship between Barometric Condenser Cooling Water Temperature and Ejector Steam Amount

Temperature	°C	10	15	20	25	30	34
Steam amount for drive	kg/h	200	250	330	425	585	720

a. Optimization of driving steam pressure

The big difference between the boosters manufactured before energy conservation was introduced and the present energy conservation type boosters is the allowance considered when manufacturers design boosters even though the specification (i.e. extraction amount) is identical.

As shown in Table 9.1.3, the traditional design values have a large allowance for the suction and delivery sides, and overlapping between the No. 1 and No. 2 boosters is large.

Table 9.1.3 Difference in Booster Setting Values

(Unit: Torr)

	Calculated Value		Conventional Value Used		Energy Conservation Type Value to be Used	
	Suction Pressure	Discharge Pressure	Suction Pressure	Discharge Pressure	Suction Pressure	Discharge Pressure
Booster No. 1	3	12.2	2.8	15	3	13
Booster No. 2	12.2	49.7	11	60	12	55

(The above values are assumed ones, not actual ones)

To retain 3 Torr with this booster, there is no problem even though the designed driving pressure is slightly reduced because the steam extraction specification has an allowance against the actual volume and overlapping is large.

To control the pressure to 4-5 Torr with this 3-Torr type booster, the No. 1 booster driving pressure is reduced and the booster is run in the low vacuum operation area. There is no theoretical support for the operation in this low vacuum operation area; therefore trials and errors may be necessary to obtain data.

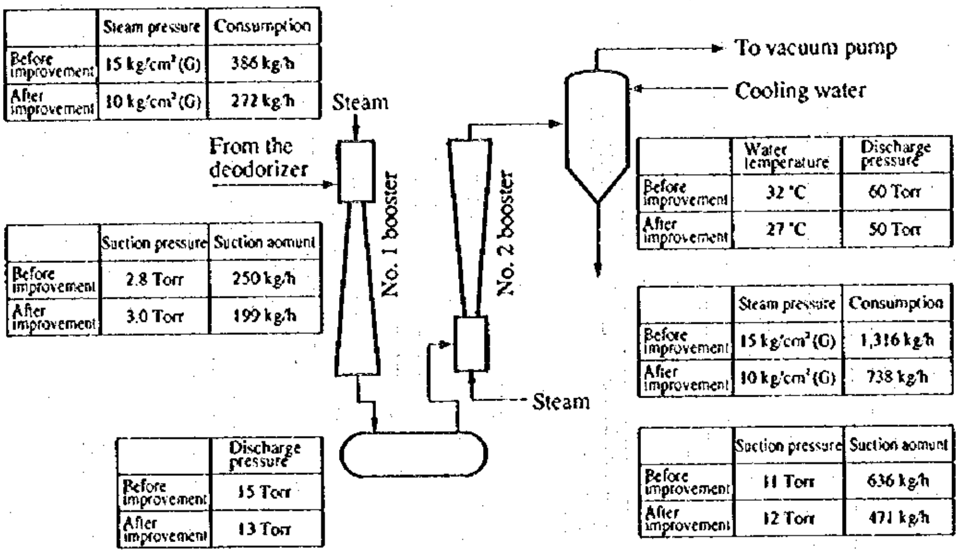
The driving steam pressure difference between 10 kg/cm^2 (G) and 7 kg/cm^2 (G) will result in 30 % reduction of the steam volume used.

b. Review of deodorizing booster capacity (improvement case)

Traditionally, a large steam ejector (i.e. booster) is used to generate vacuum required in the oil deodorizing process. Boosters manufactured before energy conservation was highly evaluated may have a too large allowance and exceed the design value. By replacing the booster with the one matching the current operating condition, energy conservation may be achieved.

We checked the booster of the deodorizing equipment constructed in 1971, to find that the booster was run with the value before improvement as shown in Figure 9.1.14 (average capability 160 t/d).

Figure 9.1.14 Operating Condition for Vacuum Device



Note: The above-mentioned steam quantities indicate the annual mean values.

The suction volume was calculated based on the required deodorizing condition, leak air measurement, and volatile matters in the raw material oil.

The maximum water temperature was determined from the annual cooling water temperature (seawater). For the suction pressures of the No. 1 booster and No. 2 booster, the minimum overlapping was selected after discussion with the manufacturer. In this case, to prevent fluctuation in the booster's driving steam pressure, a pressure lower than that in the main steam pipe was selected as the design value. (The main pipe pressure (15 kg/cm^2 (G) is reduced and 10 kg/cm^2 (G) is supplied.)

As a result, the value after improvement in Figure 9.1.14 was obtained.

Effects of energy conservation are as follows:

Annual steam saving: {(386 + 1,316) – (272 + 738)} × 7,200H = 4,982 t/y
Annual cost saving : 4,982 t × 5,000 yen/t = 24,910,000 yen/y

c. Forced cooling of the barometric condenser cooling water (improvement case)

As shown in Figure 9.1.15, there is a method that forcibly cools the barometric condenser cooling water to reduce the steam consumed by the booster. In this case, steam saving can be accomplished by performing forced cooling of the cooling water with a freezer. (See Table 9.1.4.)

Figure 9.1.15 Forced Cooling of Barometric Condenser Cooling Water

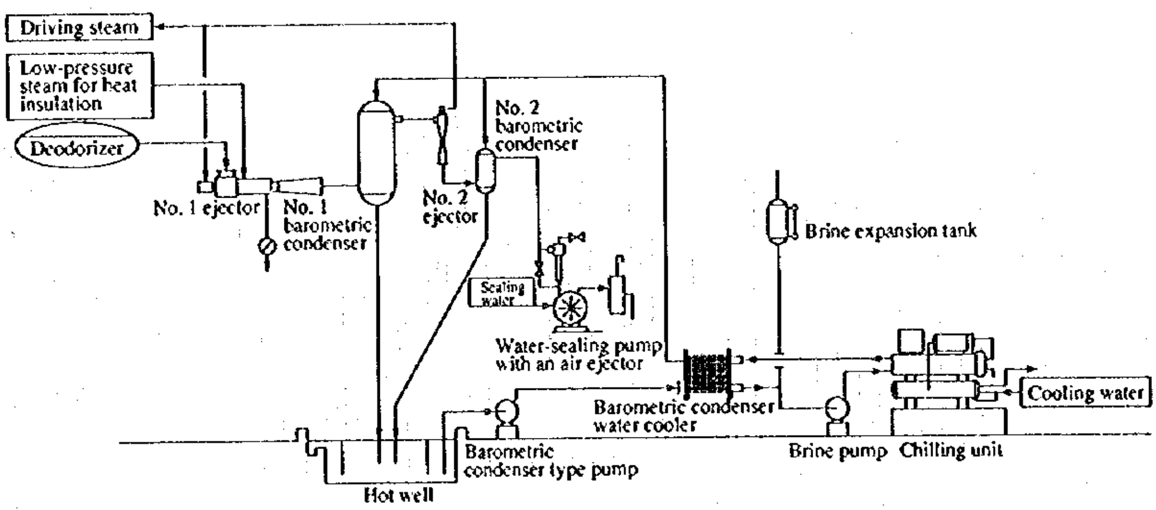


Table 9.1.4 Forced Cooling of Barometric Condenser Cooling Water

	Conventional method	After Improvement	Difference in Energy Used
Steam	197 kg	50 kg	147 kg
Electricity			
Vacuum pump	0.9 kWh	0.9 kWh	
Barometric condenser pump	4.4 kWH	1.5 kWh	
Brine cooling equipment	–	17.8 kWh	
Total	5.3 kWh	20.2 kWh	Δ14.9 kWh

(4) Deodorizing tower tray improvement

On the tray in the deodorizing tower, deodorizing is performed while blown steam ascends in the tube along with oil. After special processing, the system that allows film-type ascension has reduced the blown steam by 30 %.

(5) Energy conservation in the hydrogenation process

In the hydrogenation process, the reaction time can be reduced by effectively promoting the contact reaction between the oil and hydrogen.

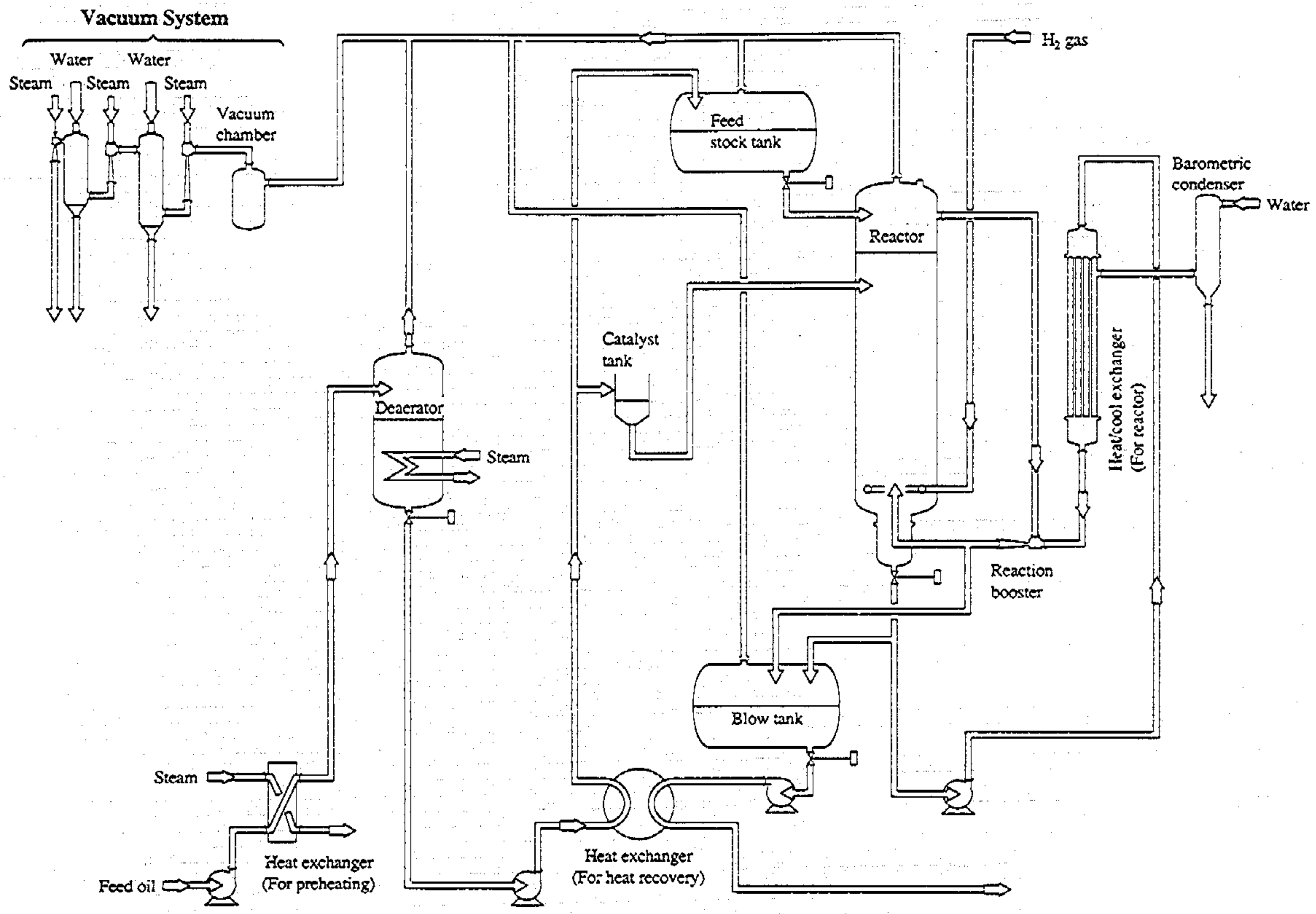
As shown in Figure 9.1.16, the hydrogen gas repeats the gas-liquid contact while ascending through the oil in the reactor. The oil is circulated through the heat exchanger, reaction booster, and agitation nozzle by the circulation pump and returns to the reactor. The non-reacted hydrogen gas that ascended through the oil is absorbed, and actively contacts the oil in the reaction booster and piping, thereby promoting the hydrogenation reaction.

Then, the hydrogen gas which did not react with the oil is discharged from the agitation nozzle provided in the reactor into the reactor and the reaction is promoted by a strong stirring effect. During the reaction, the reaction pressure/temperature is controlled.

The reaction time is approximately a half of that of the traditional type, and the steam volume used can be reduced by approximately 650 kg per 10 t/batch compared with the traditional hydrogenation equipment.

For your reference, the reaction time of soy bean oil is approximately 1.5 hours.

Figure 9.1.16 Hydrogenation Equipment



9.2 Energy Conservation in the Sugar Manufacturing Industry

9.2.1 Cane Sugar Manufacturing Processes

Figure 9.2.1 shows the cane sugar manufacturing processes.

(1) Expression (Squeezing) process

Since sugarcane maintains its life and decomposes sugar, protein, etc. even after it is harvested, it should be squeezed within 24 hours after harvesting.

With a cane cutter, the cane is cut into small pieces. Then, the small pieces are further cut by a cane shredder. If the cane shredder is not available, the cane cut by the cane cutter is crushed by a cane crusher so that sugar can be easily pressed out by the squeezing machine (i.e. mill) in the next process. The mill consists of three steel rolls, and normally, 4 to 6 sets of mills are provided. Fine cane pieces and water are passed in counter current between the rolls, and squeezing is performed by a strong pressure at this point.

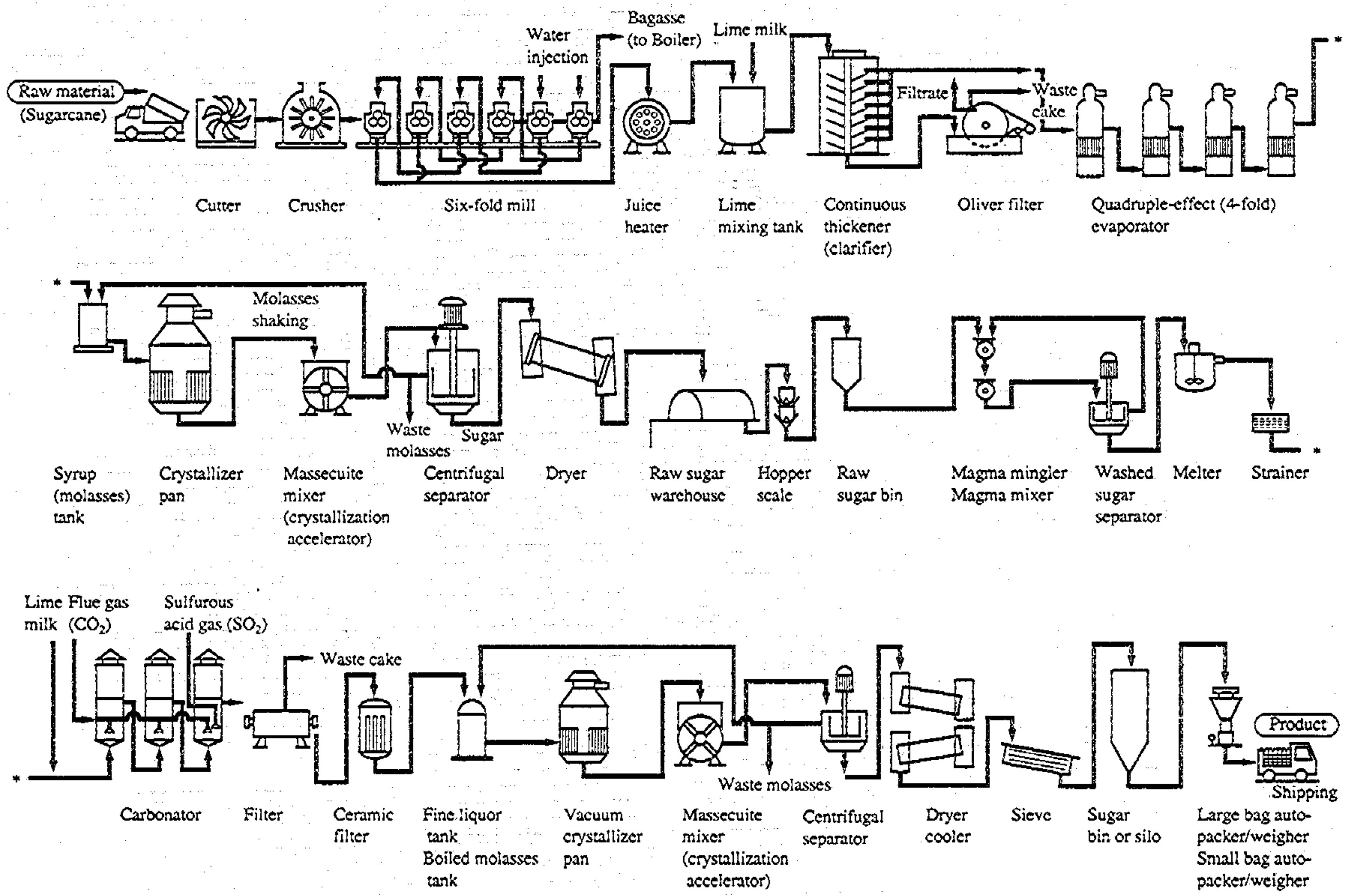
The squeezing rate of cane sugar is 94 to 96 %. The squeezed juice is separated from bagasse by filtering. Bagasse is fed to the boiler room as fuel. When bagasse is excessive as fuel, it can be used as the raw material.

Squeezed juices, which are mixed and added with lime milk, are then heated (100 °C, pH 7.6 to 8.0), and fed into a doll type or beater type continuous settling tank (clarifier), where impurities are sedimented.

In the sugarcane factory that manufactures the raw material sugar, carbonation, processing with activated carbon, and ion exchange resin are not usually performed. Recently, however, some factories perform carbonation, sulfurization, and decoloring with activated carbon to produce the value-added plantation white sugar.

In the sugarcane factory, the plantation white sugar plant may apply softening with an ion exchange resin before the condensation process which is likely to generate scales.

Figure 9.2.1 Cane Sugar Process Flow



(2) Condensation process

The supernatant liquid is fed to the multi-effect evaporator as the clarified juice (Bx13-15) and condensed to Bx60. Impurities sedimented along with lime is filtered by a continuous rotary vacuum filter (Oliver filter), and the filtered liquid is mixed with the said supernatant liquid to recover sugar.

(3) Crystallizing process

The condensed syrup is further boiled down in a vacuum crystallizing pan, forming massecuite (Bx92-93), a mixture of sugar crystals and molasses.

For the crystallizing pan, a low-head high-speed circulating streamline type has been adopted. Furthermore, for energy conservation by improving liquid circulation and saving the water addition, a stirring machine is often attached to the crystallizing pan. The massecuite is divided into sugar and molasses by a centrifugal separator.

The third massecuite is further crystallized by a crystallization accelerator with a stirring machine, and then molasses is separated.

After drying and cooling, the first and second sugars are mixed, fed to the sugar bin, and then used as the raw material sugar.

(4) Supplementary materials

Although the major supplementary materials depend on the purification method, they are lime (0.56 to 0.72 kg/t-cane), caustic soda (for peeling scales off from the evaporator; 0.022 to 0.066 kg/t-cane), and so on.

For another example per ton of product, the raw material is 9 tons, steam is 5.1 tons, dynamic power is 205 kWh, waste molasses is 0.18 tons (by-product), and lime is 3.2 kg. The yield is 11 to 13 %.

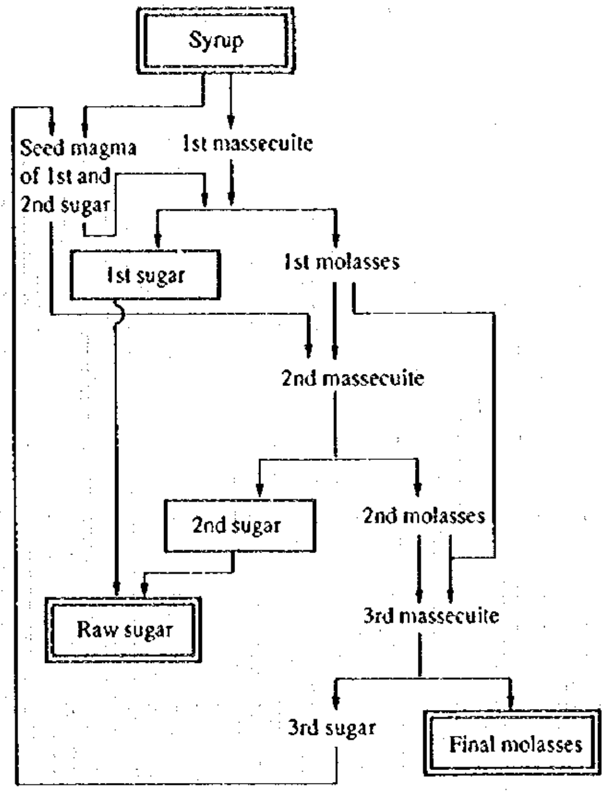
An example of bagasse composition is as follows:

Moisture %	Cellulose %	Pol %	Baggase/cane	Cal. (kcal/kg)
40.71	56.41	2.08	24.49 %	2,530

(5) Boiling system

Figure 9.2.2 shows an example of the boiling system for the raw material sugar.

Figure 9.2.2 Example of Raw Sugar Boiling System (Boiling, skimmer)



(6) Refined sugar

To make refined sugar, the raw material sugar is washed, melted, and refined.

Figure 9.2.3 shows the flow chart, and Figure 9.2.4 shows the mass balance.

Figure 9.2.3 Flow Chart of Refined Sugar

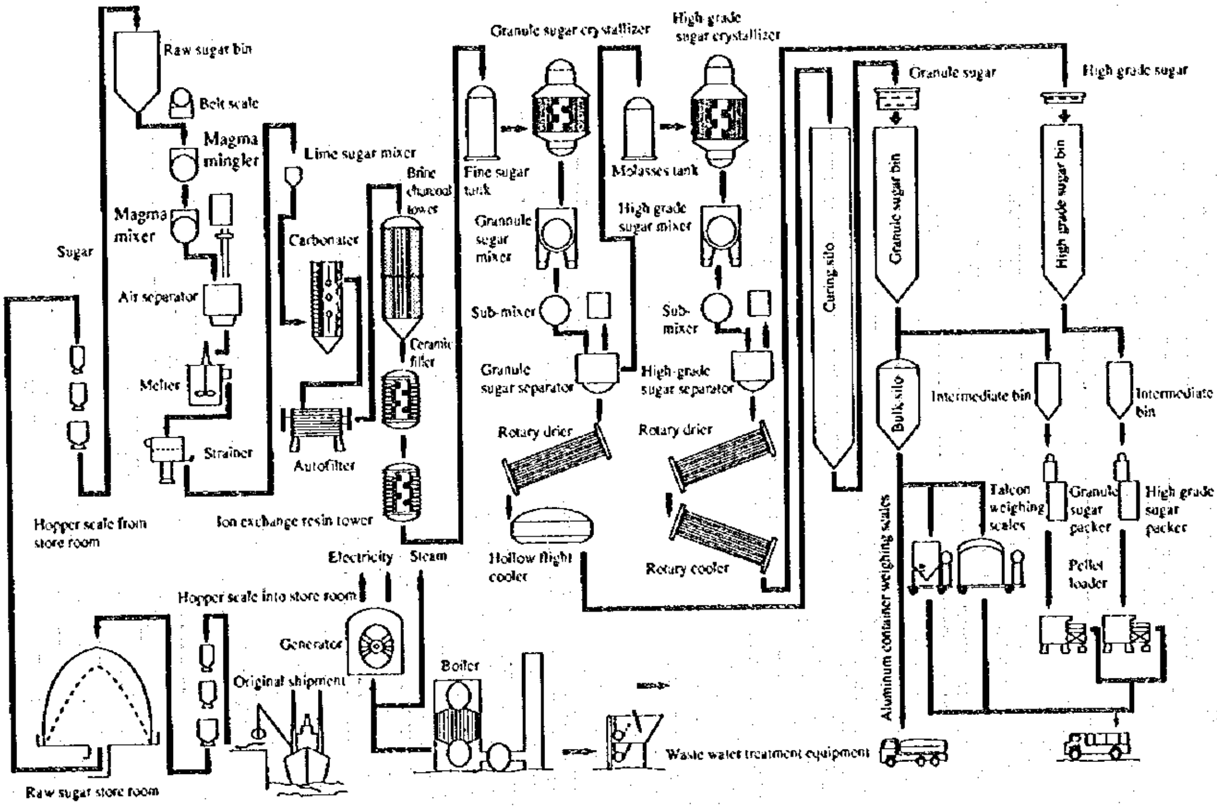
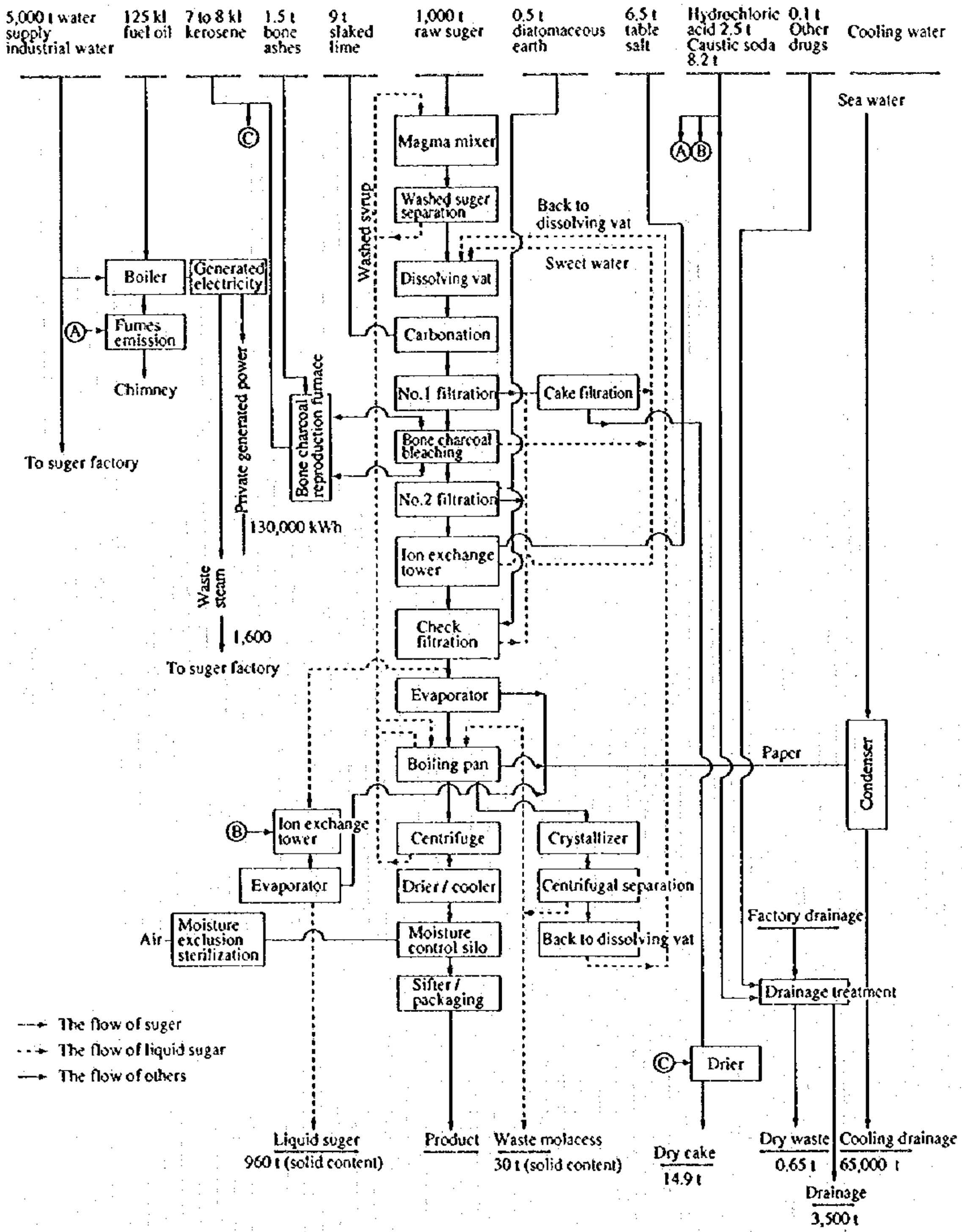


Figure 9.2.4 Example of Sugar Refining Factory Flow Sheet and Mass Balance



Manufacturing processes consist of washing, purification, boiling, and separation/ finishing.

A certain volume of raw material sugar is fed by a counting feeder. Magma (muddy crystals) is made by mixing the raw material sugar with the washed molasses. The magma is then put in a mixer, stirred, and heated up to approximately 60 °C. Then, the molasses film containing the most part of impurities is removed by the centrifugal separator.

a. Sugar washing

Crystals washed are dissolved into sweet water generated by washing the manufactured crystals (Bx60-65), and then heated up to 60 °C. Then, lime milk is added and carbonation with boiler smoke and gas is performed. The lime carbonate sedimented is removed by filtering. Then, decoloring to approximately 60 % is performed. Filtering is performed by adding slurry of activated carbon powder to the resulting filtrate (brown liquor). Alternatively, the filtrate (clear liquor) decolored by filtering the filtered liquid through the granular activated carbon layer is refined by an ion exchange resin and filtered by a ceramic filter. This filtered liquor is called the fine liquor.

b. Purification process

The fine liquor is introduced into a vacuum crystallizing pan. As a result of condensation under vacuum (50 to 60 °C), massecuite is made.

c. Boiling process

Crystals are obtained from this massecuite by using a centrifugal separator. The crystals are dried by hot airblow, and then cooled.

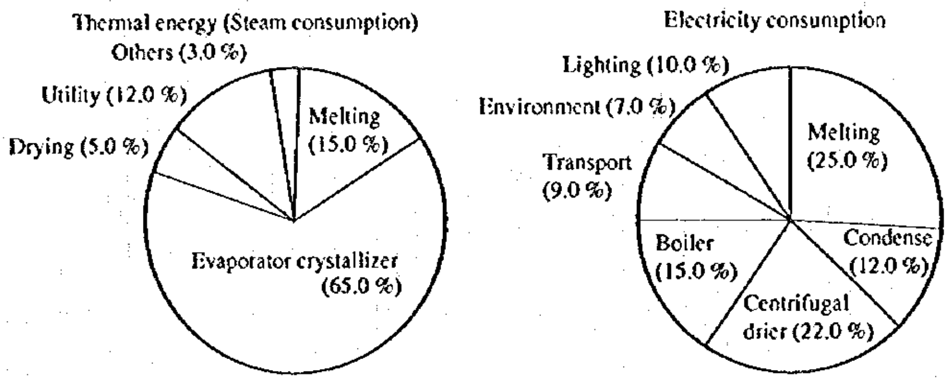
d. Separation/finishing process

Crystals are finally filtered and packaged.

9.2.2 Energy Consumption by Manufacturing Cane Sugar

Figure 9.2.5 shows an example of energy consumption in a sugar refining factory in Japan.

Figure 9.2.5 Energy Consumption Ratio in a Refined Sugar Factory



Heat energy is mainly consumed by the evaporator and crystallizing pan, followed by the melter. These three processes occupy 80 % of overall heat energy consumption. For electric power, the melting process pre-processing the raw material sugar uses 25 % and the centrifugal separator and drying process use 22 %.

In recent years energy intensity in Japan is 80 to 110 liters for fuel per product ton, 90 to 100 kWh for electric power, and 95.5 to 96 % for the yield.

For energy intensity for cane sugar, heat energy is mainly used by the evaporator (55 %) and the crystallizing pan (30 %). These two processes occupy 85 % of overall heat energy consumption.

Much electric power is consumed by the centrifugal separator and squeezing machine.

Recently, some factories have the raw material sugar processes linked with the sugar refining processes. In this case, heat energy is divided into 75 % for the raw material sugar processes and 25 % for the sugar refining processes.

9.2.3 Beet Sugar Manufacturing Processes

Beet is divided into the stem/leaf part and root part and transported to the factory after it is harvested. Working days of a beet factory are approximately 100 days around November so that sugar in the beet root will not be changed and lost. A root weighs hundreds of grams to 1 kg. The sugar content is 14 to 20 %. As a result of plant improvement and improvement of the cultivation techniques (such as planting with the paper pot), the production volume and sugar content per field area is increasing every year.

Figure 9.2.6 shows the beet sugar manufacturing processes.

Figure 9.2.6 Beet Sugar Process Flow

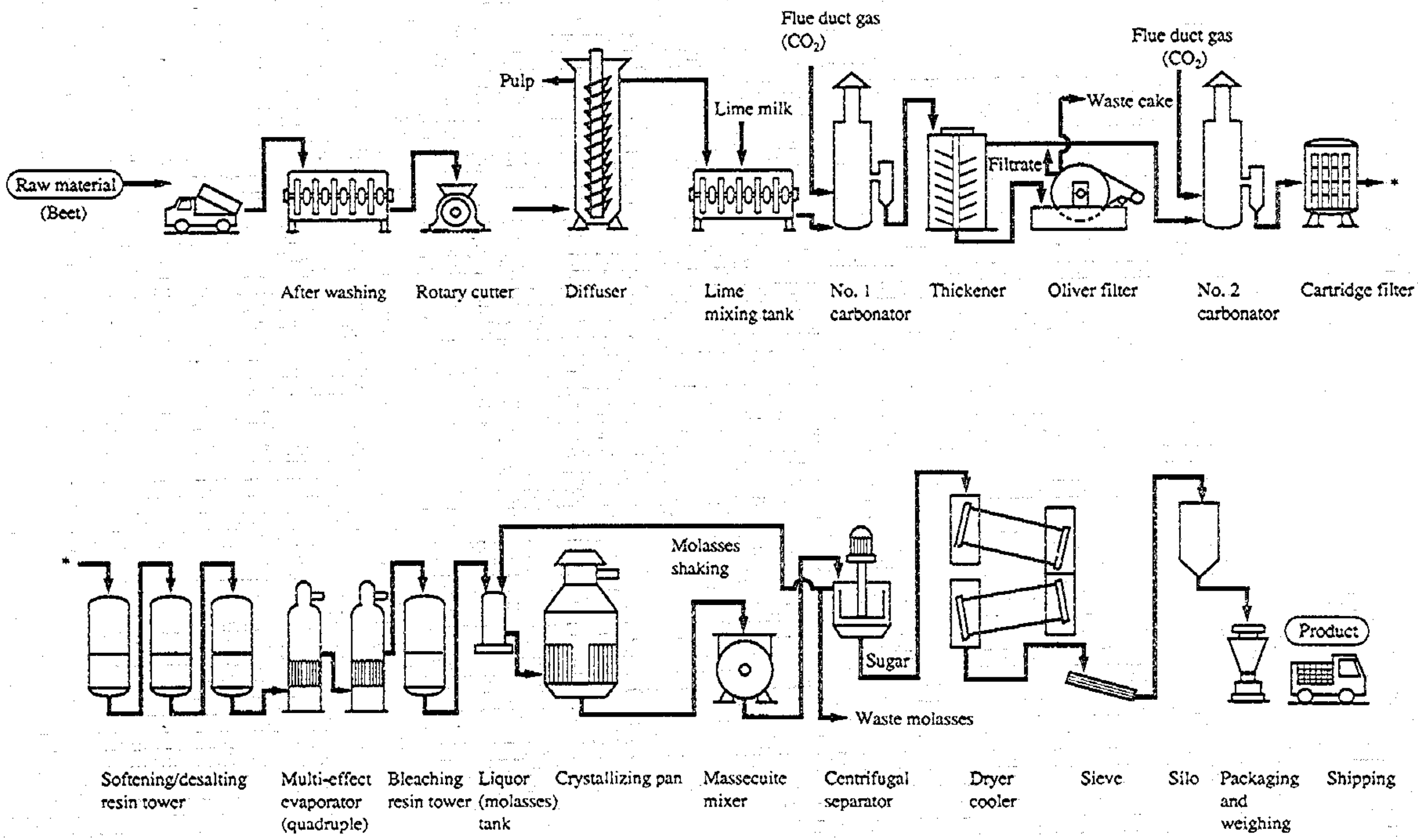


Table 9.2.1 shows the mass balance of the beet sugar manufacturing processes.

Table 9.2.1 Mass Balance of Beet Sugar Manufacturing Process

Process	Total Weight (t)	Sucrose Content (t)
Beet	1,000	160.0
Leached juice	1,200	157.2
Carbonating fluid	1,267	153.8
Clarified juice	1,270	153.0
Condensed juice	266	153.0
First massecuite (including second sugar)	326	256.0
First sugar (product)	156.5	151.3
Second massecuite	44.7	31.6
Second sugar	15.6	14.9
Waste molasses (for sale)	23.9	19.8
Beet pulp	50 to 60	

(1) Manufacturing processes and machines/equipment

Beet is fed through a ditch (also referred to as the flume) with hot water from the raw material stockyard to the factory. During this period, the water jet machine and water flow as well as mutual friction between beet pieces remove and separate the soil and grass adhered. This feed water contains a large amount of soil bacteria. If soil bacteria comes to the subsequent processes, sugar is decomposed, causing problems such as yield (i.e. sugar recovery rate) reduction. Therefore, the root and stem are further washed sufficiently, and then, water is separated and the root and stem are cut into small pieces by a slicer. These pieces are referred to as the cossets, which are fed to the next sugar diffuser. In the diffuser, water flows as countercurrent against the cossets. Water comes from the tower top, and cossets mixed with the diffused liquid is fed out of the tower bottom by the impeller.

The diffuser broadly used in recent years employs the continuous countercurrent system. Some towers are the tilted type but most are the upright type. Cossets, from which most sugar has been removed, are referred to the beet pulp, which is used as food for cattle. The diffused liquid coming out of the tower bottom is dark-gray and its sugar content is approximately 12 to 17 % although the sugar content depends on the sugar content in the raw material beet or the draft percentage (i.e, volume of sugar liquid to the raw material beet), and the draft to the raw material beet is 120 to 130 %. Fine cosset pieces, colloidal organic or inorganic non-sugar contents, and ionized inorganic non-sugar contents have been mixed or dissolved into this diffused liquid. They may reduce the sugar crystal recovery rate and increase waste molasses or reduce the crystal quality (i.e. with odor or color unique to beet). Therefore, cleaning (lime processing, carbonation, filtering, ion exchange resin processing, etc.) is conducted before the crystallization process to remove them. After lime milk is added, the diffused liquid is contacted with carbon dioxide (i.e. carbonation), thus sedimenting impurities and calcium carbonate together.

The basic of carbonation is that the sugar liquid to be refined is added with lime milk to generate slaked lime, heated up to approximately 90 °C, blown with carbon dioxide for neutralization, and then filtered. The method broadly used by beet factories presently is as follows:

(Diffused liquid)
↓
Lime pre-addition (0.2 % CaO on Beet)
↓
Lime addition (1.5 to 1.7 % CaO on Beet)
↓
Continuous carbonation
↓
Sedimentation and separation by the thickener
↓
(Mud)
↓
Filtering
↓ Second carbonation (0.1 to 0.3 % CaO on Beet)
(Cake) ↓
Filtering
↓

In a Japanese excellent factory, desalting is performed by using the positive ion exchange resin after filtering. Then, the negative ion exchange resin is used for decoloring to obtain the clarified sugar juice. This clarified juice is evaporated and condensed with the multi-effect-evaporator. In the melting tank, the No. 2 sugar is re-melted and adjusted to a certain concentration degree. A small volume of diatom earth is added for filtering, and decoloring is achieved by the ion exchange resin to make the refined sugar liquid. When the refined sugar liquid is put in the vacuum crystallizing pan, where it is crystallized, massecuite containing both sugar crystals and molasses is obtained.

Recently, factories having a stirring machine installed on the crystallizing pan are increasing in Japan. Following the sugar refining plant, the beet plant uses the stirring machine for boiling the third sugar to reduce the boiling time. For the third sugar, the boiling time is longer because the purity grade is lower, but forced stirring accelerates the crystal growth rate, thereby reducing water addition and saving the steam volume. As an example, approximately 30 % of the boiling time could be reduced (i.e. boiling the third sugar massecuite that required 10 to 12 hours now requires only 7 hours). For reference, the first sugar boiling time is 1.5 hours.

In Japan, 20 % of steam is used for the crystallizing pan, and 35 % for the evaporator. For the fuel oil, 230 to 240 liters/t-sugar is used. For electric power, 180 kWh/t-sugar is used if desalting is provided, or 120 kWh/t-sugar if desalting is not provided. In other words, 6 GJ/t-sugar is used in Europe (in Germany), while 10 GJ/t-sugar is used in beet plants in Japan.

(2) Product

The molasses of the third sugar contains many useful contents. Sugar is recovered by the Stephen method and returned to the carbonation process for recovery. From the Stephen waste liquid, betain, glutamic acid, and oligosaccharide are produced as by-products.

The liquid left after the third sugar is produced is used as waste molasses for alcohol fermentation or mixed with pulp for the food for cattle.

The beet plant uses a large volume of water. Table 9.2.2 shows an example in Japan.

Table 9.2.2 Waste Water (an example)

Total Waste Water Example (Per 1,000 t raw beet)

Waste Water Generating Source	Waste Water Amount (t)	BOD (ppm)
Beet washing waste water	1,000	950
Washing water in the cleaning process	330	400
Carbonic gas washing water	100	10
Ion exchange resin recycled waste fluid	120	15,500
Ion exchange resin washing waste water	3,800	450
Filter washing and other miscellaneous water	1,100	300
Condenser cooling water	5,500	20
Turbine and pump cooling water	1,200	10
Water for miscellaneous purposes	800	35
Total	13,950	

Note: In addition to the above, beet fluid feeding water is not discharged since it is to be recycled after precipitation.

Waste coming from manufacturing beet sugar per 1,000 tons of raw material beet is as follows:

Soil/sand and foreign matters contained in the raw material : 35 t
Sedimient cake produced by carbonation with carbon dioxide: 100 t
Cake and other sediments from the filter : 5 t

9.2.4 Energy Consumption in Manufacturing Beet Sugar Manufacture

Recently, some factories have reached 6 GJ/t-sugar for heat energy consumption in beet sugar manufacturing processes. However, heat energy consumption is 10 GJ/t-sugar in most factories. Heat energy is mainly used for the evaporator (35 %), crystallizing pan (20 %), and pulp drying (30 %), which occupy 85 % of overall heat consumption.

Electric power is mainly used by the centrifugal separator, heat pump, and slicer.

9.2.5 Energy Consumption in the Sugar Refining Factory

(1) Use of the ion exchange resin

The thin juice extracted from beet contains calcium ion as well as coloring matters and salt. If the thin juice is directly condensed, scales are generated in the evaporator and heat efficiency is extremely reduced. As a necessary process in the beet sugar factory, a juice softening equipment using the strong-acid sodium ion exchange resin should be provided before the evaporator.

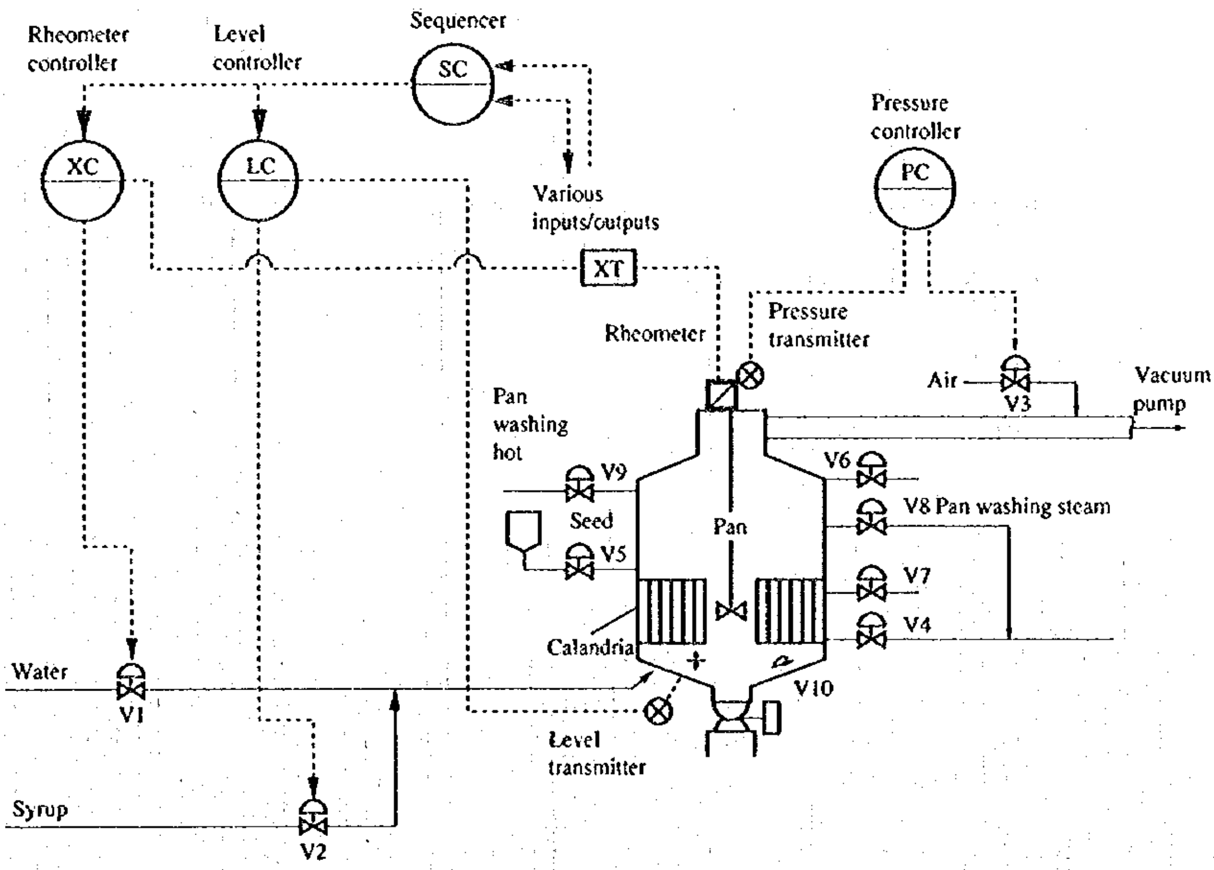
Calcium in the juice is replaced by sodium by this softening type ion exchange resin. Since the evaporator's condensation time can be reduced, Bx can be increased by 5 compared with the traditional value, and at the same time scale is less liable to form, thereby reducing the pan's boiling time, and leading to energy conservation.

(2) Reducing the boiling time by automatic control of the crystallizing pan

To reduce the boiling time, it is advisable to use the automatic control system employed by recent excellent factories.

Figure 9.2.7 shows an example of automatic control by providing a stirring machine on the crystallizing pan.

Figure 9.2.7 Pan Control Loop Diagram



It is vitally important for the pan boiling to control the concentration of the sugar liquor in the pan during sugar boiling. The sugar boiling operation is conducted in the following procedure.

a. The crystallizer pan is made vacuum.

b. The sugar liquor (syrup) or molasses is suctioned up to the level enough to fill the calandria (heat transfer surface).

c. Steam is introduced.

d. The first sugar is boiled until it becomes supersaturated (Bx84) suitable for sugar liquor to start crystallization (Supersaturation degree 84/75 = 1.12).

e. The seed sugar is suctioned to produce a base crystal. To develop this base crystal, the sugar continues to be boiled until the specified massecuite amount can be obtained while keeping the supersaturation degree of the liquor in the pan at 1.1 to 1.2 by suction of the liquor.

f. The mobility is measured, and the vacuum in the pan is relieved to make the pressure normal. Then the massecuite is let to drop on the massecuite mixer.

g. The pan is cleaned to return to normal.

Excessive supersaturation of the mother liquor surrounding a base crystal causes secondary crystallization to occur, interfering with the molasses separating operation. Moreover, crystals sticking together form crystal groups, and make the crystal size uneven, thus degrading the product value. In recent years, the proper control of liqour concentration has become available through the combined use of a mobility controller and a level controller.

The product grain size can be made uniform and the water addition can be reduced by automatically controlling syrup concentration and water addition while measuring the mobility of the liquor in the crystallizing pan so as to obtain a proper crystal concentration in the sugar being boiled.

(3) Heat recovery of pulp dryer

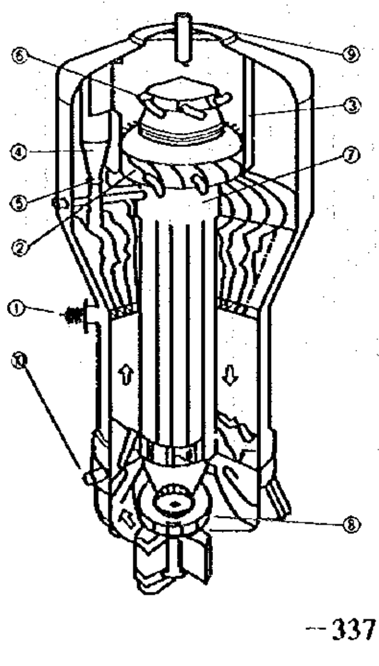
Most pulp dryers are the cocurrent heating type rotary hot airblow dryers. Normally, the pulp dryer uses approximately 30 % of steam consumption in a beet plant.

Pulp is supplied to the dryer via the two-axial screw press.

Recently, pulp is dried by overheated steam and 90 % of exhaust heat from overheated steam is recovered to the evaporator in Germany. Consequently, a factory with 120 kg/t-sugar of steam consumption in the entire factory has appeared.

Figure 9.2.8 shows the dryer structure.

Figure 9.2.8 Open View of an Industrial-scale Dryer



① Screw conveyer (charge)
② Stationary blades
③ Wall
④ Side cyclone
⑤ Ejector
⑥ Blades
⑦ Superheater
⑧ Impeller
⑨ Pipe
⑩ Screw conveyer (discharge)

Compressed pulp containing approximately 25 % of dried materials goes from the screw conveyer (①) to the first cell of 16 cells laid out around the central overheater (⑦).

Steam coming out through the cell top goes between fixed plates (②) that generates the cyclone effect in the cylinder wall (③). Dust accompanying steam is collected to the cylinder wall and then it goes in the side cyclone (④) placed on the cell via the square hole. The dust thus removed is dried for a short period and discharged smoothly.

Steam, from which the dust has been removed, goes through the fixed plate (⑥) set forming the path that converts the motion energy of the slewing motion current into a pressure rise, and is distributed to all tubes on the overheater. Then, the steam here is overheated by the higher-pressure steam. From the bottom of the equipment, steam is again blown by the blower (⑧) through the cell, completing the cycle. This blower is the only one moving part in the dryer main unit.

Steam evaporated from the beet pulp goes through tube (⑨) and discharged from the top. Since steam is taken out at the center of the slewing motion current, it does not contain dust.

This equipment is examined by several companies in Japan but has not been adopted. It is said that rotary valves at the inlet and outlet of the equipment leak and the equipment is incomplete. It is also said that the subject left last in the beet factory is energy conservation for the pulp dryer.

(4) Energy conservation for the condensing pan and vacuum system

As shown in Figure 9.2.9, energy conservation can be attempted by re-compressing vapor of the evaporator by the steam booster.

Figure 9.2.9 Triple-effect Evaporator with Steam Booster (3-1 type)

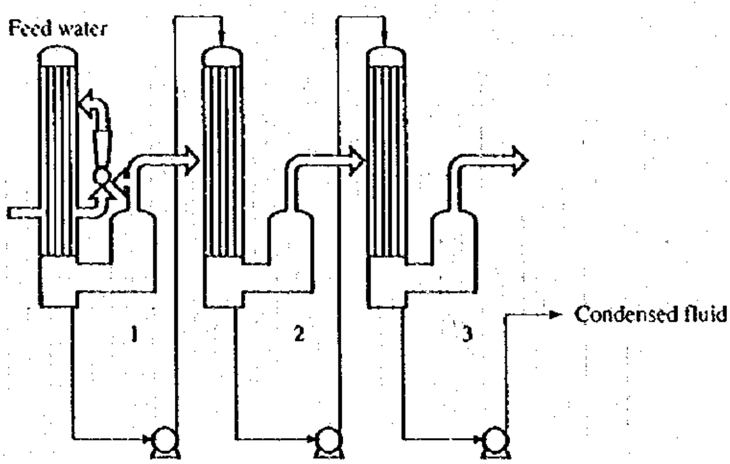
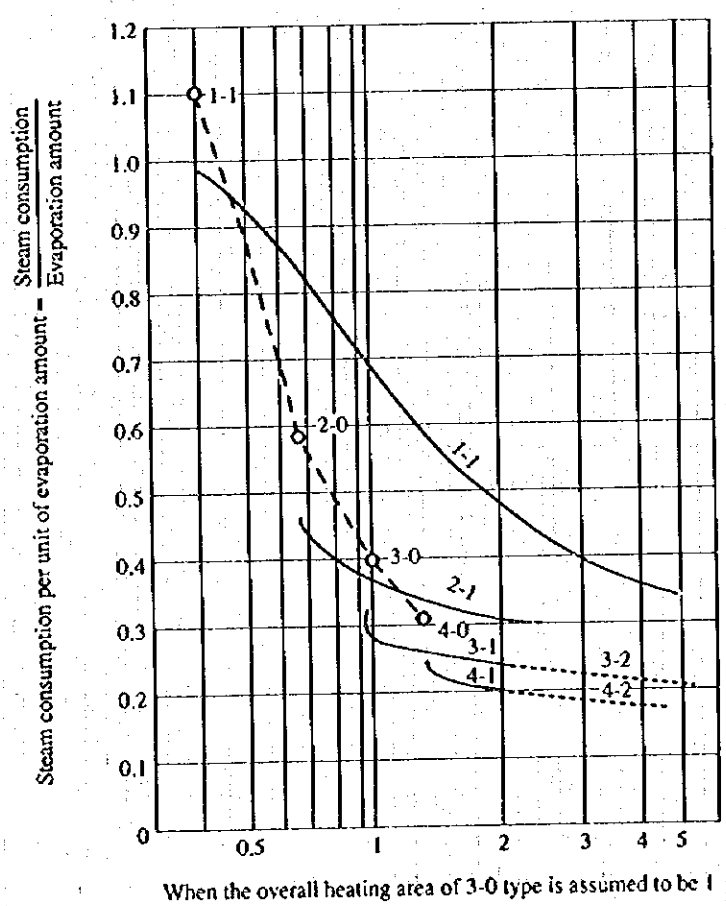


Figure 9.2.10 shows an example of steam consumption per unit evaporation amount of the multi-effect evaporator and the total heat transfer area ratio under the following conditions:

- Steam pressure (gauge) : 7 kg/cm² (0.69 MPa)
- No. 1 heating maximum temperature : 100 °C
- Final evaporator liquid temperature : 50 °C
- Condensation ratio : 5
- Rise to the boiling point of the final condensed liquid: Approximately 2.5 °C

Figure 9.2.10 Ratio of Steam Consumed by Multi-effect Evaporator per Unit Evaporation Amount and the Total Heating Area (an example)



For example, steam consumption per unit evaporation amount of the quadruple-effect evaporator is 0.3. If part of vapor of No. 1 evaporator is re-compressed by the steam booster (4-1 type), steam consumption per unit evaporation amount is 0.25.

Recently, vapor heat recovery from the crystallizing pan has been put into practice.

(5) Condensation of Steffen waste water by using low-pressure waste steam

Total solid concentration in Steffen waste water from the beet sugar manufacturing factory is 6.5 %. In Japan, where underground permeation is prohibited, a double-effect evaporator may be installed for condensation by using exhaust from the quadruple-effect evaporator in the sugar refining processes and flush steam from the condensate to reduce the waste water amount. Figure 9.2.11 shows the flow sheet of the sugar refining processes and Steffen waste water condensing process.

Figure 9.2.11 Flow Sheet for Sugar Production Process and Steffen Waste Water Concentration Process

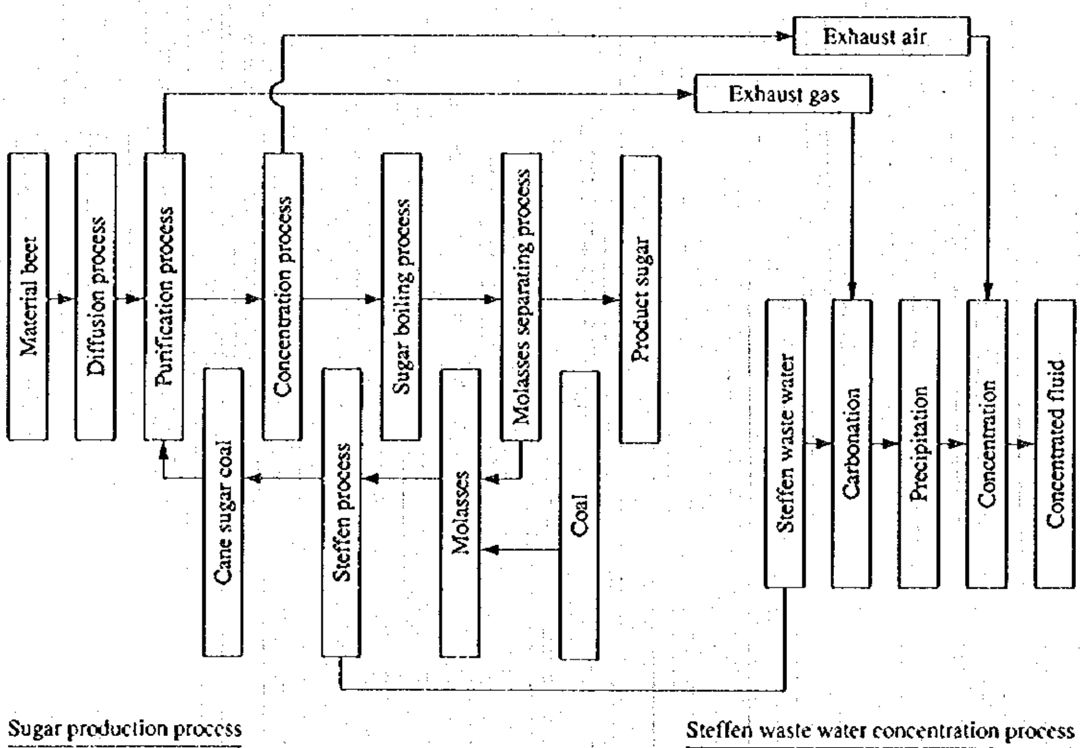


Table 9.2.3 shows the Steffen waste water analysis table. Table 9.2.4 shows the concentrated liquid analysis table. Figure 9.2.12 shows the flow sheet of the new system (PT continuous saccharate method) with less drain.

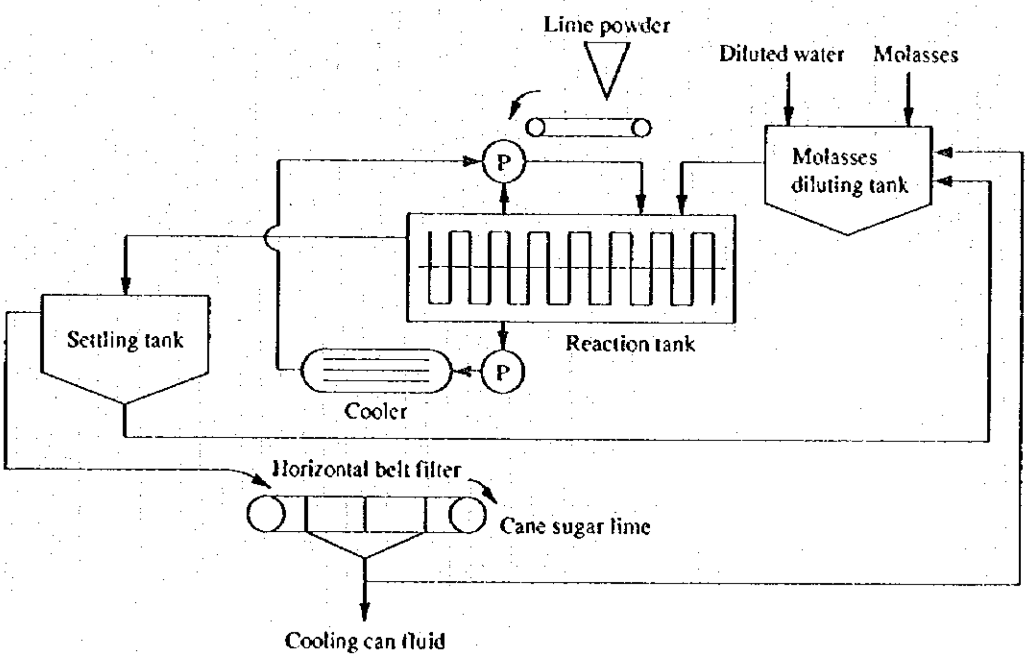
Table 9.2.3 Analytical Table of Steffen Waste Water

Appearance	pH	Total solid	Organic content	Ash content	Sugar content	Total nitrogen	BOD	COD
Yellowish brown, transparent	13.1	6.5	4.0	2.5	0.5	0.25	18,000	11,000

Table 9.2.4 Analytical Table of Concentrated Fluid (CSF)

Moisture content	Sugar content	Lime	Ash content	Phosphoric acid	Sodium	Potassium	Nitrogen	Organic matter
34.7	5.6	0.02	16.37	0.06	2.21	4.93	3.67	41.9

Figure 9.2.12 Flow Sheet for RT Continuous Saccharate Process



The features of this process are that Seffen waste water approximately ten times more than the Steffen waste water coming in the reaction tank is always circulated and the lime powder is decomposed and added, and the diluted molasses sugar content can be increased to 12 % which is approximately twice higher than that in the traditional batch system as a reaction condition. By circulating the cold filtered liquid, the Steffen waste water amount can be reduced and concentration of the solid materials can be increased. Particularly for this purpose, water for washing the belt filter cloth and component sealing water are used in addition to circulation of the cold filtered liquid back to the diluted molasses tank for reduction of Steffen waste water.

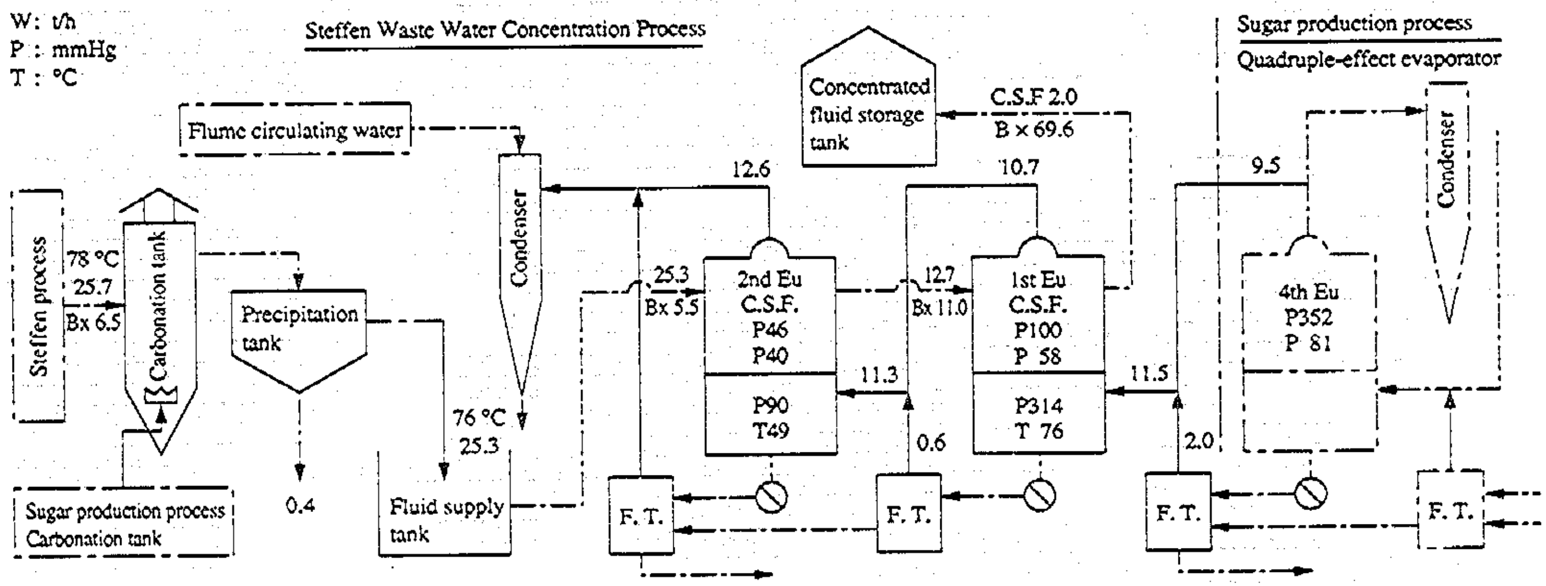
For example, as shown in Table 9.2.5, the steam load for condensation to 65 of solid concentration is a half or less of the traditional method, in a factory where the volume of raw material processed is 240,000 t, average processed volume per day is 2,200 t, and the product yield is 14.7 %.

Table 9.2.5 Comparison between Traditional Method and RT Method

	Unit	Traditional Method	RT Method
Molasses treating amount	t/d	150	150
Diluted molasses sugar content	%	5.5	12.0
Concentration of waste water solid content	%	4.0	7.3
Waste water amount	t/d	1,260	620
Evaporation load	t/d	1,200	560

Figure 9.2.13 shows the flow sheet and heat balance of the concentration process.

Figure 9.2.13 Concentration Process Flow Sheet and Heat Balance



10. ENERGY CONSERVATOIN IN BOILER

10. ENERGY CONSERVATOIN IN BOILER

10.1 Classification

Now, boilers used universally can be classified by structure as shown in Table 10.1.

Table 10.1 Classification of Boiler

Type	Model
Cylindrical boiler	Vertical boiler Flue boiler Smoke tube boiler Flue smoke tube boiler
Water tube boiler	Natural circulation water tube boiler Forced circulation water tube boiler
Once-through boiler	

10.1.1 Cylindrical Boiler

Cylindrical boiler is mainly composed of a large diameter cylinder and unsuitable for a high pressure and a larger capacity due to its structure. It has been used as a boiler of less than 10 kg/cm² and 8 t/h in evaporation.

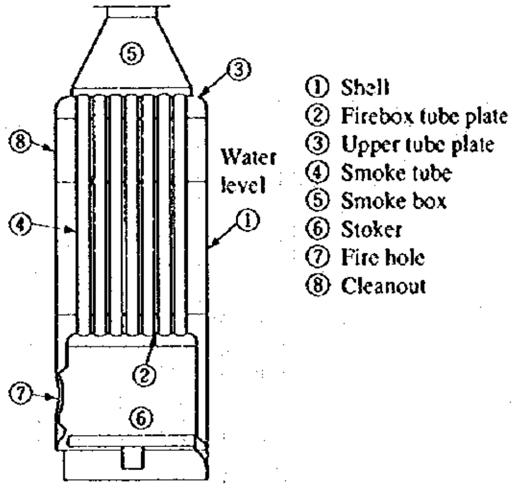
Since the cylindrical boiler has a larger water retaining volume per capacity compared with water-tube boiler, it demands much time to start up but a pressure fluctuation due to loading change is small.

(1) Vertical boiler

As shown in Figure 10.1, vertical boiler has a vertical cylinder and a combustion chamber in the bottom section. There are two systems of horizontal tube type and multi-tube type. Because it can not be provided with large heating surface area, the capacity is limited to 1 t/h or less.

It can do with a small floor area and can be set simply up, but it is hard to check and clean because of its small size. Because of the small surface area, entrainment contained in the generated steam tends to be too much.

Figure 10.1 Vertical Boiler (Multitubular type)



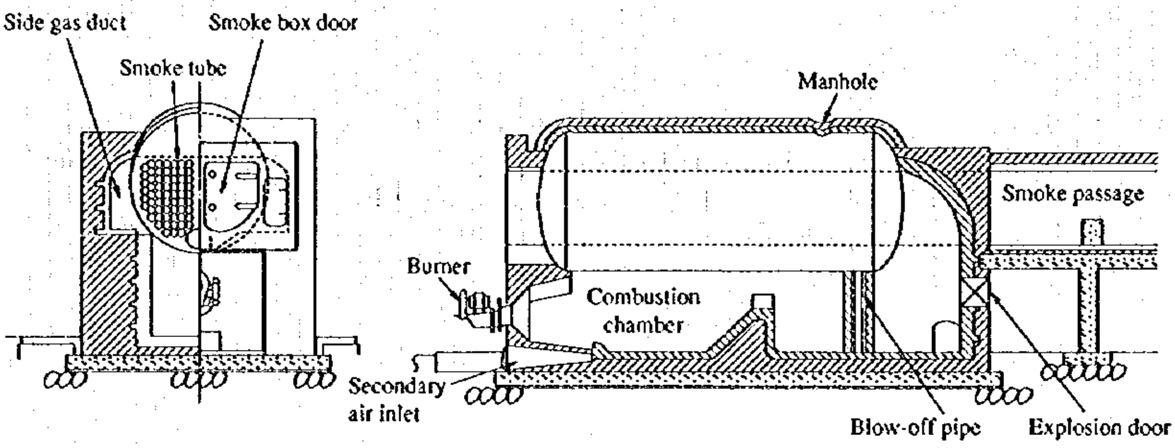
(2) Flue boiler

The flue boiler is provided with one or two flues through shell and the burners are equipped in the flue. One flue type is called a Cornish boiler and two flues type is referred to as a Lancashire boiler. Since the boiler has a small heating surface area and has lower efficiency, recently it has been scarcely manufactured.

(3) Smoke tube boiler

As shown in Figure 10.2, a smoke tube boiler is equipped with a combustion chamber formed with brick laying beneath the cylinder and arranged with a number of smoke tubes in the shell. The combustion gas heats the lower section of shell and then heats again the side surface of shell after passing the smoke tubes. As the heat loss through the brick wall is large in case of outside combustion chamber, some boiler is equipped with the combustion chamber in a part of the flue.

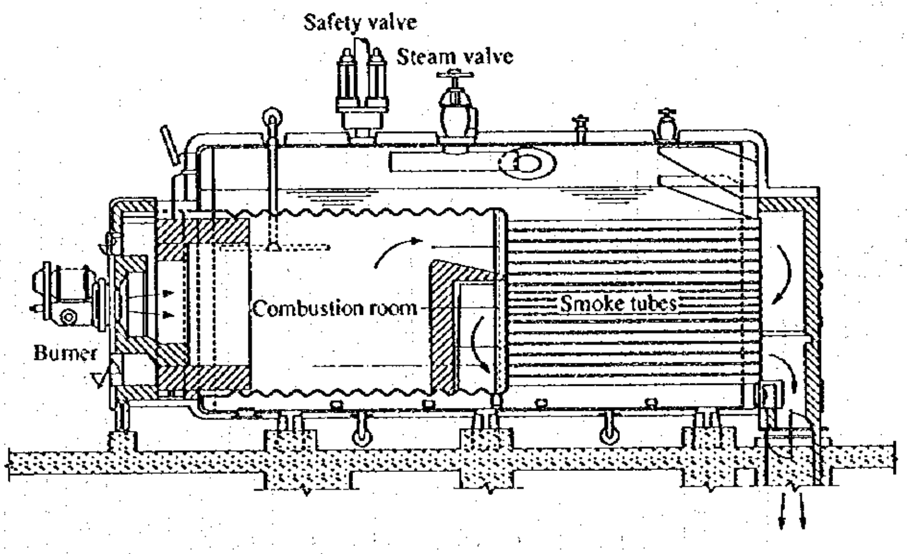
Figure 10.2 Externally Fired Horizontal Smoke Tube Boiler



(4) Flue smoke tube boiler

As shown in Figure 10.3, a flue smoke tube boiler is an internally fired boiler equipped with both of flue and smoke tubes in the shell. The boiler is generally used as a package boiler with characteristics of a relatively larger heating surface area of high efficiency even in a small capacity and has easy installation and handling. The boiler is limited to 15 kg/cm² (G) in pressure and 25 t/h in capacity. An efficiency of 85 to 92 % is obtainable. On the other hand, the structure is complex, check and cleaning in the inside are difficult and feed water is required to be high quality.

Figure 10.3 Flue Smoke Tube Boiler



10.1.2 Water-Tube Boiler

As shown in Figure 10.4, a water-tube boiler is composed of a drum for steam and water separation and a number of water tubes formed with a heating surface, and is designed to make evaporate feed water in the water tubes. Accordingly, since the heating surface can be made larger through increasing the number of water tubes, the boiler is suitable even for a large capacity and is able to obtain easily a high pressure. The features of water-tube boilers are as follows:

(1) Because the combustion chamber is able to be made in any size, the combustion is in good condition and various fuels can be adapted easily.

(2) The thermal efficiency is higher because of a larger heating surface area.

(3) The start-up time is shorter because of the small amount of retaining water per heating surface area. While a fine regulation is required since the pressure and water levels are prone to fluctuate with a loading variation.

(4) Consideration should be given to feed water and boiler water treatment.

The water-tube boiler has two systems: a natural circulation system, which utilizes the differences of the specific gravities between steam and water, and forced circulation, which uses a pump (see Figure 10.5). A high pressure boiler is required to adopt a forced circulation system because of the density difference between steam and water is small.

Figure 10.4 Water Tube Boiler

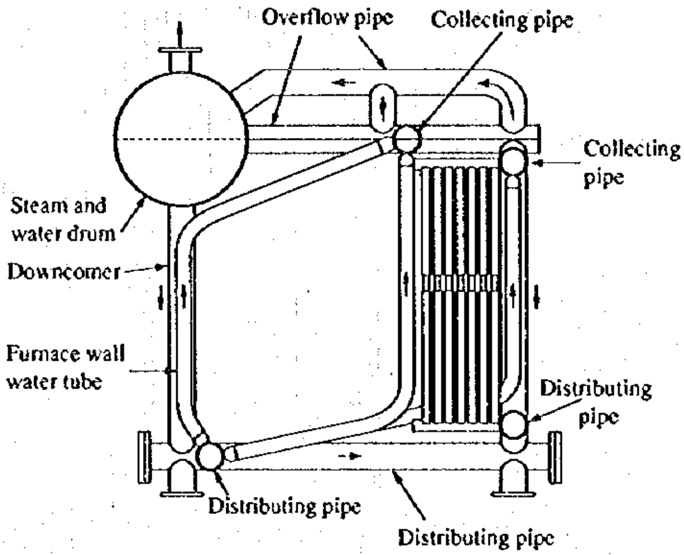
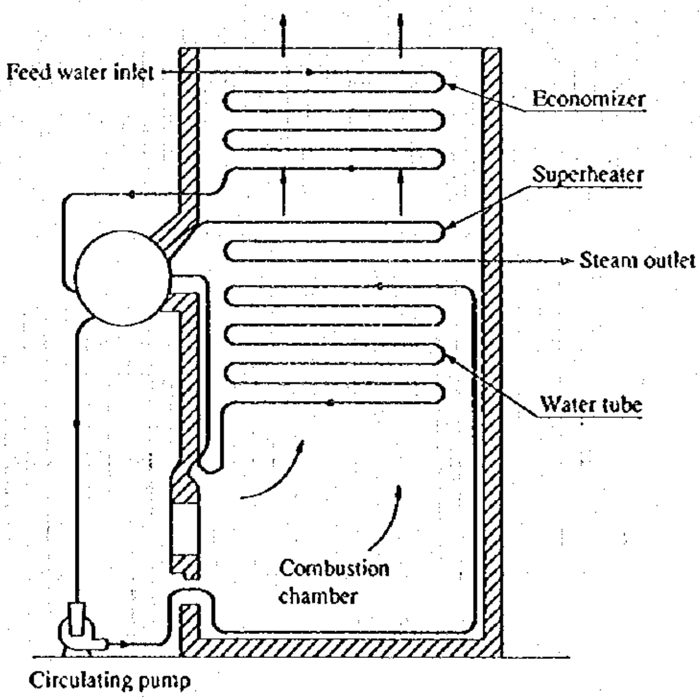


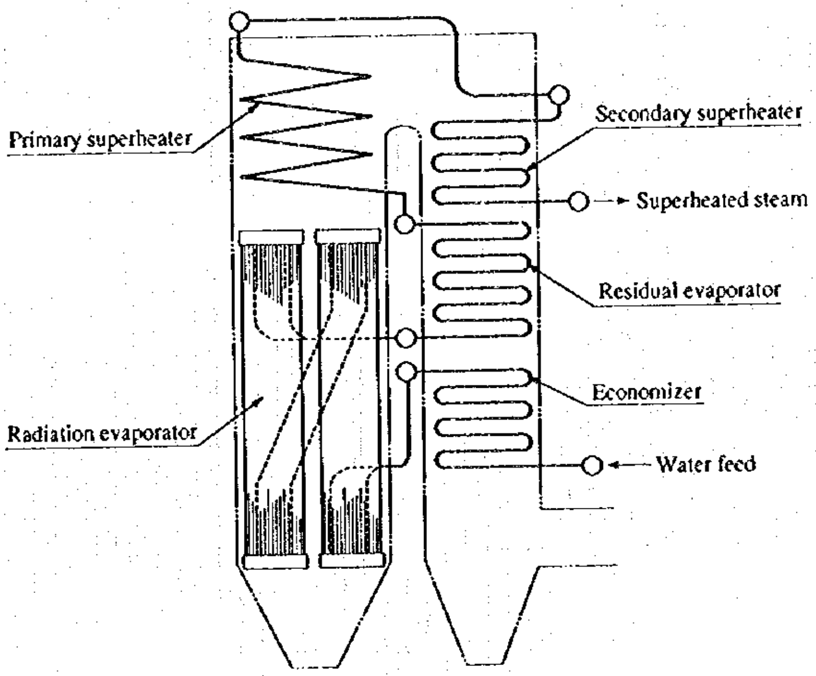
Figure 10.5 Forced Circulation Boiler



10.1.3 Once-through Boiler

A one-through boiler only composed of a series of long water tubes is designed so that feed water is pushed into the tube by a pump from the end of the tube, by turn temperature is raised, evaporated, superheated and taken out as superheated steam from another end of the tube. Accordingly boiler water is not circulated (see Figure 10.6).

Figure 10.6 Schematic Flow Diagram of Benson Boiler (Once-through Boiler)



The features of this one-through boiler are as follows:

- Suit a high pressure boiler because there is no steam drum.
- Able to be designed compactly.
- Start-up time is short because the retaining water is extremely small amount per heating surface area.
- Require an automatic control device with good response since a loading change is prone to cause large pressure fluctuation.
- Require a feed water of good quality because all the feed water evaporates in the tube.

With such characteristics, the one-through boiler has been applied in a wide variety from a supercritical pressure boiler to a small scale boiler.

10.1.4 Other Boilers

There is a boiler combined with a cast iron section which is used as a low pressure or hot water boiler, a waste heat boiler or a boiler for special fuel and so on.