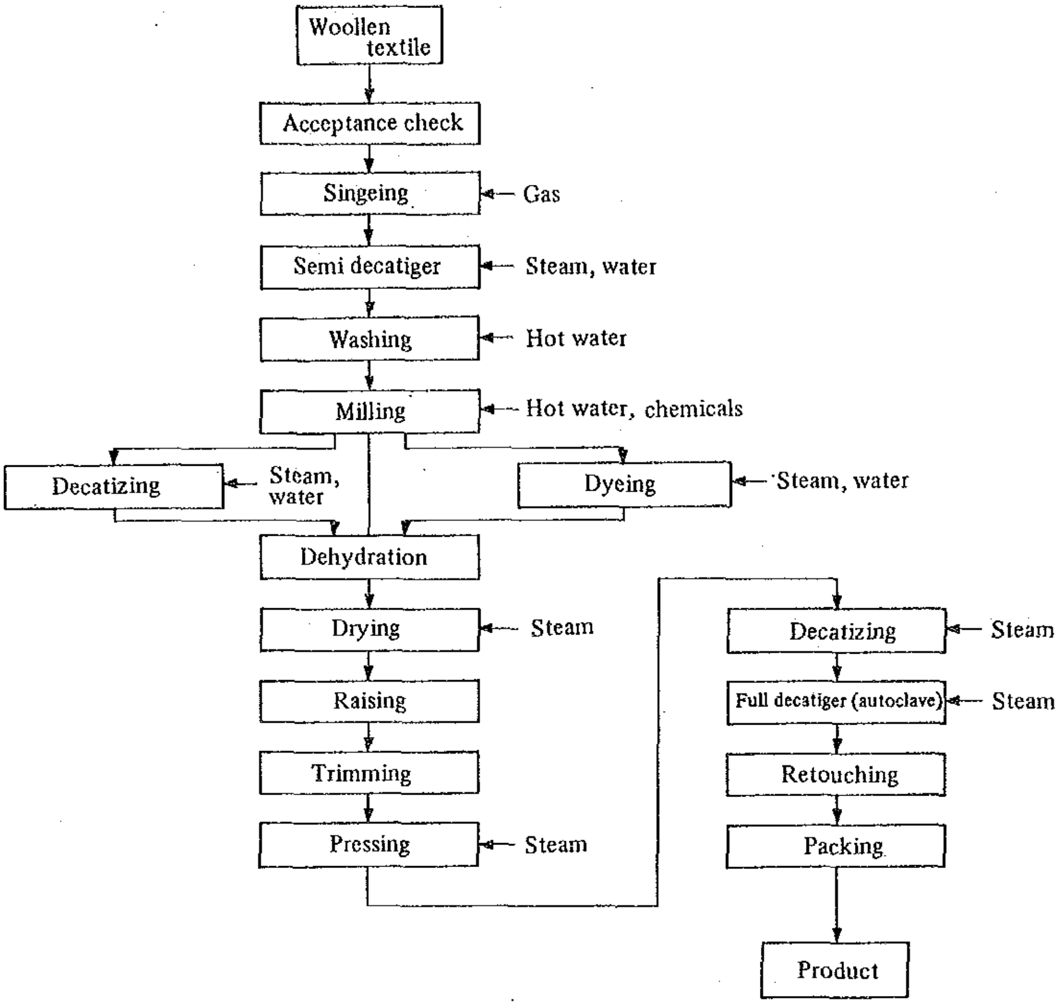


Fig 5-13 Woollen Textile Finishing Process

Synthetic fiber production versus energy consumption in Japan is shown in Table 5-1.

Compared with the reference year of 1973, the year 1988 was up 4.4% in production, down 81.2% in electric power consumption, and down 26.5% in fuel consumption. Fuel oil consumption shows tendencies of declining further.

(2) Spinning

The spinning process uses electricity for all of its parts shown in Figure 5-2 except for the twisting set that uses steam. Table 5-2 shows spinning production versus electric power consumption.

Electric power consumption in the spinning process has been increasing for not only driving the spinning machines but others. In fact, electricity was consumed about 5% more in 1988 than in 1973.

Table 5-3 shows the uses of electricity for other than driving the machines in the spinning process.

Table 5-1 Production vs. Energy Consumption in Synthetic Textile Industry by Year

Year	Production (thousands of tons/year)	Fuel oil consumption (liters/kg)	Electric power consumption
1971	1662.3	1.42	2.82
1973	1847.8	1.36	2.76
1975	1452.3	1.49	3.17
1977	1734.9	1.22	2.70
1979	1850.7	1.00	2.43
1981	1815.8	0.78	21.7
1983	1786.1	0.67	2.15
1985	1861.1	0.45	2.11
1986	1760.1	04.1	2.18
1987	1727.6	0.38	2.22
1988	1735.3	0.36	2.24

Source: MITI statistics "Textile Statistics Annual Report"

Table 5-2 Production vs. Electric Power Consumption in Spinning Industry by Year

Year	Production (thousands of tons/year)	Electric power consumption
1971	1587.5	2.61
1973	1578.1	2.85
1975	1196.3	2.94
1977	1194.2	3.00
1979	1319.4	2.89
1981	1182.8	2.90
1983	1173.0	2.87
1985	1224.8	2.80
1986	1136.1	2.84
1987	1141.5	2.88
1988	1122.3	2.99

Source: MITI statistics "Textile Statistics Annual Report"

Table 5-3 Electrical Equipment for Spinning Process by Function

Function/purpose	Spinning machine	Electrical device
Spinning	Air spinning machine	Air compressor
Knotting	Automatic winder	Air compressor
End down suction	Ring spinning machine	Suction blower
Fiber conveyance	Scutching, carding machine	Blower
Yarn dust collection, fly collection	Machinery for whole process	Blower
Cleaning	Machinery for whole process	Air compressor
Air conditioning	Whole process	Refrigerator, fan, blower, pump
Lighting	Whole process	Fluorescent lamp

Figure 5-14 shows, for your reference, a breakdown of electric power consumption by process in a cotton spinning factory that was designed for energy conservation.

Utility power accounts for 30% to 40% of the total power consumption, mostly for air conditioning.

(3) Weaving

Energy is consumed in the weaving process as shown in Table 5-4. Electricity is used except for sizing for which steam is used. The weaving machines consume 70% to 80% of the total power consumption.

For your reference, the total production and electric power consumption of the weaving industry in Japan by year is shown in Table 5-5.

Electric power consumption in the weaving process has been increasing, up 45% in 1988 over 1973, presumably because high-performance weaving machines were installed to improve productivity and save labor.

(4) Dyeing and finishing

The kinds of energy consumed in the individual parts of the dyeing and finishing process are shown in Figure 5-9 for your reference.

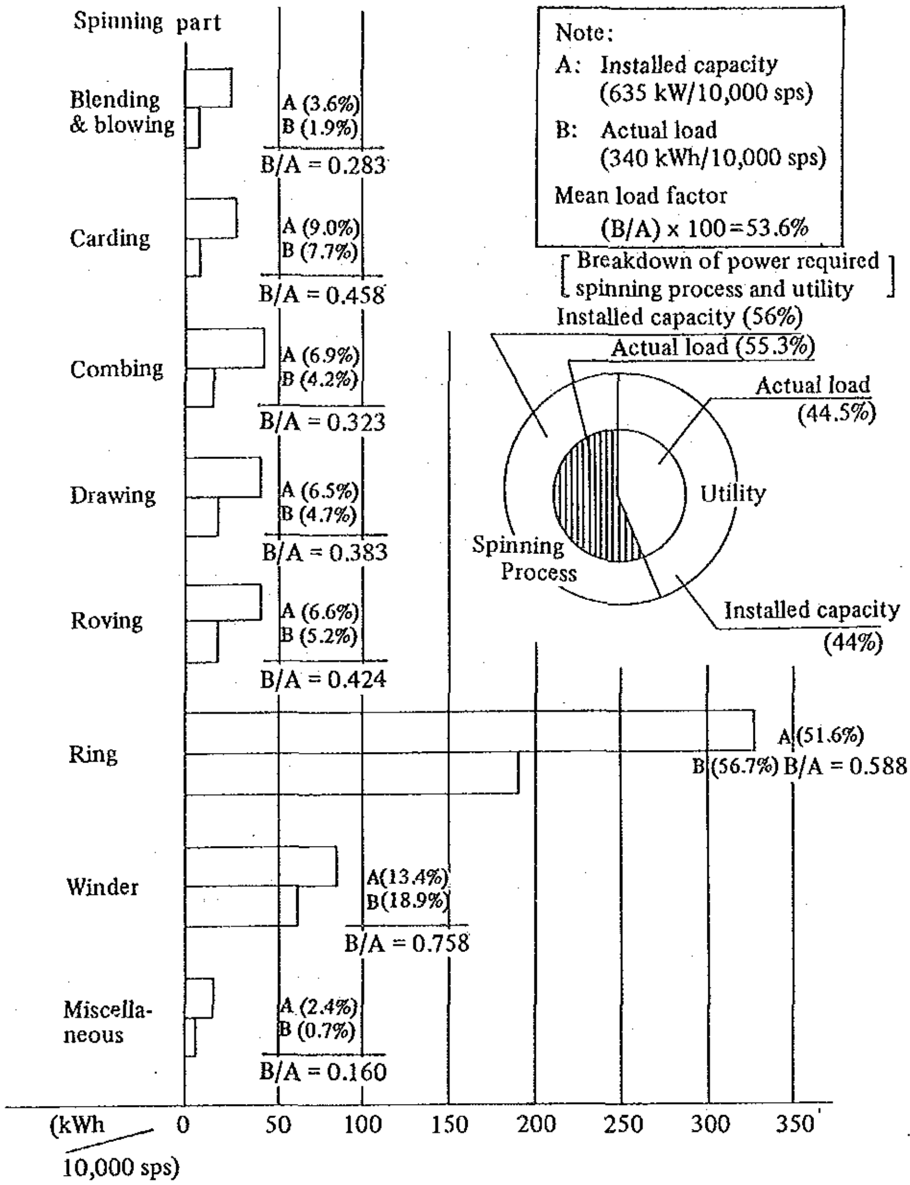


Fig 5-14 Breakdown of Power Required of Spinning Process per 10,000 sps

Table 5-4 Electrical Equipment for Weaving Process by Function

Purpose	Weaving machine	Electrical device
Weaving	Weaving machine (air jet) Weaving machine (water jet) Weaving machine (water jet)	Air compressor Pump Electric heater
Dehydration	Weaving machine (water jet)	Suction blower
Thrum	Weaving machine	Suction blower
Cleaning	Weft bobbin cleaner, etc.	Air compressor
Dust collection	Spooler, etc.	Suction blower
Air conditioning	Whole process	Refrigerator Fan blower Pump
Lighting	Whole process	Fluorescent lamp

Table 5-5 Production vs. Electric Power Consumption in Weaving Industry by Year

Year	Production (1000 m^2)	Electric power consumption (kWh/m^2)
1971	7527.2	0.267
1973	7369.6	0.301
1975	5954.8	0.337
1977	6581.5	0.340
1979	6757.0	0.344
1981	6431.4	0.353
1983	6470.0	0.346
1985	6325.8	0.366
1986	6000.5	0.371
1987	5622.7	0.383
1988	5718.0	0.388

Textiles are dyed and finished to suit different uses and designs so that there are many ways of processing them (fiber or yarn dyeing, piece dyeing, dip dyeing, printing, bleaching, etc.) according to the kinds of fiber and textile (cloth width, color, shade, yarn, fabric, etc.). The bath ratio, temperature, and processing time also vary accordingly. The dyeing and finishing process consumes energy as shown in Table 5-6. Most of the heat energy is consumed in this process.

The water used in the dyeing and finishing process is about a hundred times the weight of the fabric processed. A large amount of steam is required for repeated heating, cooling, and drying. In addition to steam, the process uses heat media for heat-setting synthetic textiles, the electric heat of the infrared ray heater for the thermosensitive dyeing machine, and gas for singeing.

Energy accounts for more than 10% of the processing cost, indicating that energy conservation is particularly needed for the dyeing and finishing process.

Table 5-7 shows the production of the dyeing and finishing process versus energy cost in Japan by year.

Table 5-6 Condition of Use of Energy

Purpose	Equipment	Energy source
Washing, Dipdyeing	Dyeing machine, Rinser etc.	Steam
Dehydration	Centrifugal separator	Electric power
Drying	Dryer	Steam · Electric power

Table 5-7 Production vs. Fuel/Electric Power Consumption in Dyeing and Finishing Industry by Year

Year	Production (1000 m^2)	Fuel oil consumption (liters/m^2)	Electric power consumption (kWh/m^2)
1973	7286.0	0.205	0.147
1975	6939.5	0.199	0.156
1977	7074.6	0.191	0.169
1979	7142.9	0.179	0.177
1981	7341.9	0.139	0.173
1983	7310.4	0.125	0.175
1985	7515.8	0.119	0.178
1986	7219.5	0.120	0.183
1987	7078.1	0.123	0.191
1988	6992.0	0.126	0.196

Fuel oil consumption dropped 61% in 1988 over 1973, while electric power consumption increased 33% over the period of 15 years, presumably because the process was transformed into an integrated, continuous process to save labor and because anti-pollution facilities were added.

Table 5-8 shows an example of survey on energy consumption by process for your reference. The data shows large difference in value because the dyeing conditions varied from one case to another.

Table 5-8 Examples of Energy Consumption Rate Each Process

Process	Short fiber				Long fiber			
	Main material	Mean fabric weight	Energy consumption rate		Main material	Mean fabric weight	Energy consumption rate	
			Fuel	Electric power			Fuel	Electric power
		g/m²	ℓ/m²	kWH/m²		g/m²	ℓ/m²	kWH/m²
Preparation process	Cotton and cotton/synthetic fiber	110~ 180	0.085~ 0.128	0.016~ 0.018	Ester finished yarn, etc.	80~ 220	0.054~ 0.275	0.027~ 0.31
Dyeing process (Dipping)	Cotton and cotton/synthetic fiber	130	0.066~ 0.083	0.071~ 0.107	Ester finished yarn, etc.	80~ 220	0.066~ 0.133	0.084~ 0.716
Dyeing process (Printing)	Cotton	110~ 130	0.049~ 0.2	0.073~ 0.167	Polyester	100~ 120	0.127	
Finishing process	Cotton and cotton/synthetic fiber	110~ 130	0.06~ 0.11	0.073~ 0.082	Ester finished yarn, etc.	80~ 220	0.071~ 0.306	0.083~ 0.108

(5) Wool

Energy consumption in the spinning, weaving, and finishing processes of worsted yarn and woollen yarn is basically the same as that of the cotton spinning, weaving, dyeing and finishing processes. In fact, the statistical data shown in Tables 5-2, 5-5, and 5-7 includes wool-related data.

The characteristics of heat energy consumption in processing woollen products can be summarized as follows:

- Woollen fabrics are batch-processed, mostly for dip-dyeing in small lots. Continuous processing is hardly possible for reasons of cost.
- The processing bath is changed to adjust pH every batch.
- A high bath ratio of 1-to-15 or more is often required for fabric dyeing for reasons of quality.
- The bath liquid must be heated, cooled, and heated with time to control the amount of dye and assistant to deposit on the fabric.
- Acid dye may require boiling, and in that case, there will be much heat loss in waste water.

These are the factors contributing to increased energy consumption.

Top making, the first stage of worsted yarn spinning, consumes much heat energy for washing and drying. The washing process requires mainly electric energy to discharge water.

5.2 Rationalized Use of Energy

5.2.1 Synthetic fibers

Important points for energy conservation in producing chemical and synthetic fibers are shortening the processes, improving the heating and cooling patterns, rationalizing the equipment operating methods, introducing energy-saving machines and devices, recovering waste heat, and optimizing equipment capacity.

Table 5-9 shows the main energy conservation measures that have been taken so far in Japan.

Table 5-9 Main Energy Conservation Measures in Synthetic Fiber Factories

Energy saving measure	Equipment
Recovery and reuse of waste heat	
• Use of waste heat	Waste heat boiler
• Multi-effect use of evaporator	Adding/improving evaporator
• Use of low-temperature waste heat	Heat pump
• Power generation using low/ medium-temperature waste heat	Low-voltage generator, etc.
Effective use of energy	
• Heat storage using nighttime electricity	Accumulater
• Raising efficiency of electrical equipment	High-efficiency electrical eqipment
Rationalizing operation	
• Integrated operation of equipment	Automatic controller
• Intermittent operation of pumps and ejectors	
Optimizing equipment capacity	
• Equipment speed (rpm) control	Speed controller
Combustion control	Automatic controller
Process improvement	Continuous polymerization spinning equipment Drawing, false twisting machine, etc. High-speed multi yarn reeling machine, etc.

The basic procedures for implementing energy conservation measures and their effects are discussed below in a case study of generating equipment.

(1) Boiler combustion control, etc.

Refer to the chapter on boilers and steam.

(2) Radiation prevention

The manufacturing process up to melting is similar to that used in chemical plants. A large number of towers and tanks are connected to one another with pipes, and the object is heated to 100°C – 300°C by a heat medium. It is important, therefore, to prevent heat radiation from the surfaces of these constituents of the process. Generally, the main equipment itself is well-insulated, but the flanges and end pipes small in diameter tend to be left uninsulated, or improperly insulated.

(3) Use of flash steam

Refer to the chapter on boilers and steam.

High-pressure steam is used in some part of the process to heat to high temperature. Its condensate should be returned to the flash tank to generate low-pressure steam and make effective use of it.

(4) Condensate recovery

Refer to the chapter on boilers and steam.

(5) Use of back-pressure steam

In applications where steam of different pressures is used, steam of different pressures is generated using two or more boilers, or a high-pressure boiler is used to generate steam, and part of it is reduced using a valve. If high-pressure boilers only are used and if a steam turbine is employed in place of the ruducing valve to generate electricity with its motive power, electricity can be efficiently obtained.

Factories using the above system have been increasing because small-sized efficient turbines have become available.

[Instance 1] Economy of power generation using an exiting boiler

Let's consider the case of a factory which has boiler (10 kg/dm^2g x saturation 45 t/h), requires process steam of 3.5 kg/cm^2g x 140°C x 40 t/h, and has a steam turbine generator installed instead of a reducing valve.

(a) If a reducing valve is used, steam shows isoenthalpic change so that its calorific value remains unchanged before and after the reducing valve. (A – B in steam i-s line diagram, Figure 5-15) If fuel (fuel oil C) has a heating value of 10,000 kcal/kg, boiler efficiency is 80%, and feed water temperature is 80°C, the fuel consumption rate in this case will be as expressed by the following equation.

$$Fv = \frac{(662.4 - 80) \times 40{,}000}{10{,}000 \times 0.80} = 2{,}912 \text{ kg/h}$$

(b) If electric power is generated by the steam turbine, the enthalpy of steam decreases (A – C' in the steam i-s line diagram). The generated energy, heat balance, and economic efficiency at this point will be as follows:

Steam pressure at turbine inlet: 8.5 kg/cm^2g

Steam enthalpy at turbine inlet: 662.4 kcal/kg

Exhaust pressure at turbine outlet: 3.5 kg/cm^2g

Theoretical adiabatic heat drop (A – C') (662.4 – 629.4) = 33 kcal/kg

Ratoh double reduction turbine

– Internal efficiency: 67.15%

– Effective heat drop (33 x 0.6715): 22.2 kcal/kg

– Exhaust enthalpy (662.4 – 22.2): 640.2 kcal/kg

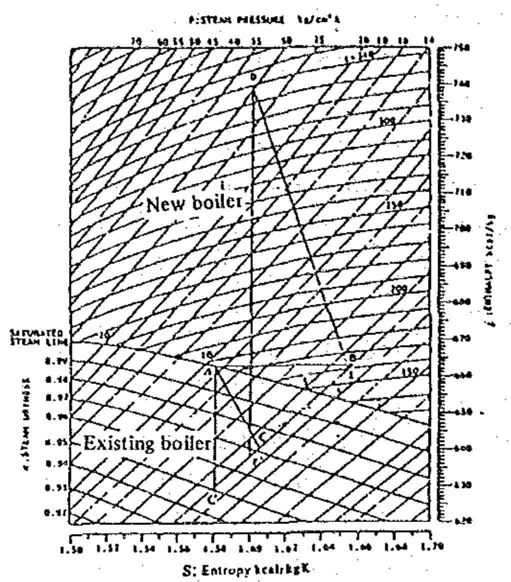


Fig 5-15 Steam i - s Chart

Amount of required process steam

$$40{,}000 \times \frac{662.4}{640.2} \qquad 41{,}387 \text{ kg/h}$$

Generated energy

– Overall efficiency of turbine including generator (η_0): 60.92%

– Steam consumption $\frac{860}{\text{Theoretical adiabatic heat drop} \times \eta_0}$: 42.8 kg/kWh

– Generated energy (Process steam amount ÷ steam consumption):

967 kWh

Heat balance: Process steam must be supplied 1.387 kg/h more than when a reducing valve is used.

At turbine inlet
- Q = 41.387
- P = 8.5
- T = 177
- I = 662.4

At turbine outlet (Process inlet)
- Q = 41,387
- P = 3.5
- T = 147
- I = 640.2

Fuel consumption:

$$Ft = \frac{(662.4 - 80) \times 41{,}387}{10{,}000 \times 0.8} = 3{,}013 \text{ kg/h}$$

Economic efficiency tentatively calculated: Calculated from the cost difference between purchased electric power and house -generated power and from annual operating hours as follows:

(1) Increase in fuel: $Ft - Fv = 3{,}013 - 2{,}912 = 101$ kg/h

(2) Unit price of fuel: $0.1/kg

(3) Generated electric energy: 967 kWh

(4) Unit price of house-generated power:

$$\frac{\text{Increased fuel cost}}{\text{Generated energy}} \fallingdotseq \$0.01/\text{kWh}$$

(5) Unit price of purchased power: $0.06/kWh

(6) Annual saving in electric energy charge: Assuming that the annual operating time is 7,200 hours,

$(0.06 - 0.01) \times 967 \times 7{,}200 = 348{,}100$ $/y

The above example refers to a case of saving electric energy charges by installing a power generator turbine using steam pressure difference in place of the existing reducing valve in the factory. The resultant saving was so great that the capital investment in the turbine generator, piping, foundation, etc. could be recovered in less than a year.

[Instance 2] Power generation and economic efficiency with a newly installed boiler

If a boiler must be renewed soon, it would be wise to replace it with a high-pressure, high-temperature boiler to increase electric energy generation and thus drastically raising economic efficiency. If a superheating boiler of 33 kg/cm²g x 350°C x 45 t/h is installed for the same process as in instance 1, the economic efficiency can be calculated as follows:

Generated energy: 3,300 kW, calculated in the same way as in instance 1

Heat balance:

At turbine inlet	Q = 40,000 P = 30 T = 340 I = 738.7
At turbine outlet (Process inlet)	Q = 40,000 P = 3.5 T = 160 I = 662

Fuel consumption:

$$Fn = \frac{(738.7 - 80) \times 40{,}000}{10{,}000 \times 0.85} = 3{,}099 \text{ kg/h}$$

(Ffficiency of newly installed boiler assumed as 85%)

Economic efficiency: Calculated in the same way as in instance 1, assuming that the annual operating time is 7,200 hours:

(1) Increase in fuel: 187 kg/h

($Fn - Fv = 3{,}099 - 2{,}912$)

(2) Unit price of fuel: $0.1/kg

(3) Generated electric energy: 3,300 kWh

(4) Unit price of house-generated power: $0.0067/kWh

(5) Unit price of purchased power: $0.06/kWh

(6) Annual saving in electric energy charge:

$(0.06 - 0.0067) \times 3{,}300 \times 7{,}200 = 1{,}266{,}400$ \$/y

(6) Distillation equipment

A large quantity of steam is consumed for heating and pressure reduction in a process of concentrating unreacted monomers.

To save steam for the ejector, attention must be paid to the following.

(A) Periodically replace the gaskets and weld the flanges within a possible range to prevent air from entering the vacuum system.

(B) Try to save water supply to the condenser while keeping the temperature necessary to maintain the vacuum.

(C) Review the vacuum conditions, and conduct a test to determine whether steam pressure can be reduced and, in case of a multiple-stage process, whether the final stage can be eliminated.

(D) Also study the advantages and disadvantages of using a vacuum pump in combination, or substituting a vacuum pump. If there is no problem of corrosion and dust, it would be better to substitute a vacuum pump as can be witnessed from an instance in which the capital investment was recovered in less than a year.

(E) Use double- or triple-effect evaporators instead of single-effect evaporators.

(7) Change of process

Energy-conservation type processes such as described below may be considered in building a new factory.

(A) Continuous polymerization spinning equipment

The conventional process cools the molten polymer generated by a polymerizer to solidify, removes unreacted monomers from the polymer, re-melts it, and then spins it. (See Figure 5-16.)

A new process, however, directly carries the molten polymer generated by a polymerizer as it is, and spins it. Therefore, the process is greatly shortened as compared with the conventional process.

(B) High-speed, multi-thread yarn making

In the past, molten polymer was extruded from a spinning head, the extruded threads were cooled and wound, and then drawn into a yarn using a separately installed drawing machine.

A new process, however, simultaneously draws and spins yarn at high speed, and multi-thread takeup is performed along with it. Thus, omission of a drawing machine permits reduction of power and heat loss.

Spinning speed is raised from 1,000 – 1,500 m/min to 3,000 m/min or over, and the number of threads is 4 or more for less than 630 denier, and 2 or more for 630 denier and over.

The energy consumption ratio between spinning and drawing is about 3 to 2. The above improvement permits energy saving to a great extent, but may not be applicable to some uses of yarn.

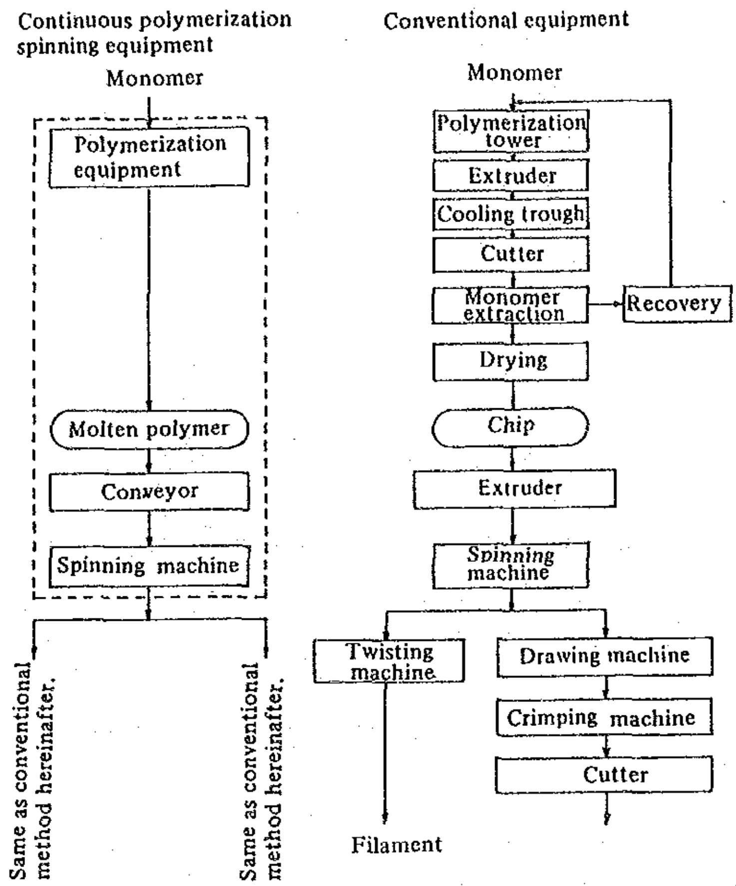


Fig 5-16 **Improvement of Polyester Polymerization Process**

(8) Change of heating source for heat media

Electricity is used as heating source for a heat medium boiler, but the thermal efficiency at power generation level is only slightly over 35%. For instance, there was a factory in which the several electric type, heat-medium boilers were all replaced with a single heat-medium boiler that burns fuel oil.

5.2.2 Spinning (Including Worsted yarn Spinning)

(1) Basic measures

Before a factory takes measures, regardless of whether they concerns quality control, labor saving, or energy conservation, it is necessary to review the state of management of the factory. If the factory is not managed in a satisfactory way, new measures will not be fully effective, and can make the processes even more complex and possibly end incomplete.

Thus, before taking energy saving measures of one kind or another, it is important to check the following. (See Figure 5-17.)

(1) *Motor performance check*

Measure the power of each motor, check whether any motor is defective, and adjust defective motors that can be adjusted, or replace them if not adjustable. Be sure to minimum the differences among the motors. If motors must be replaced, examine the advisability of replacing them with high-efficiency motors.

- **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**

Fig 5-17 Check Points in First Step

(2) Reducing the motor base load

Accurately center the motor bases through proper maintenance, adjust the drive belts or tapes to the correct tension, and ensure the correct engagement of gearwheels. Periodic cleaning, oiling, and maintenance must be thoroughly performed in an effort to maintain the motor bases in good condition. It is also important to employ bearings for rotating parts to ensure smooth, satisfactory rotation.

(3) Study of economical speed

When the speed of a production machine is raised, its energy consumption increases exponentially. Determine a number of machines and their operating speed which will be most economical for a given quantity of production, and use them as operating standards.

(2) Concept of energy conservation for individual processes

(1) Blowing

The blowing process has many machines, which vary in use from one to another. These machines are connected to each other, an have a fan for dust collection, and often use air to convey the material fiber.

Measure the power consumption of the blower system. If air flow is controlled with dampers, lower the operating speed of the blowers to control the suction and discharge pressures and air flow rate of the blower system.

To prevent operation trouble, it would be better to lower the operating speed of the blowers step by step, by about 10%, for example, and after checking that operation is normal, by another 5%.

(2) Carding

There are so many carding machines that require energy conservation measures. Carding machines have a rotary body that is heavier than that of other production machines. The power consumption of the old type carding machines can be reduced by using bearings for their rotary parts. The new type carding machines are equipped with an independent dust collector to save labor, and improve quality and working environment through automatic dust collection. The blowers for dust collection still have an excess capacity and are generally operating at low efficiency. Energy can be saved by grouping or integrating the individual dust collectors.

(3) Drawing and roving

The new type drawing machines and roving machines have a large pneumatic dust collector. One common way of saving energy is to reduce the outside diameter of the impeller (impeller cut).

The mechanical structure of the roving machines is similar to the ring frame mentioned below, and energy conservation measures for the ring frame may be applied to the roving machines themselves.

(4) Energy conservation for ring frames

(1) Use of bearing for draft part

The draft part now uses a bearing as the conventional roller weight was replaced by a top arm. The use of a bearing for this part reduces power consumption.

(2) Modification of spindle part

Replace the spindle tape with a narrower one made of an elastic material to reduce air friction loss and prevent slipping. Daily maintenance should be improved by, for example, reducing the amount of lubricating oil applied to the spindle support.

The spindle wheels have been made smaller in diameter, but because this costs much, raising spindle wheel speed should also be taken into consideration.

(3) The pneumafil attached to the ring frame has increased in capacity with rising productivity. But the blower capacity for the pneumafil now tends to decrease with a review of the economical operating speed of the ring frame and improved daily maintenance to prevent duct blocking. The energy consumption of the existing blowers can be reduced by reducing the outside diameter of the impeller. At integrated system such as mentioned in the paragraph on carding is employed.

(4) Intermittent operation of the traveling cleaner for removing fly from the ring frames, or extending the range of its operation may also be possible.

(5) When it is necessary to replace old main motors, install high-efficiency motors in their place.

(5) Winder

Modernization has been achieved in this area earlier than in any other area. Many high-performance machines have already been installed.

However, the power consumption of these high-performance winders is extremely high, particularly in the operation of their yarn collector blowers.

Thus, a collective suction system consisting of groups of 5 to 10 yarn collection suction lines for winders is generally employed for energy conservation. In this case, energy conservation depends on the specifications of the selected blowers.

(6) Air conditioning (See the chapter on electricity.)

(A) Re-examination of air conditioning loads

Electric power consumption for air conditioning corresponds to about 30% of the power directly consumed for production.

The conditions of air conditioning for the spinning process influence yarn quality and productivity, and each factory sets its own conditions. However, they should be re-examined whenever necessary with technological development.

A certain factory in Japan changed the temperature and humidity by degrees, checked thread quality and working environment each time they were changed, and thus determined limits of change which would be free of problems. The constant conditions applied throughout the year were changed to conditions varying from season to season, which resulted in a 14% reduction of refrigeration loadand a 16% saving in humidifying and heating steam.

The air conditioning loads can also be reduced by better insulating the building and heat-generating devices.

(B) Change of spray nozzles

In case of directly cooling air by cold water spray, the delivery pressure of the water pumps can be reduced by using fewer, but larger spray mozzles. This will reduce pump drive power and, depending on the case, the number of pumps.

A certain factory in Japan replaced 15,400 nozzles, 4 mm in diameter, with 212 nozzles, 44 mm in diameter, with the reuslt that the spray pressure was lowered from 3 kg/cm^2 to 2 kg/cm^2 and that annual power consumption was reduced by about 470,000 kwh.

(C) Introduction of high-efficiency refrigerators

Old refrigerators do not perform to their original design efficiency.

A certain factory in Japan replaced its refrigerator, when its consumption rate increased from the design value of 1.28 kW/JRT (Note: 1 JRT = 79,680 kcal/d) to 1.41 kW/JRT, with a high-efficiency refrigerator whose consumption rate is 0.91 kW/JRT. This replacement resulted in a saving of 750 kW.

(D) Refrigerator operating speed (rpm) control

In factories using turbo compressors, it would be effective to control the number of operating turbo compressors or their operating speed in cases where load variation occurs frequently. An example of reducing power consumption is shown in Figure 5-18.

Table 5-10 shows an example of energy conservation measures for the individual processes. Considerable effects can be expected by including organized energy saving activities in daily management.

Table 5-10 (1) Example of Energy Conservation Measures for Individual Processes

Process	Measure	Description (Example)	Remarks
Scutching	1. Optimizing condenser fan speed	• 1,200rpm → 1,000rpm	• 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	5. 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	• 2,240rpm → 1,640rpm	• 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 pressure 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 maintenance of auto lap changer (preventing air leaks; centering various parts).

Table 5-10 (2) Example of Energy Conservation Measures for Individual Processes

Process	Measure	Description (Example)	Remarks
	4. Reducing operating speed of comber cylinder brush	• 1,240rpm→780rpm	• Cylinder needles are hardly blocked in uni-combing. Brush operating speed (rpm) should 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	• 1,970rpm→1,600rpm • 40mmAq→32mmAq	• Because of sliver joining, static pressure of 25 to 30 mm. Aq. is sufficient for perforated roller. Determin 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 spinlde tape	• Elastic tape: 13mm→11mm	• Take slip ratio into consideration.
	4. Reducing spindle tape tension	• 1.9→1.5lb/4sp	• Take slip ratio into consideration.
	5. Using spindle warp of smaller diameter	• 23.8→20.2mm	• 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 5-10 (3) Example of Energy Conservation Measures for Individual Processes

Process	Measure	Description (Example)	Remarks
	8. Interlocking pneumafil 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	• 715→620m²/min	• Drill shaft hole in motor pulleys on hand.
	2. Reducing operating speed of pre-spinning carrier fan	• 2,590→1,735m²/min	
	3. Reducing operating speed of spinning carrier fan	• 360→325mmϕ	• Use pulleys on hand.
	4. Reducing size of finish spray blower	• 27m²/min x 30kW→6.8m²/min x 7.5kW	

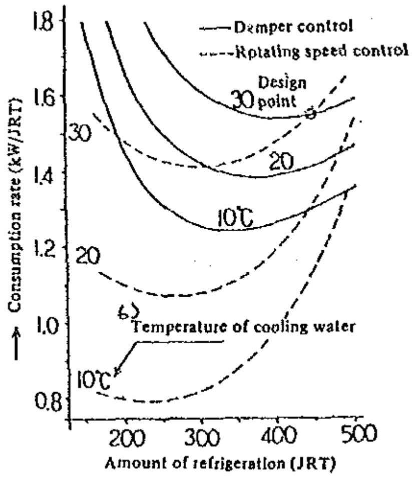


Fig 5-18 Characteristic Comparison of Capacity Adjustment

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

Preconditions

Assuming that the production conditions are constant in each process, the effect of energy conservation for each process was calculated.

The energy conservation measures taken for each process and the resultant effect are shown in Figure 5-19.

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

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

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%)

Fig 5-19 Example of Energy Conservation Measures under Constant Process Conditions (Power consumption for direct production: 520 kwh/400 lbs)

It can be said from this case study that the effect of energy conservation is especially great for winding and spinning machines. Figure 5-20 shows power consumption per bale (400 lbs) for each process. Figure 5-21 shows a palette diagram of power consumption for each process.

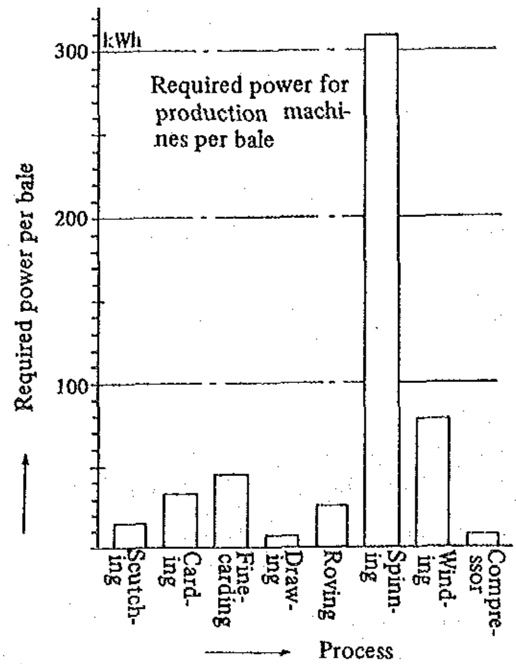


Fig 5-20 Required Power per Bale

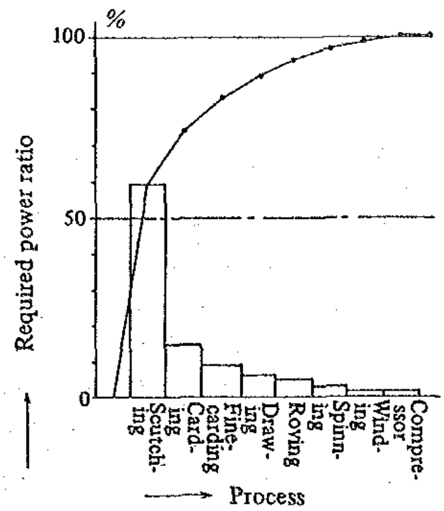


Fig 5-21 Pareto's Diagram of Required Power (%)

(4) Energy conservation problems for future

The following should be studied in working out energy conservation measures for the spinning process.

(1) Review of process design conditions (Determination: rpm, etc.)
(2) Review of each package size and unit quantity.
(3) Examination of plain belt material and replacement of V-belt with cog belt
(4) Study of energy-saving type rubber rollers
(5) Use of ball bearings for skewer metal
(6) Use of oilless bearings
(7) Thorough control on empty spindles (using computer)
(8) Reduction of working hours by improving operating efficiency
(9) Reduction of impeller diameter for pneumatic fans
(10) Integration of air compressors
(11) Integration of machine fans
(12) Change in use of compressed air for cleaning
(13) Reduction of intermittent operation time of dust collection cotton collection equipment
(14) Recovery and reuse of exhaust heat from spinning machines
(15) Introduction of high-efficiency spinning machines (winding and twisting machines)

5.2.3 Weaving (Including Woollen Textiles)

(1) Preparations for taking energy conservation measures

The production machines used in the weaving process have motors that are smaller in capacity per machine and more in number than in the spinning process. Therefore, it is difficult to implement efficient energy conservation measures.

As in the case of the spinning process, it is necessary to strictly observe the basics of energy conservation.

(2) Energy conservation measures by type of process

(A) Preparations

The preparatory process consists of rewinders, quillers, warpers, sizing machines, and drawing machines. The utilities used in this process include electricity, steam, water, and compressed air.

(a) Electricity energy is used for not only driving the production machines but also the following purposes.

i) Suction blowers for dust collectors

ii) Compressed air for removing waste thread and cotton

o The power consumption of the dust collector blowers is in direct proportion to the cube of blower rpm. Thus, if blower rpm is lowered by 10% through reduction of suction port area and review of filter cleaning intervals with resultant reduction in the required air flow, power consumption can be reduced by 23%.

o Reducing compressed air for cleaning

Electric power can be saved by lowering the discharge pressure of the air compressor. If compressed air pressure is lowered from 7 kgf/cm^2G to 5 kgf/cm^2G, power can be saved by about 14%. The cleaning nozzles are mostly house-made. If gun-type nozzles are used and are provided with a lever to open or close them, a more power saving effect can be expected.

(b) Sizing machine

(A) Better heat insulation

Thoroughly heat-insulate the tanks, headers, and piping.

(B) Mounting a hood

This helps keep temperature around the cylinders and quickly dispel vapor.

(C) Squeezing at higher pressure

If squeezing pressure after sizing is raised from 350 kg to 1,500 kg, for example, evaporation can be reduced by 33%.

(D) Change of sizing material

If a different type of sizing material is used, it can be prepared at lower temperature and sizing can be done at lower temperature. If the material compounding temperature is lowered from 130°C to 80°C, for example, steam can be saved by 13%.

(E) Increasing the number of sizing pieces

Increasing the number of sizing pieces saves energy as a whole, though speed goes down.

(F) Improving cylinder heat transfer

Adjust the siphon and arrange the traps so that condensate in the cylinder will be smoothly discharged.

(G) Recovery of condensate

See the chapter on boilers and steam.

(H) Management of exhaust air from hot air dryer

The hot air dryer has lower heat efficiency than the cylinder dryer. So exhaust rate and drying temperature should be controlled to prevent overdrying.

(B) Weaving

(a) The shuttle driving type weaving machines called looms acount for the greater part of the weaving machines. In fact, there are a great number of them.

Electric energy is used to drive the waving machines -- rotating and reciprocating -- different from other production machines. Energy conservation measures for the weaving machines should be based on proper maintenance.

(b) Energy conservation measures

(1) Reducing the suction area of waste thread suction blowers and preventing blocking with waste thread

(2) Replacing power transmission drive belts with energy saving type cog belts. A 4% power saving can be expected.

(3) Adjusting belts to proper tension

(4) Managing lubricating oil for various part of machine bases (proper oil level, early repair of leaking parts)

(5) Replacing conventional motors with high-efficiency type motors when the former must be renewed (Price difference between the standard type and high-efficiency type can be recovered in one year or two.)

(6) Managing compressed air for cleaning in the same way as described in the section on the preparatory process

(7) Air conditioning system

A high humidity of 70% to 80% RH is necessary depending on the kind of yarn. Generally, a system combining an air washer with an indoor direct humidifier is used. If indoor direct humidifying is increased, the air supply rate can be reduced, which means a lower operating speed of the blower and less power consumption.

(8) New type weaving machines

The air jet loom and water jet loom consume less energy than shuttle looms. However, the new type looms require not only the power to drive the machines themselves but also the power to generate compressed air and pressure water and drive electric heat cutters and dryers. Then, energy conservation measures are necessary for the peripheral devices. The air jet loom needs driving pneumatic power setting according to the kind of weaving, and the water jet loom requires efficient drying of fabrics to remove moisture.

(9) Introducing a production monitoring system

This system will reduce machine down time due to end down, and thus improve the operating ratio. A factory is reported to have improved its operating ratio by more than 10% with this system.

(10) Maintenance of machinery

- o Preventing off-load motor operation
- o Adjusting belts to proper tension
- o Optimizing lubrication quantity or level

These are the essential basics that must be strictly observed.

(c) Finishing

Shearing consumes much electric energy in the finishing process. Particularly, the dust collectors account for a large percentage of power consumption in the process.

Finishing is the final process of production, and care must be exercised to prevent quality problems.

Energy conservation measures for the individual processes are summarized in Figure 5-22.

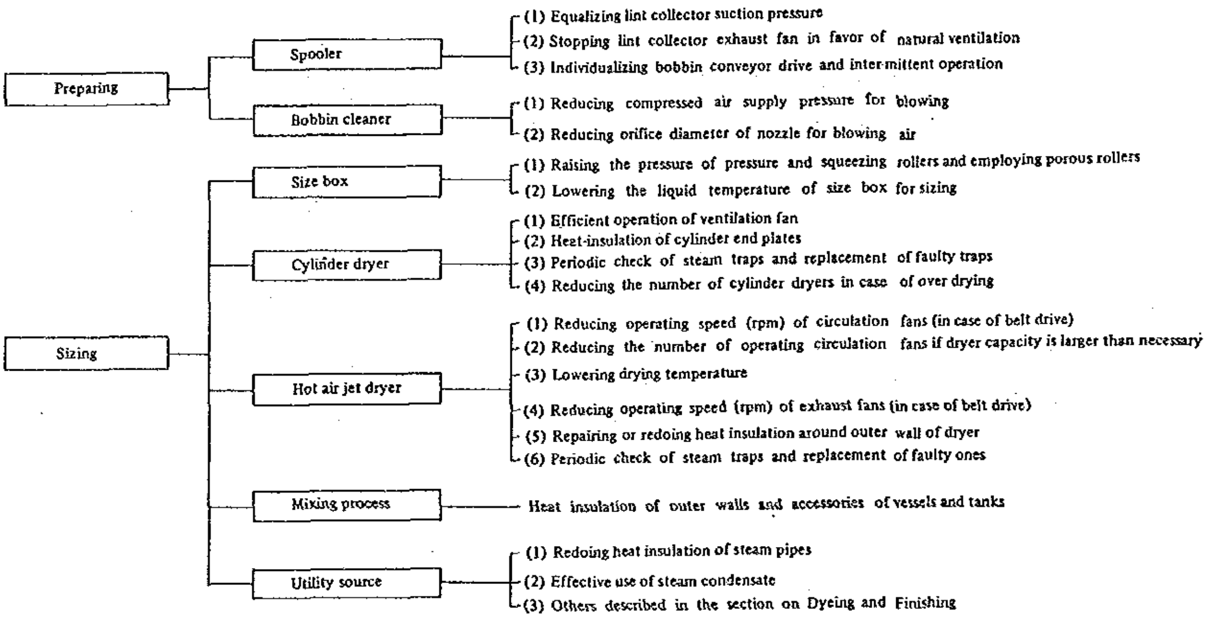


Fig 5-22 (1) Items of Study for Energy Conservation in Individual Processes

(1) Reducing bath ratio

The dyeing industry consumes much water, heated water in many cases, so that water saving means energy saving.

The quantity of water (in liters) used to dye 1 kilogram of a dyeing object is called the bath ratio, which varies considerably depending on the dyeing method and dyeing machines.

The following may be taken into account in dyeing.

(A) Cheese dyeing (8 to 15) uses a smaller bath ratio than bank dyeing (25 to 35).

(B) Even in cheese dyeing, the bath ratio can be lowered by means of winding density, spindle arrangements, etc.

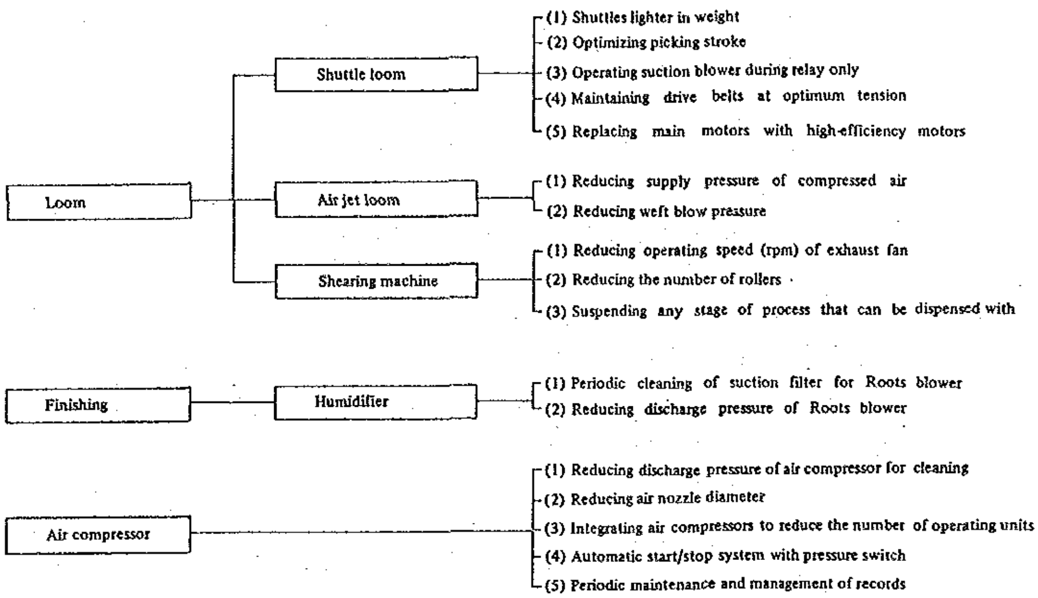


Fig 5-22 (2)

(C) The bath ratio can be lowered to 3 or less by distributing the dye liquor uniformly in the form of foam or mist.

Foam dyeing is applicable to plain dyeing. Air is injected into the dye liquor to generate foam, fine and uniform, to dye the fabric.

(D) Using one-bath dyeing, instead of two-bath dyeing, for mixed yarn is effective for lowering the bath ratio and shortening time.

Various types of dyeing machines featuring a low bath ratio have already been developed.

Improving cloth exposure to the dye liquor by high-speed rotation of more than 200 m/min and vibration reduces the ordinary bath ratio of 1:20 – 1:30 to 1:11 or even less. Examples of performance comparison between a low bath ratio type and conventional type are shown in Table 5-11 and 5-12.

Table 5-11 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 5-12 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	x	0.8	x	2.5	=	48	÷	300m	= 0.16 kWh/m (100)
Low bath ratio type	16.5 kw	x	0.8	x	2.5	=	33	÷	500m	= 0.066 kWh/m (41)

Another type which reduces the required energy to 1/10 or less by rapid heating with microwave has also been developed.

(2) Reducing the amount of washing water

Various types of high-efficiency washing machines has been developed. Their operation is based on the following.

(1) Increased exposure of cloth to washing water

(2) Supplying water opposite to cloth

(3) Vibrating both water and cloth

The washing effect is increased by the above. A washing machine of high efficiency type, for example, reduces water and steam consumption to 1/10 and power consumption to 1/4 compared with the conventional type.

(3) Shortening dyeing time

A polyester dyeing method which raises temperature as quickly as possible within the temperature range in which dyeing is not affected, and dispenses with the need for leveling has been developed.

(4) Lowering treatment temperature

Lower the temperature for bleaching, dyeing, etc. by changing chemicals, etc. also study the possibility of rinsing at lower temperature.

(5) Saving drying energy

(A) Dyeing is a process of repeated dipping in the dye liquor and drying. Depending on the kind of fiber, squeezing is directly followed by the next process without drying. (This is called the wet-on-wet method.) In one instance, a method of uniformly applying a finishing agent to wet cloth was developed to dispense with the need for drying after dyeing. This contributed to an energy saving of more than 8%.

(B) Save thermal energy to completely dehydrate with a mangle before drying. Adjust rubber-covered rolls of appropriate hardness so that the linear pressure will be uniform in the width direction. Sime equipment featuring improved efficiency uses rolls of nonwoven cloth or a means of vacuum suction through slits. A method of dehydration by blowing with high-speed air currents is also effective.

Because moisture content can be reduced to anywhere from 25% to 50%, cloth will be dried twice as fast and drying cost will be lowered by 17% according to an instance.

(C) If a fiber, dried in excess of a certain limit, is exposed to the air, it absorbs moisture again to equilibrium moisture. Therefore, excessive drying above the percentages specified in Table 5-13 will result in energy loss.

(D) Circulating hot air in a hot air dryer will increase drying speed and save energy. Periodically measure the moisture content of exhaust air, and adjust the exhaust rate. If a combustible solvent is contained, care must be taken to prevent explosion.

As regards the drying of woollen textiles, it is necessary to study the automatic control of drying temperature and exhaust air moisture content for not only quality control but also preventing overdrying.

Table 5-13 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.

(E) The cylinder (thrasher type) dryer is more advantageous to the hot air dryer in terms of thermal efficiency. To efficiently use it, inspection and maintenance of the internal siphon pipe for drawing condensate out of the cylinder and the steam traps is necessary.

(F) When applying chemicals, such as a waterproofing agent to textiles, drying energy can be saved by limiting their amount to a low level by means of a screen roll, for example.

(6) Radiation prevention

(A) Most of the dyeing machines and washing machines are not heat-insulated presumably because, for one thing, the conventional fibrous or porous heat insulating materials easily absorb water and, for another, it would be costly to ensure completely waterproof heat insulation in a high-humidity environment such as in a dyeing factory. Recently, however, a closed-cell foam type of water repelling plastic was developed, and it can be bonded to objects with a chloroprene adhesive. Polypropylene and hard urethane can be used at up to about 120°C, while medium-pressure polyethylene foam can be used at temperature below 100°C.

A simple insulation method is to cover an object with an insulating material and then with vinyl sheets like a skirt to keep water out. An instance of using this method saved steam by about 20%.

(B) Hot water tanks

Heat-insulate the hot water tanks and use a cover or a floating lid to prevent heat radiation from the top surfaces.

(C) Heat-insulate the outer walls of the dryers and make the openings as small as possible.

(7) Waste heat recovery

An example of analysis of the thermal energy used in a dyeing factory is shown in Table 5-14. As shown, the percentage of heat lost in waste liquid is high. This is why there are many cases of using dye waste water for heat exchange with feed water, or using cooling water as the next supply of water.

Table 5-14 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

Instance 1

A knit dyeing factory uses only waste water of over 60°C from the dyeing machines, passes it through two spiral heat exchangers to obtain hot water of 50°C to 60°C, and use it in the next dyeing.

Of 200 m^3/d of waste water, 100 m^3/d is used for heat recovery, and 100 m^3/d of hot water is obtained from it. The capital investment amounted to U$S100,000, and fuel oil consumption was reduced by 25%. The investment was recovered in 2.2 years.

Instance 2

A polyester and rayong yarn dyeing factory with 40 employees took the following measures.

(a) Condensate from the dyeing machines and dryers was recovered into boiler feed water to raise feed water temperature to 80°C.

(b) Cooling water from the high-pressure dyeing machine was recovered into the hot water tank.

(c) Waste water of over 57°C from the dyeing machines was selected using a thermal sensor and fed to the heat exchanger to recover hot water 170 m^3/day of 60°C on the average.

The factory also made improvements on dyes, assistants, and dyeing method to permit dyeing at 60°C.

The factory invested U$S180,000 for the relocation, piping, and heat-insulation of the dyeing machines, condensate recovery pumps, and hot water tanks, U$S30,000 for the heat exchangers and pumps for a total of U$S210,000. The final oil consumption rate was lowered by 45% from 0.85 liter/kg to 0.47 liter/kg with a fuel saving amounting to U$S270,000/year. Thus, the investment was recovered in less than a year.

Instance 3

A yarn dyeing factory with 12 employees took energy conservation measures of recovering condensate and the heat of waste liquid from the dyeing machine. Condensate is generated in the dyeing machine and dryer. Because the dyeing solution may get into the condensate, it is not directly mixed with boiler feed water, but is passed through the heat exchanger to heat the boiler feed water. The heat exchanger is a plate type that is easy to clean, and is made of stainless steel (304) to prepare for the possibility of contamination by an acidic bath. (See Figure 5-23.)

10 to 15 tons of dyeing waste solution, 50°C to 100°C, is generated an hour. After removing cellulose sludge from the waste liquid by passing it through a vortex filter, it is used to preheat 30°C water to 48°C with the plate type heat exchanger (stainless steel). The heat exchanger has a pipe connected to it for back washing. Temperature and flow rate can be set for automatic operation.

The factory invested U$S120,000 for two heat exchangers, pumps, tanks, pipings, etc., which was recovered in about 3 years because fuel was saved by 22%, giving an annual saving of U$S38,000.

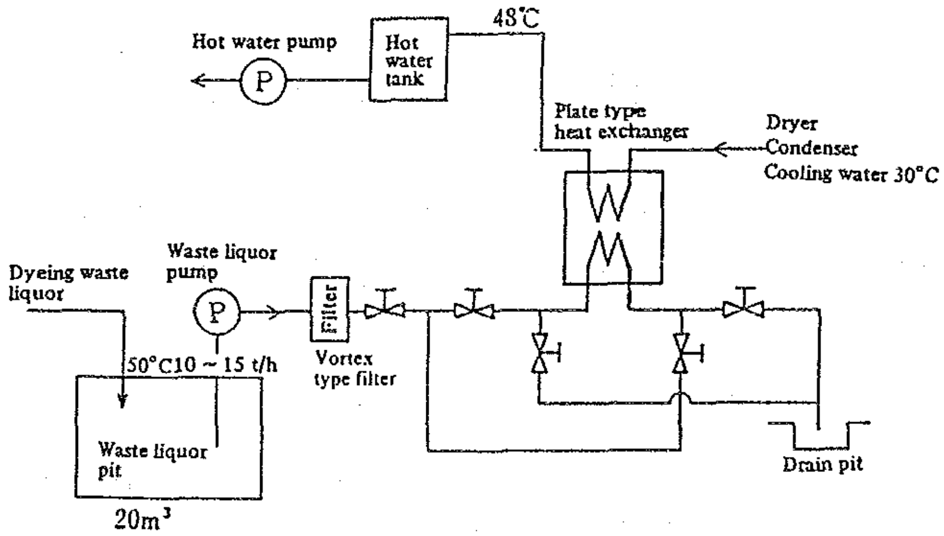


Fig 5-23 Dyeing Waste Liquor Recovery Equipment

Instance 4

Hot waste water from the dyeing and bleaching processes had been used for heating feed water by heat recovery through a heat exchanger. It was found, however, that further heat recovery from low-temperature waste water could be made by a suction heat pump. Waste heat from the air conditioning system which had been discharged through the refrigerators and cooling towers into the atmosphere was also recovered to heat water. (See Figure 5-24.)

The flow sheet is shown in Figure 5-24. The capital investment amounted to U$S250,000, which produced energy saving effects as shown in Table 5-15.

There is another instance in which the heat of exhaust air is recovered to heat feed air using a rotary heat exchanger.

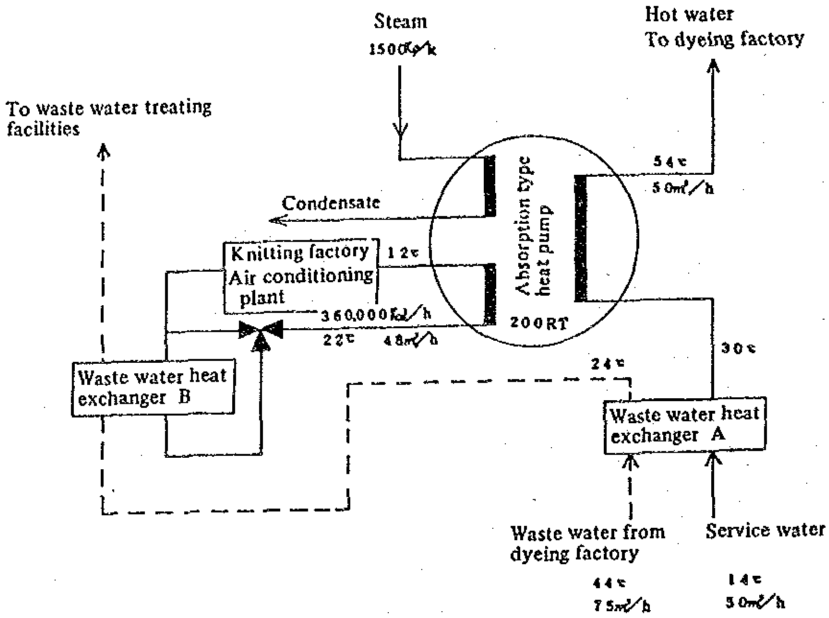


Fig 5-24 Flow Sheet of Heat Pump System

Table 5-15 Energy Conservation Effect

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

For energy conservations measures pertaining to steam supply and transport, refer to the chapter on the boilers and steam.

6. Paper and Pulp

6. Paper

6.1 Characteristics of the Use of Energy

6.1.1 Manufacturing Process

The flow of the paper making process is as shown in Figure 6-1.

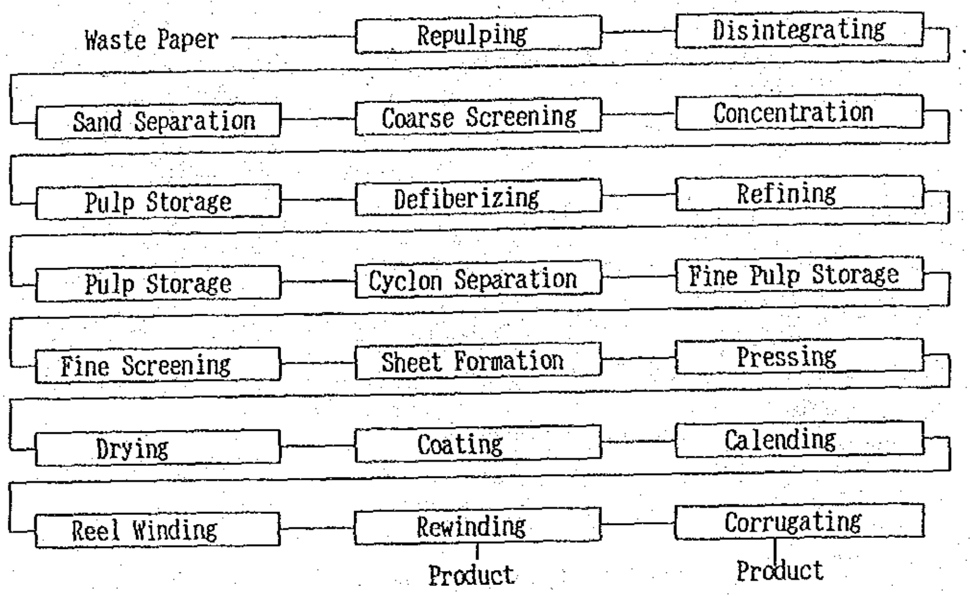


Figure 6–1 Production Process

In order to make wooden fiber sheets, the fiber is carefully selected and beaten in preparation procedures, and is gradually dehydrated in uniform dispersed condition. In the final stage, moisture approx. twice as much is evaporated by steam. This paper making industry is a large-scale equipped industry. In addition to electric power for driving the equipment, this industry uses 500 to 1,000 tons of water per ton of paper. Also an enormous amount of electric power is required for moving this water. This is one of the reasons why the paper making industry is an energy intensive industry.

6-1-2 Status of Energy Consumption

(1) Places where energy consumption is required

The places at the paper mill where energy is consumed are as shown in Table 6-1. Almost all the majority of thermal energy is consumed in the dryer part excepting the pulp manufacturing section. As only an exception, some paper mills were using steam for the purposes of drying after coating in the continuous paper-making and coating unit, and for pulper to promote the defiberizing and to accelerate beating and fibrillation caused by swelling of the fiber. Electric energy is used as rotary power for the rotor or the impeller which directly acts on the fiber in defiberizing, beating, circulation, stirring, and cleaning of raw materials. It is also used as rotary power for the cylinder for washing filter, dryer, etc. and transportation power for water, and raw materials. The process is divided into the preparation of raw materials and the paper machine. However, it is difficult to classify the electric power consumption by system or part. Aside from the mill equipped with only one unit of paper machine, it is common that the preparation process is not arranged with the paper machine in series as a systematized line. For in-

Table 6–1 Equipment and Energy of Paper Mill

Name of equipment	Purpose	Energy source
Pulper	Pulp disintegration	Electricity and steam
screen separator	Removal of undissolved and foreign matter	Electricity
Filter Thickner	Pulp washing and concentrate	Electricity
Beater Refiner	Fiber beating and defiberizing	Electricity
Chest	Circulation of stored pulp	Electricity
Cyclone separator	Separation of united fiber and microparticles	Electricity
Paper machine	Driving of wire part, press part and dryer part	Electricity
Suction box Suction couch	Dehydration of wire part	Electricity
Suction press Suction box	Dehydration of press part	Electricity
Dryer	Drying of wet paper and canvas	Steam
Coater	Painting and drying	Electricity and steam
Calender	Smoothing and glossing	Electricity
Cutter	Cutting	Electricity

stance, suppose that 2 units of paper machines and 4 units of refiners for the former are provided. The paper machine A) uses 3 units of refiners, and the paper machine B) uses the remaining one unit of refiner depending on manufacturing quality. Thus the combination of equipment varies according to the quality of ordered product. In addition, the pulp disintegration and coarse-mesh screen and the refining equipment are sometimes separated from each other for layout convenience. The latter is ordinarily located near the paper machine, so they often share the same electric power distributor. However, it is for the establishment of the optimum unit of the management of energy for the paper mill to divide the electric power systems into two sections such as preparation part and paper making. Arrangements should be made so that the division of the electric power system may be achieved without fail whenever equipment is newly installed or a large-scale modification of the mill is carried out.

In the preparation parts at the paper mill without a pulp manufacturing section, direct thermal energy consumption is at a low level. Steam is only used for heating the pupler for used paper disintegration, dye dissolution and the glue making from starch at the printing paper mill. This steam consumption is very little, compared with steam consumption by the dryer. The energy consumed in the sheet formation process is almost entirely electric power and it is used for raw material transportation, raw material circulation in the chest, defiberization and beating. Most of this energy is converted to friction heat which is turn, increases the system temperature or is released into the atmosphere. Although it is not easy to control the release of this beat into the atmosphere, white water should at least be recycled and the aforementioned friction heat should be recovered to the maximum possible extent. Also the temperature drop by the use of fresh water should be prevented and the drying effect of the paper making process should be maximized.

The direct measure for the saving of electric energy is to maintain the highest concentration of pulp suitable to the given equipment.

An increasing of the concentration economizes the power for transportation. In addition, the storage capacity of the chest is increased, so it is possible to reduce the number of chests for the same stock amount. Consequently, the electric power consumption can be cut.

Almost all of the mills, taking precautions against possible operating trouble such as raw material clogging, were operating at lower than the proper concentration. For raw material transportation, defiberizing and beating, the quantity of water 20 to 30 times the quantity of raw material is used and the quantity of water 100 to 200 times as much is used for screening, dusting and paper formation. It is strongly suggested that positive efforts be made regarding the process at high concentration.

(2) Heat balance

Almost all of the energy input at the mill is lost into waste water of the mill in the form of thermal energy or is released into the atmosphere.

For instance, in case of a mill capable of 20 tons per day in Argentine,

– Temperature of fresh water for mill's use	20°C
– Temperature of mill's waste water	30°C
– Consumption of fresh water	50 m^3/t
– Heat input of fuel	2,250 x 10^3 kcal/t
– Electric power consumption	476 kwh/t x 860 kcal = 409 x 10^3 kcal/t
– Heat lost into waste water	10°C x 50,000 ℓ ≒ 500 x 10^3 kcal/t

It is estimated that 1/4 of the total energy input is lost into waste water. In addition, the thermal energy is as large as 85% of the total energy input, and the majority of it is consumed in the dryer part. The dryer part is an important part from the energy conservation point of view and also for determining the quality of finished product and governing production, production efficiency, and eventually the mill's profitability.

(3) Unit energy consumption rate

In Japan, the standard unit energy consumption rate of the paper making in 1979 to 1980 is as shown in Table 6-2.

Since the steam and electricity accounted for 2.75 t/t and 476 kwh/t respectively at the mill checked in the Argentine Republic, the values are a little higher than the average values in Japan.

Table 6–2 In Japan, the Standard Unit Energy Consumption Rate of the Sheet Making Section in 1979 to 1980

	Steam (t/t) 1979 Oct. ~ 1980 Sep.		Electricity (kWh/t) 1979 Oct. ~ 1980 Sep.	
	Range	Typical value	Range	Typical value
Printing paper A (high quality)	1.6 ~ 5.0	(3.2)	320 ~ 1,280	(775)
Printing paper B (intermediate quality)	1.9 ~ 3.6	(2.75)	480 ~ 940	(710)
Printing paper C (high groundwood paper)	1.9 ~ 3.1	(2.45)	440 ~ 950	(665)
Other printing and writing paper	1.9 ~ 3.6	(2.8)	370 ~ 790	(565)
Kraft paper (multiple sack use)	1.8 ~ 3.8	(2.60)	490 ~ 1,080	(770)
Kraft paper	2.1 ~ 4.2	(3.00)	420 ~ 1,450	(855)
Other wrapping paper	1.8 ~ 3.8	(2.95)	200 ~ 1,210	(750)
Kraft liner for external fitting	1.4 ~ 4.1	(2.60)	350 ~ 750	(540)
Jute liner for external fitting	1.6 ~ 2.9	(2.15)	300 ~ 700	(490)
Pulp core	1.7 ~ 2.9	(2.20)	30 ~ 600	(295)
Coated Manila cardboard	1.9 ~ 3.9	(2.90)	250 ~ 1,150	(700)
Coated white cardboard	1.8 ~ 3.4	(2.55)	220 ~ 650	(895)
Non-coated white cardboard	2.4 ~ 2.7	(2.55)	390 ~ 440	(420)
Core paper or Tube board	1.9 ~ 2.5	(2.20)	180 ~ 700	(430)
Color paper board	2.0 ~ 2.2	(2.05)	520 ~ 530	(525)

By courtesy of Japan Technical Association of Pulp and Paper Industry magazine No. 37-1 dated January, 1983

6.2 Rationalization of the Utilization of Thermal Energy

6.2.1 Steps of Measures for Energy Conservation

It is recommended that measures for energy conservation at the paper mill be taken step-wise as shown in Table 6-3.

First step – Improve the operating procedures without large investment.

Second step – Improve them with a little investment.

Third step – Remodel manufacturing equipment and process. This means large investment in equipment.

As the first step for the promotion of step-wise energy conservation, the effective utilization of the existing equipment and its more effective management are pointed out. However, it may well be the first step for the promotion of energy conservation to determine by data whether the energy is being utilized effectively.

If the load rate is close to 100% in the continuous operation without interruption, the large-scale equipped industry would consume less energy and have improved profitability. The same is true about the paper manufacturing industry. The best contributing factor toward energy conservation among other factors would be to eliminate the shutdown by the paper break and operate at full load.

It is necessary to be conscious about the fact that not only heat balance but also almost all data in the mill covering production control, quality control, process management, raw materials, management of auxiliary raw materials, etc. are related to energy conservation.

Table 6–3 Example of Step-Wide Promotion Plans

Step	Equipment	Others
First step Effective utilization of and sufficient management of existing equipment	Maintenance of various equipment screen, separator Pressure gauge blanket washer insulation, repair of steam leakage installation of steam flow meter.	Keeping a daily report in order . . . data collection. Setting qualitative standard. Setting operating standard. Setting standard for equipment, maintenance. Carrying out quality tests Checking the quality of blanket and canvas.
Second step Recovery of waste heat	Repair of press Maintenance of dryer Condensate recovery system. White water circulating system Improvement of ventilation for dryer part. Updating of faulty equipment.	Data analysis Re-evaluation of standard.
Third step Introduction of new equipment.	Completion of equipment maintenance services. Remodeling of screen, press for high concentration so that it may have higher operating efficiency. Recovery of heat from dryer.	

6.2.2 Items of Measures for Energy Conservation

The contributing factors for energy conservation, and their expected results at the paper manufacturing mill are as shown in Table 6-4.

In order to grasp the status of the mentioned factors, the items requiring checking and the recording of checked results are as shown in Table 6-5.

Energy conservation in the paper manufacturing process can be achieved by the following methods.

(1) Sufficient preparation of the raw material to decrease shives and foreign matter

(2) Thorough fibrillation for making fiber that produces well interlaced and strong texture when it takes a sheet form

(3) Maintenance of paper machine to obtain wet paper with uniform texture

(4) Uniform dehydration by press

(5) Effective transfer of steam heat to paper to evapolate moisture unifirmly

The following is an example to show the importance of the maintenance of equipment.

If the center of the table roll in the wire part is out of order, the material will be splashed to cause uneven texture and more moisture fluctuation of the wet paper after pressing. This causes an increase of steam consumed by a dryer as well as the paper break due to uneven drying.

Improper contact of a doctor causes the uneven moisture of wet paper in the press part because of the wetting of blanket by the surrounding water, and causes the deterioration of paper quality and the increase of steam consumption due to the mixing of sludge into paper in the dryer part.

Moreover, if the shower hole is clogged, uneven sprahing is performed, and if the pipe scale is mixed in water, wires are partially clogged in the wire part and the texture becomes thin, while the blanket stain increases in the press part, causing inferior dehydration and paper break.

6.2.3 Removal of Foreign Matter (Admixture)

The removal of foreign matter is indispensable for securing satisfactory quality of finished product and at the same time, is very important for achieving energy conservation.

In case the quantity of foreign matter in raw materials is increased, extra energy is required to remove it. If the removal of foreign matter is insufficient, the consumption of steam energy will be increased, or the production efficiency will be reduced by the occurrence of trouble with the manufacturing process.

If foreign matter and shives are included in a sheet, the portion will have much moisture and become a dark stain. To erase it the moisture of the portion must be decreased. In this case, as paper must be dried excessively in the total width direction, paper becomes weak and easily broken.

If the texture structure in the wire part is good and less foreign matter is included, it becomes possible to uniformly squeeze water with a press. If the density of such a wet paper is increased by press pressuring, the strength of the wet paper will be improved, the tension of paper running will become uniform, and paper break will be decreased.

In addition, if paper is not dried excessively, its smoothness at calender can be improved with ease, and it helps to improve the quality.

Nevertheless, it seems that generally, little concern is given to foreign matter from the viewpoint of energy conservation. Operators are apt to have an idea that in processing raw materials for paper, foreign matter and admixture are removed by the machinery automatically. Therefore, little consideration is given to the mixing of stray foreign matter at the stock yard for raw materials. Used paper should be placed on a pallet or arranged in good order on a well-maintained concrete floor. Actually, however, such a scene was sighted that used paper had been left directly on the ground and no concern was shown about the soiling of used paper by tires or dirty feet. Soiled used paper recessitates extra expenses for removal of firt and, subsequently, requires increased energy consumption.

For the above reasons, a campaign for establishing the undermentioned systems should be launched.

(1) Establishment of the system for management of used paper inventory

The persons in charge of materials who purchase used paper and manage the inventory should:

Table 6–4 **The Contributing Factors for Energy Conservation, Expected Results and Points of Equipment Requiring Care at the Paper Manufacturing Mill**

Process	Factors concerning energy saving	Effects
Pulping	Use of white water Appropriate high consistency	Preventing temperature drop Saving of electric power
Dust removal	Keeping appropriate consistency Adjustment of mesh, slit and plate Cyclone separator keeping inner surface smooth Keeping appropriate pressure at inlet and outlet Retaining appropriate liquid volume Use of appropriate quantity of white water for shower	Quality improvement Prevent of wet paper break Saving of electric power Preventing temperature drop
Beating and refining	Beating at high concentration to avoid fiber cut Keeping proper freeness Adjustment of blade	Maintaining paper strength and uniformity
Recycling of white water	Fresh water should be used only for wire part and blanket washing Thorough cleaning of each equipment during shutdown	Preventing temperature drop Saving fresh water Saving waste water treatment cost
Formation	Cleaning wire Arrangement of suction box Arrangement of table roll Cleaning blanket Arrangement of squeezing roll	Stabilization of paper strength and moisture
Press	Thorough washing of blanket – to retain elasticity Increasing pressure Cleaning of roll surface Adjustment of roll crown Maintenance of suction box	Improvement of dehydration rate
Drying	Insulation of steam pipe condensate pipe and valve Adjustment of steam pressure by cylinders Condensate recovery Utilization of flash steam Installation of steam flowmeter Repairing steam leakage Cleaning cylinder surface by doctor maintenance Adjustinginner siphon Appropriate ventilation and fresh air flow control Applying pocket ventilation Thorough cleaning of canvas	Reduction of radiation heat loss Effective use of steam Raising temperature of Boiler feed water Effective heat transfer Uniform drying

Table 6–5 Items of Daily Checking and Recording

Operation

Process	Item		Frequency
Preparation	Pulper	Disintegration time (min) frequency per day charge (kg)	each time
	Screen	Temperature consistency pH (%)	twice/shift
	Refiner	Temperature pressure consistency pH freeness electric power consumption	2–3 times/ shift
	Cyclone separator	Inlet pressure outlet pressure temperature	twice/shift
	Chest	Temperature pH freeness	twice/shift
Paper making	Stuff box	Opening of gate	every change
	Head box	Head	every change
	Wire part	Suction vacuum life of wire	every 2 hours
	Press part	Pressure frequency of breaking wet paper life of blanket	
	Dryer part	Speed steam pressure flow exhaust pressure Frequency of breaking wet paper Paper weight thickness moisture strength size	

Periodical test of material

Material	Item	Frequency
Purchased pulp	Make sheets according to standard and carry out quality test	once/month
Raw material after screening	Make sheets according to standard and carry out quality test dirt determination	once/month once/shift
Raw material after refining	Make sheets according to standard and carry out quality test	once/month

Inspection of equipment

Equipment	Item		Frequency
Screen	Screen mesh concentrator wire cyclon separator	Clogging, breakage Pressure gauge inner smoothness reject tail	once/month During shutdown
Wire part	Wire table roll vat suction box Breast roll Couch roll	Clogging, breakage deformation, level check and clean smoothness of upper surface adjusting seal check and clean Check and clean Check and clean	During shutdown
Press part	Press roll Blanket washer Shower	Adjusting crown adjusting press Check and clean Check and clean	During shutdown
Dryer part	Siphon Doctor Steam nozzle Hood Air heater Steam trap	Adjusting Adjusting Check and repair Check and repair Check and repair Check and repair	During shutdown

a. Try their best to purchase raw materials containing less foreign matter.

b. Arrange the storage yard so that purchased raw materials may be free from foreign matter and may not be scattered or degraded dur to put refaction.

c. Adopt a way to prevent raw materials from being lost, contaminated or from falling down during carrying operation for delivery to an operating site.

The manufacturing department should:

a. Always instruct the persons in charge of purchasing materials so that the purchase of raw materials containing less foreign matter may be made, and show data on the actual status of foreign matter, its samples, etc. periodically.

b. In close cooperation with each department of the factory, display the slogan such as "don't step on paper" or "handle paper carefully" so that employees may be highly conscious about the importance of reducing paper loss at the factory.

c. Place the poster "don't make broke paper" or "broke paper means the proof of immature paper making technology" at every salient place so that employees may improve their paper making technology.

(2) Means to remove foreign matter

There are two different types: the dry-type method and the wet-type method. The dry-type method is an extremely effective method for the selection and removal of foreign matter during the check on raw materials received. Under the mechanical dry-type method, raw materials are crushed by the shredder, dusted by the rotary drum-type duster, and separated from foreign matter by cyclone. At present, this method is not extensively employed, but the wet-type method is more popular. Under the wet-type method, raw materials are once defiberized by the pulper, and suspended in liquid. Thus foreign matter is removed by the following means:

a. Pulper lugger: removes light and long packing string, rays, etc. by winding them on a suspension chain.

b. Pulper jack box: removes heavy stone and iron pieces.

c. Pulper strainer: removes objects which will not easily be defiberized.

d. High concentration screen: removes heavy objects.

e. Coarse screen: removes fiber which has not been defiberized.

f. Centricleaner: removes fine and slightly heavy objects (microsand, scale) and fibrous flocks.

g. Secondary screen: removes fibrous-flocks and light splinters.

From the viewpoint of principle, every one of the above utilizes the differential of specific gravity and dimension.

(3) Equipment for separation by differential in specific gravity

For separation by the differential in specific gravity, there are two different methods: the precipitation method and the liquid cyclone method. When particles in water precipitate under the effect of specific gravity and the upward effects of buoyancy and fluid resistance, this phenomenon is called "free precipitation." In a suspension of raw materials for paper, it is not easy for independent particles to freely precipitate, so "coherant precipitation" should occur.

The chohesion among foreign matter particles is insignificant, but fibers are apt to be mutually entangled. Consequently, the precipitation separation has to be carried out in a liquid of low concentration.

A) Riffler

The riffler is available as the simplest equipment. It is called "sand table," "sand catcher" or "sand trap" and is an effective device for separating metal, sand, etc. The The riffler can be home-made and less expensive for installation. The most popular type is of a trough shape having a rectangular cross-section measuring approx. 1 m in width and 0.5 m in depth with a baffle provided at the bottom which precipitates particles moving in the flow direction under the effect of impact.

This baffle is easily attachable and detachable to allow feasible cleaning. The only things requiring careful attention are to provide an angle to the baffle so that raw materials flowing downwards may be turned upward by the baffle, and to also make curve at the turning point.

Suppose that the volume of liquid flowing through the riffler is Q cm^3/sec. Then the following equation is established:

$$Q = V \cdot b \cdot h$$

V: Horizontal current velocity (cm/sec)

b: Width (cm)

h: Water depth (cm)

If the precipitating velocity of particles to be separated is u cm/sec, the following conditions are required for the precipitation of particles up to the end of the riffler:

$$h/u \geqq \ell/V$$

$$V = \frac{Q}{b \cdot h}$$

Therefore

$$h/u \geqslant \frac{\ell \cdot b \cdot h}{Q}$$

$$u \leqslant \frac{Q}{\ell \cdot b}$$

ℓ: Length of trough (cm)

According to the above equations, the surfacial area is to control the separation threshold regardless of the water depth of the riffler.

Accordingly, the riffler, although occupying a large area, will be an economical foreign matter remover, if outdoor space is utilized.

B) Liquid cyclone

A pulp suspension is tangentially injected under pressure into the upper part of the cyclone cylinder through the crude liquid inlet. The influent proceeds rotating to the conical part along the cylindrical inner wall and particles of high specific gravity in the fluid run downstream by centrifugal force, mixing in the slow stream of the boundary layer along the wall. Then these particles are continuously discharged from the ejection port. On the other hand, the fluid after separation of the particles is inversed after reaching the lower end and gyrated upward in the center to flow out the upper center. The following conditions are for the effective separation of particles.

a. The differential in specific gravity between the particle and fluid (pulp suspension) is significant.

b. The centrifugal acceleration is high and the inlet pressure is also high (there is a pressure drop in the cleaner).

c. Time subjected to the centrifugal acceleration is long (the residing time in the cleaner is long).

d. The moving distance in the radial direction during the separation is short (the diameter of the cleaner barrel is small).

e. The concentration of suspension is low.

f. The inner wall of the cyclone is smooth. The material is less susceptible to wear and is periorically checked and replaced.

The separation capacity has to do with the ratio of reject (tail) flow and input flow. This is an important point at which attention should be given in the operation of the liquid cyclone. The elements affecting the flow ratio are dimension and shape of the cyclone, its inlet pressure, concentration and many others. However, the most important element is the ratio (Du/De) of the diameter of tail tube Du and that of accepting tube De.

The approximate value of the flow ratio (Rf) when an air core is formed in the center of the cyclone due to the release of tail tube into the atmosphere as seen in the conventional centricleaner and the reject is flowing out as an umbrella-shaped tray, is sought by the following equation:

$$1 - Rf = \frac{0.95}{(Du/De)^4 + 1}$$

Generally, Rf ranges from 10 to 30%.

If the diameter of the tail tube is too large, the reject volume is increased, diminishing the yield. On the contrary, if the diameter of the tail tube is small, the fluidity may sometimes be decreased on account of the entanglement of separated foreign matter with fiber, resulting in the clogging of the pipe.

6.2.4 More Effective Dehydration by Press

(1) Theory of water squeezing on the press

Generally, it is estimated that cost for drying the wet paper in the drying process would be more than 5 times the cost for mechanical dehydration in the press part. Therefore, if the moisture in the press part is dehydrated for an extra 1%, it will be possible to save the steam quantity in the dryer part by 3 to 5%. The key point of drying the wet paper is whether it is possible to dehydrate moisture evenly in the width direction and as much as possible in the press part. However, in order to make sure that the pressing in the press part is carried out, it is necessary to take sufficient pre-treatment procedures such as dusting and beating (refining) prior to entering the paper machine and sheet formation in the wire part. If there are large amounts of shines and foreign matter, it is impossible to expect the formation of highquality sheets in the wire part. Also the moisture distribution will be uneven, so that if pressed by the press roll, paper will often be cut. This situation does not allow sufficient pressing operation. In addition, because of their moisture content, shines and foreign matter darken the paper, i.e. causing fish eyes. In order to hide fish eyes, overdrying tends to be carried out. As a result, paper shiringkage and paper break is apt to occur, if foreign matter exists at the end. High frequency of paper break means an overload on the shoulder of operators and their subsequent negligence to concentrate in assigned work. Further, waste paper is also circulated, resulting in an unstable quality of paper and an inefficient consumption of energy.

Water squeezing on the press is carried out by passing wet paper through the weighted nip formed by two pieces of press roll together with felt as a water squeezing medium. The reason why felt is used is that it has a capillary structure, elesticity and surfacial flexibility. The number and configuration of presses used vary according to the paper machine.

The fourdrinier paper machine having 2 to 3 sets of presses is generally most popular. However, recently the squeezing capacity of a press has been increased and the number of pressing steps has shown a tendency to decrease, following the development of new technologies for the past few years. As basic types of press, the following two types are available: 1) the historically oldest plane roll type provided with a combination of a top roll using granite, etc. and an elastic bottom roll having an approx. 25 mm-thick rubber wound around an iron core; and 2) the suction press type provided with water squeezing and suction functions by perforating numerous suction holes of 6 to 7-mm diameter on the rubber surface of the bottom roll and setting a fixed suction box in the roll. The debut of the suction press has played an important role in improving the sheet making rate.

There are a few water squeezing theories for the press. However, in the age of the plane press, it was theorized that the wet paper and blanket are compressed by the press and the blanket begins to expand when passing the center of the nip and, simultaneously, moisture contained in the paper is transferred to the blanket. Yet during the suction press age, a theory as shown in Figure 6-2 was advocated.

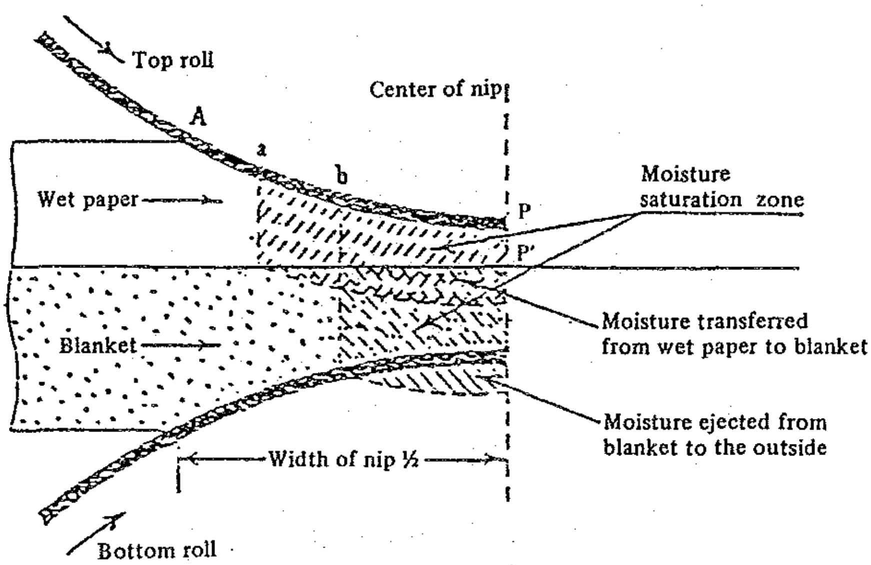


Figure 6–2 Water Movement in Press Nip

As the compression goes further, moisture in the paper gradually reaches a saturation point. Following the increase of density in the sheet, a fluid pressure is generated, causing a differential pressure between the unsaturated blanket and the paper. Thus the moisture moves from the paper to the blanket.

If the rotation is advanced and the compression increased, the blanket is also in a saturated state, and the squeezed surplus water is flooded over and sucked into the suction hole.

In the plane press age, the sheet making rate was limited because of wet sheet crushing occurring in the press. However, this limit was eliminated by the development of the suction press method, making the high-speed sheet making process possible. Reviewing this situation, it is considered that the excess overflowing water in the press nip should have been responsible for wet sheet crushing. The suction press is very effective for increased pressure application as well as for increasing the sheet making speed. Thus it may well be an equipment contributing toward energy conservation.

(2) Adjustment of moisture in wet sheet and moisture distribution

Even if the moisture content after pressing could be decreased, it would be quite useless, unless an uneven moisture distribution in the width direction is improved. The factors for adjusting the moisture distribution in the width direction is graphically described as shown in Figure 6-3.

With regard to these factors, make sure that the following are periodically checked:

– Measurement of moisture content in the width direction

– Measurement of press nip pressure in the width direction

– Measurement of crown and hardness of roll

The moisture content is normally measured in the width of the paper machine. It is recommended, however, that the measurement be made at an interval of approx. 10 cm.

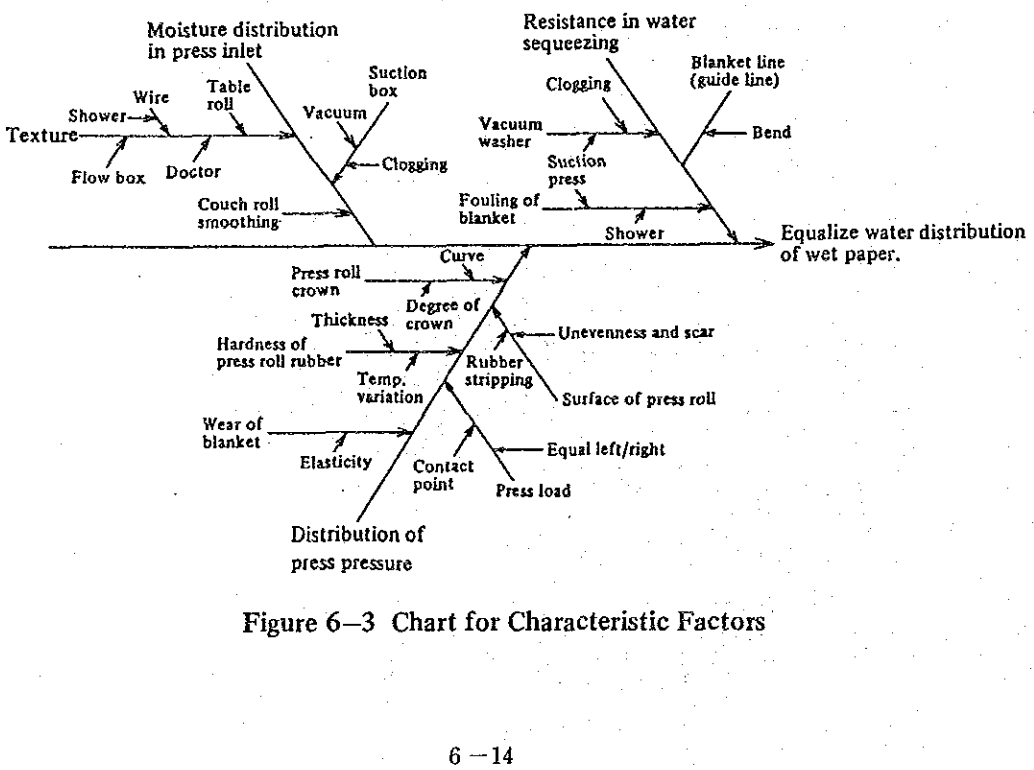


Figure 6–3 Chart for Characteristic Factors

The nip pressure means a pressure generated per unit area, but not a linear pressure. If the same linear pressure load is applied to a soft rubber roll and a hard rubber roll, the width of the contact part of the soft rubber roll becomes larger than that of the hard rubber roll. On the other hand, the nip pressure per unit area (average) of the hard rubber roll becomes higher than that of the soft rubber roll.

Since it is the pressure per unit area that controls water squeezing, the nip width generated by the contact deformation of the roll is also as important as the linear pressure.

If pressure applied to the roll is changed, the nip width will change in proportion to the square root of the nip pressure as shown in Figure 6-4. Accordingly, the change of the linear pressure on the same conditions signifies the change of the average nip pressure as follows:

$$p = \frac{P_L}{k \cdot \sqrt{P_L}} = k' \sqrt{P_L}$$

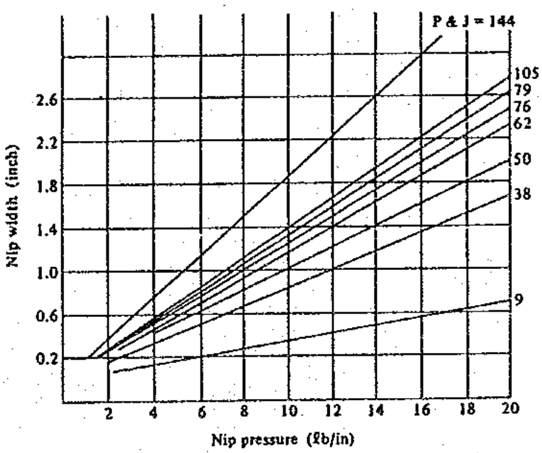
p : Average nip pressure

P_L : Linear pressure

k, k': Constant

Based on the above, if the linear pressure is doubled, the pressure per unit area related to a water squeezing effect will be only 1.4 times as much.

Under a constant linear pressure, the nip width is increased or decreased in proportion to the rubber hardness indicated by the P & J hardness (refer to Figure 6-5).



P & J (Pusey & Jones Plastometer)

Figure 6–4 Nip Pressure and Nip Width

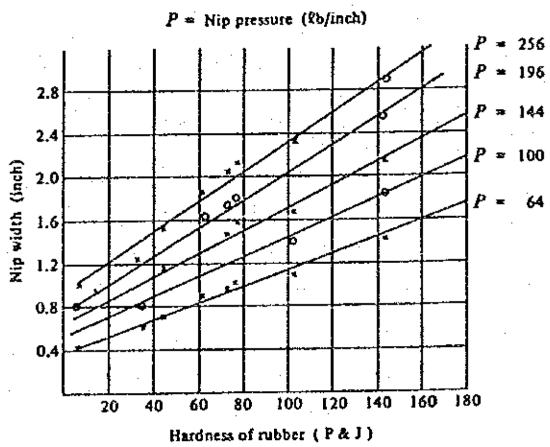


Figure 6–5 Nip Width and Rubber Hardness

The nip width has to do with the diameter of the roll. The smaller the diameter of the roll, the smaller the nip width. In addition, the nip width varies according to the sheet making speed. If the sheet making speed is increased under the same conditions, the nip width is reduced. The nip width also changes depending on the thickness of rubber and is proportional to the thickness of coat.

The hardness and thickness of rubber must be selected considering sheet making quality, sheet making speed, machine width, equipment strength, roll material quality, etc. When studying the selection, it is suggested that an experienced specialist manufacturer be consulted for opinions, and sufficient discussions with him be carried out. Necessary data such as moisture distribution, nip pressure condition, crown, paper quality (thickness, density, tension, tear, air permeability) must always be collected for use at any time.

A) Hardness of rubber roll

There are a variety of ways to measure the hardness of rubber roll. In Japan, the spring hardness testers Model A and Model C and the constant load system Pusay Johns type hardness tester are available under JIS (K6301). In addition, the Shore hardness tester Model A is available. Regarding the referential value of rubber hardness of rolls used for the paper machine, data furnished by the Voith Co. are shown in Table 6-6.

The hardness of rubber roll, if left alone, shows an increase of approx. 2 on account of the oxidation of its surfacial layer. The press roll shows a change in the hardness of its surfacial layer after a long time of use. The roll may sometimes become soft or hard depending on its materials. The change of rubber hardness by temperature is comparatively significant; the higher the temperature becomes, the lower the hardness. Although the difference is significant according to the kind of rubber, the difference of rubber hardness generated is approx. 3 to 5 at a temperature difference of 50°C. Accordingly, it is necessary to designate a temperature during the measurement when the hardness is designated.

Table 6–6 Kind and Hardness of Rolls

No.	Kind of roll	Hardness by Pusey & Jones 1/8" sphere
1	Pressed roll	5~10
2	Table roll	0~5
3	Wire roll	0~5
4	Lamp roll for suction couch	180~200
5	Lower roll for the first press	65~70
6	Lower roll for the second press	60~65
7	Lower roll for the third press	50~55
8	Lower roll for the 4th press	40~45
9	Suction press roll	28~32
10	Upper roll for ringer plane press	10~15
11	Lower roll for ringer plane press	70~75
12	Upper roll for ringer suction press	60~65
13	Suction roll for ringer suction press	28~32
14	Wet felt roll	0~5
15	Transfer roll and draw roll	0~5
16	Paper roll	0~5
17	Top roll for offset press	30~40
18	Pressed rolls for cylinder dryer and yankee dryer	25~30
19	Gloss press roll for yankee dryer	25~30
20	Suction touch roll for yankee dryer	28~30
21	Coating or size press roll	
	Roll of high hardness	5~40
	Roll of low hardness	30~50

Quoted literature: Voith Tech. Bellage 1966 S. 45

B) Check on the crown

It is not exaggerating to mention that the stableness of operation of the paper machine and product quality can almost be achieved by the scheduled grinding of rolls. It is necessary to regrind the rubber-coated suction roll every 3 to 6 months considering the hardness of rubber or the pressure of press nip. The ribber roll should be used by repeating its grinding until the thickness becomes 13 to 15 mm.

When carrying out the grinding, attention should be paid to the crown. The roll is in the form of a beam whose ends are supported, so it sags by its own weight. In case of a pair of upper and lower press rolls, the lower roll is curved downward by its own weight. In the meantime, although the upper roll sags downward by its own weight, it is curved upward as a whole, because the upward sag caused by a load applied to the journals of its both ends is generally more significant (refer to Figure 6-6).

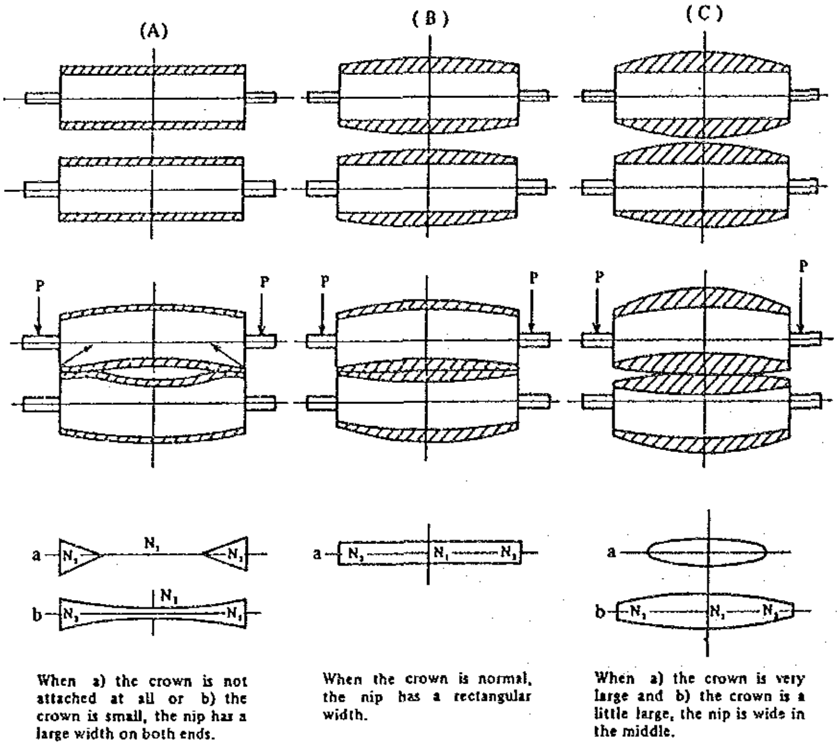


Figure 6–6 Crown and Nip Width

Consequently, a clearance is formed at a center part, even if both ends of the roll tightly adhere to the core. Padding for filling this clearance is called "crown." If the crown is inappropriate, it is impossible to obtain a uniform nip pressure across the width. For a simple visual determination of the crown state, the undermentioned objects are inserted between the rolls to confirm their marks or traces.

a. Carbon and tracing paper

b. Pressure-sensitive paper

c. Aluminium foil with embossed surface

Place any of these on the lower roll and apply pressure so that both ends of the upper roll may touch the lower roll simultaneously. If the upper roll is raised, excepting a load, the nip will be recorded across the entire width.

If a narrow mark appears at one side, it means that the load on the front and back is not uniform or the roll is deviating out of its right position.

The equation for calculating a crown value based on the marked nip width is as follows:

$$C = \frac{(N_2^2 - N_1^2)(D_1 + D_2)}{2D_1 D_2}$$

C : Crown value to be corrected

N_1 : Nip width at the center of roll marked

N_2 : Nip width at both ends of roll marked

D_1 : Diameter of upper roll

D_2 : Diameter of lower roll

If the diameters of the upper and lower rolls are the same, the following equation is established:

$$C = \frac{N_2^2 - N_1^2}{D}$$

If the calculation showed a negative result, it signifies the necessity to reduce the crown value by this negative amount. Here attention should be given to the fact that the difference of 1"/10 of the nip width appears as a change of 15"/1000 of the crown. When measuring the nip width, be extremely careful about the selection of pressure-sensitive materials which print a clear mark because it is necessary to read the mark correctly.

6.2.5 More Effective Drying

(1) Mechanism for drying wet paper containing approx. 60% of moisture to approx. 5% level.

a. Steam injected into the dryer cylinder heats the surface of the cylinder and becomes condensate.

b. The wet paper touches the smooth surface of the heated cylinder and absorbs heat effectively and uniformly over the entire width. Then the temperature of the wet paper is increased, resulting in the evaporation of moisture.

c. The wet paper, coming in touch with the cylinder, covers approx. 65% of the entire external circumference of the cylinder. However, the porous canvas travels on the exterior of the wet paper, holding down the latter, so the evaporated steam is condensed inside the canvas.

d. The temperature of the canvas containing a condensate rises and consequently the partial pressure of the internal vapor also rises. Then the canvas instantaneously evaporates moisture absorbed by the former in the free space between cylinders.

e. In order to make sure that the moisture ejection action of absorbing, condensing and releasing steam is carried out effectively, the canvas must be highly air-permeable, at high temperatures and well dried.

f. The wet paper retains a considerably high temperature when passing from the cylinder to the free space. Consequently, its vapor pressure is so high that the evaporation action on both surfaces of the paper is very effective.

g. The evaporation rate at that time is in proportion to the difference between the partial pressure of vapor in the surface of the paper (almost equals to the saturated steam at the temperature of paper surface), and the partial pressure of water vapor in the air. Accordingly, it is a means for improvement of efficiency to reduce the humidity of air in the surroundings of the paper.

h. If the condensate inside the cylinder is resident or formed into a water film ring, the thermal efficiency drops so that the condensate should be discharged effectively.

The above is a summary explanation on the drying mechanism of the dryer part. It is necessary for effective drying operation to have sufficient knowledge about the movement of moisture in the paper layer during the drying cycle.

(2) Movement of moisture in the paper layer

It is essential for the understanding of the drying mechanism to look into the relationship between the evaporation rate of moisture and the moisture content of paper during the process of moisture evaporation from the paper layer. The typical paper drying curve is shown in Figure 6-7.

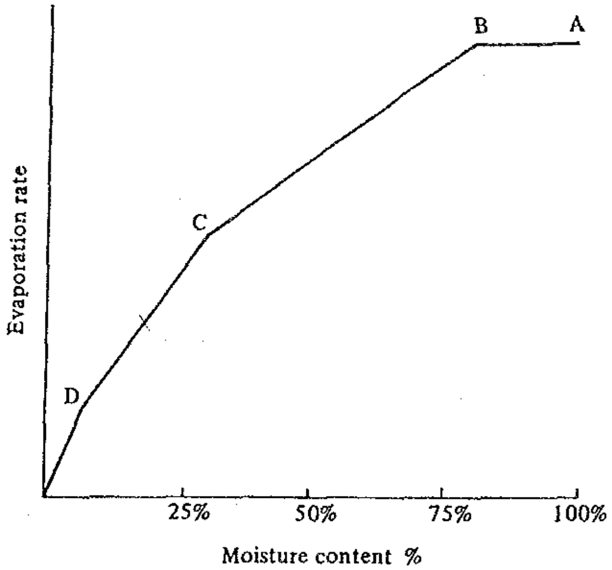


Figure 6–7 Drying Curve of Paper

A → B: The evaporation rate is constant during the drying process under a high moisture content state. This is due to the fact that under a condition where the paper surface is covered by water, the moisture, even if evaporated, is continuously replenished through comparatively large capillaries or fibrous clearances in the inner paper layer. If this evaporation status proceeds further, the paper reaches the stage where it is impossible to retain sufficient moisture in the surface of the paper "B" point.

This phenomenon is considered attributable to the increasing flow resistance resulting from the gradual shift mainly to the movement of water from tiny capillaries.

B → C: Under this process, the resistance of moisture moving from the internal clearance, onto the surface of the paper layer, becomes gradually stronger and the evaporotation rate becomes gradually lower following the decrease of moisture. Various factors of the resistance are conceivable. However, the size distribution of capillaries affected by the beaten condition of fiber should be estimated as a most important factor.

C → D: The "C" point represents a turning point indicating the initiation of exaporation of moisture absorbed in microcapillaries or fibers. The evaporation rate is lower in the C → D. It is said that the quantity of moisture absorbed into the fiber should have to do with the content of hemicelulose and the degree of beating.

D → E: At the "D" point, moisture hydrated into the fiber begins to evaporate. In this process, the resistance is higher. The hydrated moisture is restrained by cellulose or hemicellulose particles, or is absorbed in them as a particle layer.

(3) Conditions controlling the drying speed of paper

It is considered that the mechanism of moisture evaporation from wet paper and the process of evaporation in dryer should already be well understood. Yet, important in the actual operation is uniform drying in the width direction. The essential points of drying are that the sheet formation should be uniform in thickness and density and the wet paper be free from admixtures such as shives and foreign matter. General conditions controlling the drying speed are described below.

The three controlling elements are as follows:

A) Surfacial temperature of dryer

B) Character and velocity of air contacting the surface of paper

C) Heat transfer resistance (contact resistance) on the contact surface between the surface of dryer and paper

With regard to Item A) if the discharge of condensate is normal, it would not be a cause for uneven drying. However, cases where a siphon is missing inside the cylinder, causing uneven drying were often experienced. As regards Item B) the air between paper and the cylinder is often a problem. Explanation is made of the relationship between air conditions and drying speed in Figure 6-8.

Figure 6-8 shows the state of air contacting the wet paper. The essential point is how rapidly heat required for the evaporation of moisture in the wet paper should be supplied to the wet paper. And there is a principle that heat transfer speed between two points is proportional to the temperature difference between the two points. Accordingly. in order to quicken the heat transfer speed, the difference between the cylinder's surfacial temperature and the wet paper's temperature must be large. In order to obtain such a difference, a) the surfacial temperature T of the cylinder shall be increased or b) the temperature t of wet paper shall be decreased.

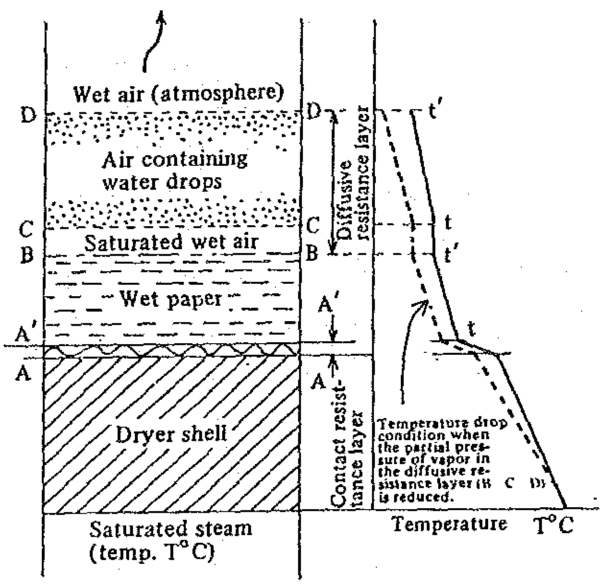


Figure 6–8 The Relationship between Air Conditions and Drying Speed

a. In order to maintain the cylinder at high surfacial temperatures, the steam adjusting valve has only to be opened. However, the problem is the decrease in temperature of wet paper and its effect. The moisture is vaporized by the heat of vaporization and then is released into the atmosphere from the surface of wet paper through the saturated wet air layer B-C (layer saturated with vapor evaporated from wet paper at high temp.) and the layer of saturated wet air containing water drops C-D (layer of water drops condensed from part of the vapor at lower temperatures than the B-C layer). However, the lower the partial pressure of vapor in the C-D layer, the more extensively the vapor of the B-C layer is diffused. Consequently, the evaporation rate of vapor from the wet paper increases and, as a result, the wet paper loses its heat of vaporization and is at low temperature levels. Consequently, the temperature difference between the wet paper and steam becomes large, increasing the heat transfer rate. Thus, the environmental conditions around the wet paper (temperature, humidity, and wind velocity) are an important factors for affecting the drying speed and for the evenness in drying in the width drection.

Next, as regards Item C), if each factor of heat transfer resistance in the contact surface between the dryer's surface and paper is normal, the possibilities that the drying speed might be uneven are small.

a) Film resistance on the internal surface of the cylinder
b) Resistance of cylinder wall
c) Air film resistance between the cylinder surface and paper
d) Resistance of the paper layer itself

With regard to the above, the item to which attention must be given is c), because of the uncartainty and sensitive beyond expectation.

For the elimination of wrinkles and air held, the leading dryer is sometimes installed. Figuree 6-9 shows its operating procedures. The leading dryer is slightly smaller in diameter than the dryer cylinder and heated at approx. 50°C.

As described above, it is essential to check, maintain, service and improve equipment, auxiliary machines, and tools in accordance with the drying function of the dryer part and operate them satisfactorily to meet the circumstances.

Regarding the routine operation, attention needs to be given to simple work, namely, a) maintenance and check of the doctor, and removal of refuse to keep the cylinder's surface always clean, b) removal of clogging and humidity in the canvas, and c) prevention of the flow of cold and wet air to the dryer.

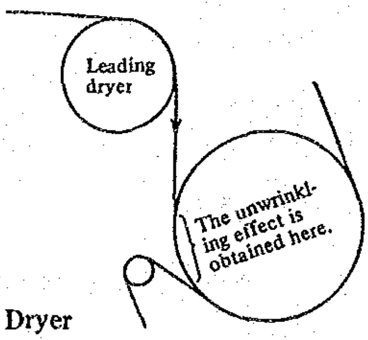
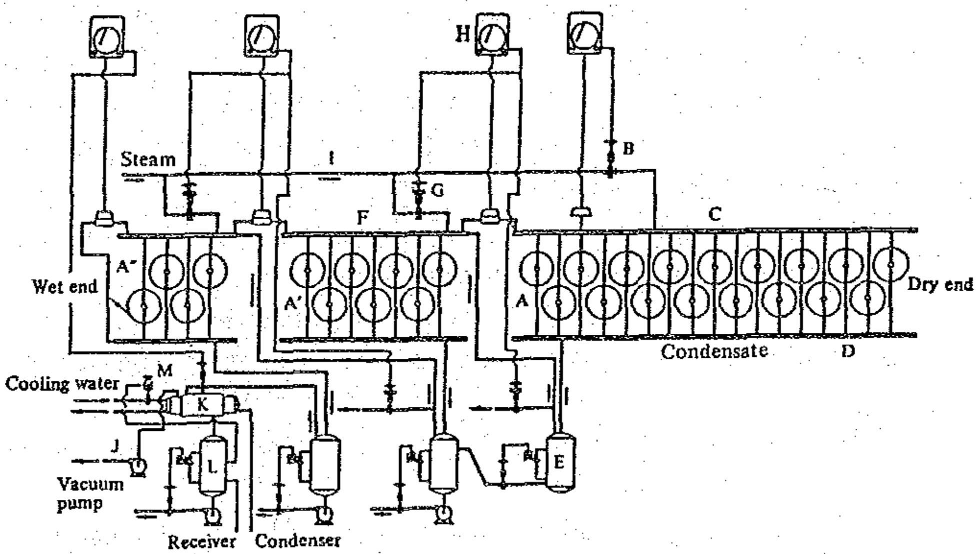


Figure 6–9 Leading Dryer

(4) Steam supply and exhaust system

In the case of paper drying, it is necessary to consider the qualitative problem according to the kind of paper. However, it is generally required that the surfacial temperature of the dryer is gradually increased from the wet and to the dry end. This requirement agrees with a condition that the drying resistance increases in accordance with a decreases in the moisture of paper and, at the same time, the heat transfer rate of the cylinder decreases. Accordingly, the dryer part should be divided into 2 to 3 dryer groups to change the steam pressure. In other words, it should be arranged so that steam consumption can be increased for the dryer groups of the dry end, and steam consumption can be decreased for the dryer groups of the wet end.

As the standard for the grouping of cylinders, the ratio of the number of cylinders should be 1:2:4 from the wet end, for instance, in the case of 3 groups. Figure 6-10 shows the typical drainage system of 3 groups called "blow through systems."



A : First group dryer (A': second group dryer, A": third group dryer)

B : First group control valve

C : First group steam header

D : First group condensate header

E : First group condensate receiver tank

F : Second group steam header

G : Second group control valve

H : First group and second group differential pressure controller

I : Main steam pipe

J : Non-condensive gas ejection vacuum pump

K : Condenser

L : Receiver tank

M : Cooling water control valve

Figure 6–10 Typical Third Group Drainage System (Blow Through System)

(Explanation of Figure 6-10)

Steam flowing into the header (C) for the first dryer groups (A) from the control valve (B), enters the drain header (D) as drain and then the receiver tank (E). In this receiver tank where the pressure is lower than A), the steam is revaporized, resulting in the separation of steam from drain. This revaporized steam enters the steam header (F) of the following intermediate dryer section (A'). Between the steam headers of (A) and (A'), the control valve (G) and the controller (H) are provided for keeping constant differential pressure. This differential pressure is set so that the condensate flow for (A) can be in the most ideal state. However, if the differential pressure is higher than the set value, the control valve (G) will be opened, causing the steam to flow from the main steam pipe (I) to the steam header (F) of (A') until the differential pressure reaches the fixed pressure level.

In case the sum of the revaporized steam volume and the siphon's blow-through steam volume is larger than the steam consumption of the following dryer group, the steam should be partially released into the atmosphere. Otherwise the differential pressure cannot be controlled, and subsequently, the system will be further complicated. For this reason, it is also necessary to make negative the pressure of the drain header for the final stage's wet end dryer section (A'').

At the same time, a vacuum pump (J) is provided for the purpose of ejecting non-condensive gas forcibly. In normal cases, a condenser (K) is also installed along with the vacuum pump for assisting the latter. The cooling water volume for the dondenser is adjusted by means of a control valve (M) according to the temperature of the receiver tank (L).

Each receiver tank is equipped with a level controller so that the liquid level can always be kept at a constant level.

The drain is collected into the collection tank and returned to the boiler.

Table 6–7 Flash Tank Capacity Index

Diameter (mm)	Diameter (inch)	Maximum drain volume (kg/hr)
150	6	900
200	8	2,250
300	12	4,500
380	15	9,000
460	18	13,000
500	20	16,000
600	24	20,000
760	30	34,000
920	36	50,000

Table 6–8 Flash Tank Height Index

Diameter (mm)	(inch)	Height (mm)
150	6	940
200	8	940
300	12	1,000
380	15	1,100
400	18	1,200
500	20	1,400
600	24	1,400
760	30	1,400
920	36	1,500

(5) Supply and exhaust of air in the dryer part

If the best dried and high-temperature air is supplied into the surroundings of the dryer cylinder, and the high-humidity exhaust is rapidly ejected into the atmosphere, the drying efficiency will be improved.

The air discharged from the dryer part is at high humidity and, at the same time, is at high temperatures (60 to 80°C). Therefore, if the heat is recovered in some way, the heat balance will be improved.

In order to achieve the above mentioned purposes, the hood covering the dryer cylinder group plays an important role.

A) Dryer hood

In the ordinary paper machine, approx. 2 tons of moisture are evaporated for drying one ton of paper. For ejecting this vapor, 50 to 60 tons of air are required. Therefore, from the structural point of view, the following design considerations must be given to the construction of the dryer hood.

a. The width of the hood and the height of the side wall should have sufficient dimensions for capturing wet air. In the case of the open hood, it is necessary that the height of the side wall is at least 2 m and the location is almost at 30 to 35° against the internal surface of the sole plate as the distance from the machine frame (refer to Figure 6-11). This must be done from the operational point of view and to sufficiently treat the blowout of vapor from the dryer pocket or the expansion of an ascending air current passing on the internal surface of the sole plate.

The upper inclination is designed to prevent the dropping of condensed water in the interior. The upper space capacity should also be large enough.

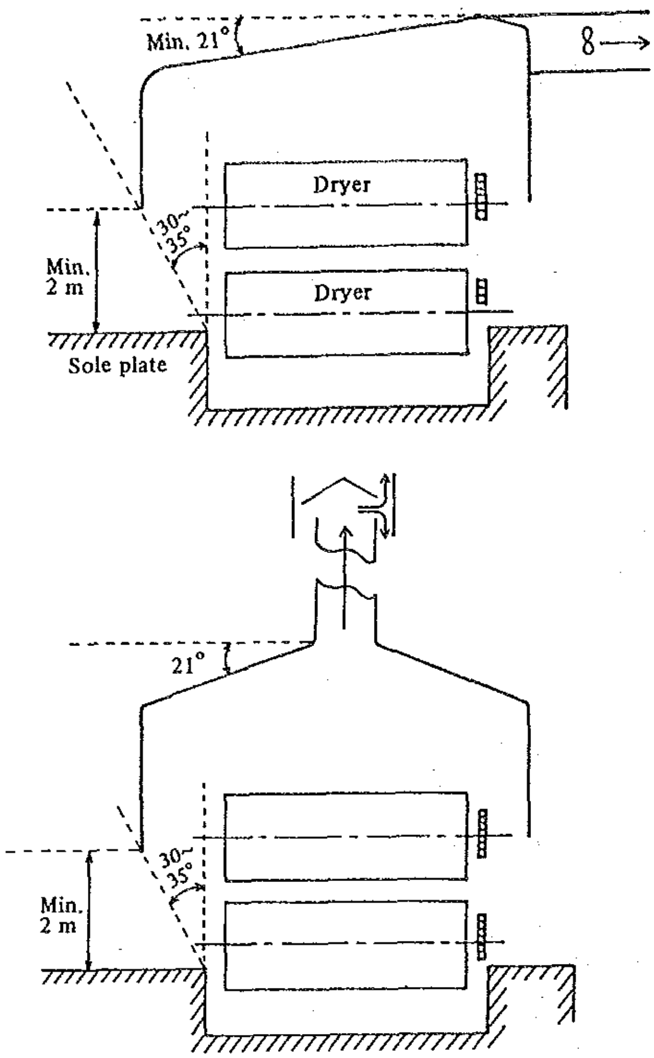


Figure 6–11 Design of Open Hood

b. The location, size and shape of the exhaust port should be provided so that they can fully eject wet air without fail. At the same time, the exhaust port should not make deflected air current which would be the cause for uneven drying in the paper width direction.

In case the exhaust port is directly mounted to the hood ceiling, it should be provided at the portion equivalent to 3/4 of the wet end of the dryer part. This is because most of the vapor is generated in the so-called constant rate drying zone where the paper moisture is kept at about 15%.

c. The dryer hood should have such a structure that it does not disturb paper feed operation.

d. The hood should also be so designed as it allows easy access to the operator for the maintenance, repair and cleaning of the dryer.

e. Material for the hood should be water-proof, fire-resistant, and anti-corrosive.

f. The hood ceiling should be strong enough for the passage of the operator.

In the conventional paper machine, a roof-shaped hood was provided on the group of dryer cylinders and the hood was equipped with 3 to 4 pieces of large exhaust ducts for exhaust by natural ventilation.

For developing the high-speed paper machine of high productivity the drying performance was reevaluated. And the machine was improved by the rocedures such as the adoption of forced exhaust, introduction of hot blast supply equipment, complete sealing of hood and building-in of waste heat recycling device. In case of the totally sealed hood, it is possible to make a theoretical design and to calculate the heat balance easily. However, in case of the open-type hood, it is possible to sequentially modify and improve it to meet the production requirements in the actual operation.

The relationship between the dryer's steam evaporation amount and the exhaust amount is expressed by the following equations.

$$E = P \times \frac{\omega_1 \leftrightarrow \omega_2}{100 - \omega_1}$$

$$G = \frac{E}{x_2 - x_1}$$

E: Evaporation amount kg/h

P: Paper feed amount kg/h

ω_1: Moisture at inlet

ω_2: Moisture at outlet

G: Air exhaust amount kg/h

x_2: Absolute humidity against dew point at the hood output kg/kg

x_1: Absolute humidity of fresh air to be supplied to the hood kg/kg

x_1 changes according to season and location and x_2 can be changed by operation. the higher the value of x_2, the less the value of G. Namely, the maintenance of the dew point of exhaust at high level contributes toward the decreasing the unit steam consumption rate. Therefore, it is important to study various factors involved in such a contribution and work out plans carefully to deal with these factors.

It is reasonable and effective to hang a transparent film curtain from the side wall end of the open-type hood. The measure will also improve the operating environment.

The air volume normally required per 1 ton of paper is as follows:

- Hoodless paper machine 75 – 80 tons
- Paper machine with open-type hood 50 – 60 tons
- Paper machine with closed-type hood 25 – 30 tons

If the hood device is improved, less air consumption is required, and subsequently, the unit steam consumption rate is reduced. Figure 6-12 shows the difference between the open-type hood and the closed-type hood.

When the dryer is at a marginal capacity, an approx. 20% increase of the capacity is expected, if the closed-type hood is adopted.

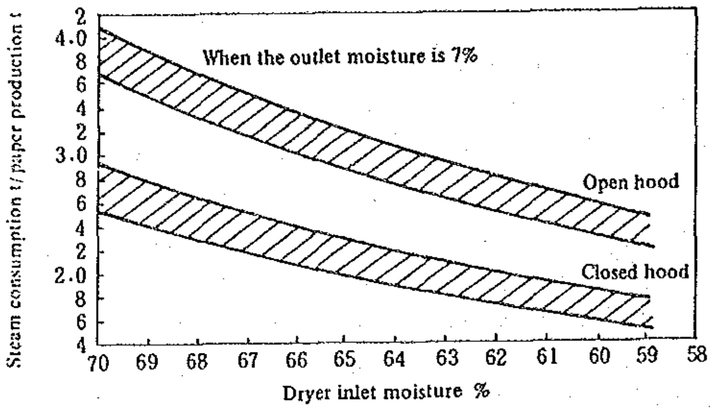


Figure 6–12 Unit Steam Consumption Rate for Open Hood and Closed Hood

B) Improvement of dryer ventilation

In the case of the closed hood, it is suggested that the ventilation system be built into the paper machine with the dryer. Otherwise, the drying effect would be reduced. The well-balanced air supply and exhaust, and appropriate temperature will be contributing factors toward the effective consumption of thermal and electric energies and the stabilization of paper quality.

Water vaporized from the dryer part is released as an exhaust of high dew point. It is suggested that air or water at high temperature be obtained by heat exchange in the process of the said release, and that hot air be used as an air supply to the dryer and hot water for blanket washing and pulp washing process.

The dryer ventilation system is a system where high-efficiency vaporization and waste heat recycling are carried out by means of ventilation control. One example of this system is shown in Figure 6-13. The waste heat recycling flow and the ventilation control system are shown in Figure 6-14.

The pocket ventilation system is effective for equalizing moisture distribution across the entire width of wet paper and thus economizing steam consumption. In addition, this system prevents overdrying at both ends of the paper and also prevents paper break. Therefore, its effects are remarkable. In case of the open hood, the stagnation of vapor is a problem remaining to be solved. The devices such as PV roll and Grevin nozzle incorporated in the canvas roll are also available. In some cases, air is injected into a part where vapor is stagnant.

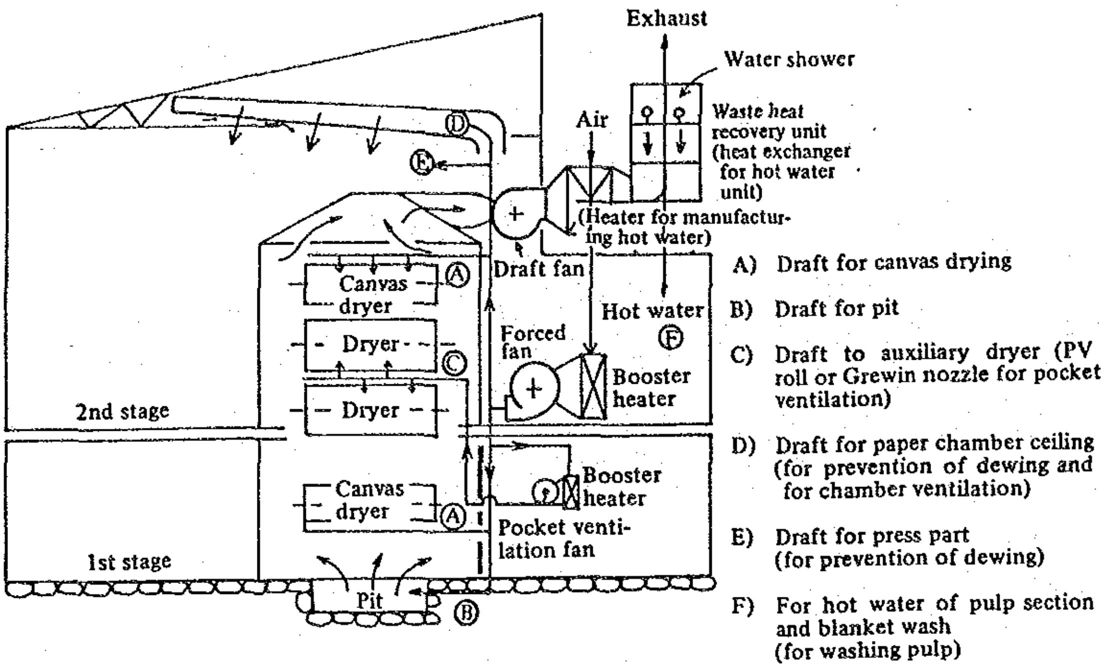


Figure 6–13 An Example of "Closed Hood Ventilation System"

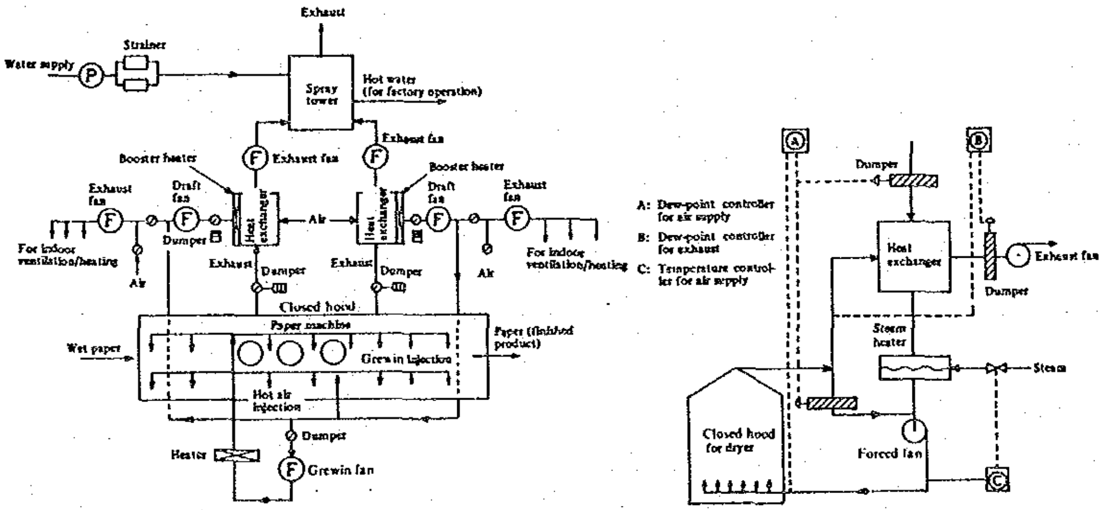


Figure 6–14

Waste Heat Recovery Flow for Closed Hood Ventilation System and Control System

7. Leather

7. Leather

7.1 Characteristics of the Use of Energy

7.1.1 Manufacturing Process

Typical examples of chrome tanning are shown as Figure 7-1.

Hide & Skin
↓
① Soaking
↓
② Fleshing
↓
③ Liming & Unhairing
↓
④ Splitting
↓
⑤ Scudding
↓
⑥ Reliming
↓
⑦ Deliming, Bating
↓
⑧ Pickling
↓
⑨ Chrome tanning
↓
⑩ Squeezing
↓
⑪ Shaving
↓
⑫ Rechrome tanning
↓
⑬ Neutralization
↓
⑭ Dyeing & Oiling
↓
⑮ Squeezing & Setting
↓
⑯ Drying
↓
⑰ Conditioning
↓
⑱ Staking
↓
⑲ Toggling & tacking
↓
⑳ Trimming
↓
㉑ Buffing
↓
㉒ Seasoning & Spraying
↓
㉓ Glazing & press
↓
㉔ Measuring
↓
㉕ Leather product

Figure 7–1 Production Process

Hide and skin

Generally, hide and skin are distinguished one from the other as follows: That which is thick, large, and heavy is called hide; that which is thin, small, and light in weight, such as that of calf and sheep, is called skin.

(1) Soaking

Soaking is an important process of removing blood, filth, etc. from hide/skin, and adding water to it to be close to raw hide/skin to ensure satisfactory chemical treatment later.

(Example of operation)

One hour of soaking in 300% water at 20°C; 30 minutes of drum rotation; one hour of soaking; 15 minutes of drum rotation; 20 minutes of washing with water; discharging water.

Adding 300%, 20°C water and 0.1% surface active agent for soaking, drum is run for 15 minutes; then drum is driven for 10 minutes at 90-minute intervals for a total of 18 hours of soaking, followed by 20 minutes of washing with water.

(2) Fleshing

Flesh and fat on the flesh (inner) side of hide/skin are removed using a fleshing machine.

(3) Liming and unhairing

Hide/skin is immersed in limemilk to make it swell withe the alkali, loosen its collagen fibers, and also decompose and remove hair, fat, and epidermis. This process helps make hide/skin soft as it originally is.

(Example of operation)

Adding 300% water (25°) and 0.2% surface active agent for degreasing, drum is driven for 10 minutes. Adding 1.5% sodium sulfide, drum is driven for 20 minutes. Adding 1.5% sodium hydroxide and 1.5% calcium hydroxide, drum is driven for 20 minutes, then leaving it still for 60 minutes. Adding 2.5% calcium hydroxide, drum is driven for 20 minutes, followed by 10-minute operation of drum at 1-hour intervals for a total of 4 hours, again followed by 10-minute operation of drum at 90-minute intervals till the next morning.

(4) Splitting

Hide/skin is split into two layers of the specified thickness using splitting, band-knife machines: Grain (right) side and flesh (back) side.

(5) Scudding

Hair roots not removed in the liming and unhairing process are removed here to make the grain side clean. A scudding machine or fleshing knife is used to remove them.

(6) Reliming

Hide/skin is soaked in limemilk again to loosen the collagen fibers by alkaline action. This is an indispensable process for soft hide/skin and something like suede.

(7) Deliming, bating

The lime that remains on hide/skin after the liming and unhairing process and the reliming process is removed here. This neutralizes the limed hide/skin and facilitates penetration of the tanning agent in the tanning process.

Bating decomposes and removes the unnecessary proteins using protein decomposing enzyme, and thus makes the grain smooth.

(Example of operation)

20 minutes of washing with water. Adding 300% water (35°C) and 0.5% ammonium chloride, drum is driven for 15 minutes. Adding bating agent and 0.5% ammonium chloride, drum is driven for 20 minutes.

(8) Pickling

The chemicals used for tanning will be dissolved only in acids. So hide/skin is immersed in an acid solution before the tanning process to make it easy to absorb the tanning agent.

(9) Chrome tanning

Trivalent chrome tanning agent is absorbed by hide/skin to be coupled to collagen fibers, thus making hide/skin heat-resistant and durable.

(Example of operation)

Pickling

Adding 90% water (18°C) and 7% sodium chloride, drum is driven for 10 minutes. Adding 1.25% sulfuric acid (diluted 1 to 10), drum is driven for 2 hours. Immersed overnight in a pickling bath. Drum is driven for 10 minutes next morning, then the bath is emptied.

Chrome tanning

Adding 50% water (30°C) and 1.5% sodium chloride, drum is driven for 5 minutes. Adding a chrome solution, drum is driven for 2 hours. 1.35% sodium bicarbonate (dissolved 1 to 10) is added in 2 hours and 30 minutes, followed by operation of drum for 3.5 hours.

(10) Squeezing

Hide/skin is squeezed to remove excess water using a squeezing machine.

(11) Shaving

Hide/skin is shaved on the flesh side to even thickness using a shaving machine.

(12) Rechrome tanning

Chrome tanning alone is not enough to produce leather most suited to various uses. Hide/skin is given qualities suited to specific uses by this process that uses a synthetic tanning agent or a natural vegetable tanning agent.

(Example of operation)

Washing with water:	300% water (30°C). Drum is driven for 10 minutes, then water is drained.
Washing with water:	300% water (30°C). Drum is driven for 10 minutes, then water is drained.
Rechrome tanning:	Adding 8% retanning agent and 1.5% sodium bicarbonate, drum is driven for 60 minutes.
	100% warm water (40°C). Drum is driven for 20 minutes, then water is drained.
Washing with water:	300% warm water (50°C). Drum is driven for 10 minutes, then water is drained.

(13) Neutralization

The acids in hide/skin are neutralized by alkalis so that dyestuffs and oiling agents will be uniformly absorbed by hide/skin.

(Example of operation)

Adding 300% water (20°C) and 0.4% calcium formate, drum is driven for 20 minutes. Further adding 0.5% sodium bicarbonate, drum is driven for 10 minutes. Washing with water for 10 minutes.

(14) Dyeing and oiling

Leather is dyed to desired colors using dyestuffs. Dyestuffs are requested to have necessary characteristics such as color, solubility, and dyeing properties.

Generally, acid and direct dyestuffs are anionic and their acidity ranges from medium to low. They are good for dyeing leather.

Leather is oiled using refined raw oils or synthetic oils to give softness, fullness, and other characteristics.

(Example of operation)

Adding 400% water (50°C) and dyestuff, drum is driven for 30 minutes. Adding fat-liquoring agents, drum is driven for 40 minutes, followed by 5 minutes of washing with water.

(15) Squeezing and setting

After dyeing and oiling, leather generally has a water content of 70%. Before drying leather, water is removed from it using a squeezing machine. Leather is passed through the two rolls of the squeezing machine, which have tubes of thick felt attached to them to absorb and discharge the water squeezed out.

(16) Drying

Leather is dried to fix the dyestuffs and oiling agents in it. Natural drying or artificial drying with hot air, hot plate, etc. is used. This is an important process which directly affects the feel of leather.

(17) Conditioning

Leather is given an appropriate amount of moisture to make it less stiff.

(18) Staking

Leather is flexed to make it soft and elastic using a staking machine.

(19) Toggling and tacking

Leather is tacked to a board with nails or to a screen board with toggles to let it dry in a flat state.

(20) Trimming

Leather is trimmed to remove unnecessary edges before finishing it.

(21) Buffing

To process leather into suede, it is buffed using a buffing machine.

(22) Seasoning and spraying

Paint is sprayed to the grain side of leather to emphasize appearance in color and gloss, and to make it more durable.

(23) Glazing and press

The leather surface is glazed by a machine, or is ironed. If necessary, leather is pressed or flexed.

(24) Measuring

Leather is measured to determine its area using a measuring machine. Leather area is expressed in either ds (square decimeters: dm^2) or sf (square feet: approximately 9.3 decimeters).

7.1.2 Use of Energy

(1) Heat shrinkage temperature

Leather factories use low temperatures. Because leather quality responds sensitively to temperature, special care must be exercised in maintaining set temperatures.

It is necessary to exercise caution not to exceed heat shrinkage temperature in the production process, even in a part of it. (Heat shrinkage temperature means the temperature at which hide/skin or leather begins to shrink when heated in water. It serves as a reference in determining leather heat resistance and the degree of tanning. Heat shrinkage temperature varies depending on the kind of leather and the degree of tanning.)

(2) Collagen decomposition by liming temperature

Liming temperature of up to 30°C will increase dehairing without seriously damaging collagens. At over 35°C, however, the collagens will be decomposed so much that they will be liquefied overnight, and hide/skin no longer appears as such. Proteins account for 90% to 95% of the solids of hide/skin, and collagens are their main constituent. Cow hide, for example, has collagens that account for about 80% of its proteins.

(3) Tanning

Generally, chemical reaction rapidly proceeds with rising temperature. This is also true of tanning. Chrome tanning, however, is subject to a large extent to physical conditions apart from chemical reaction. Therefore, the size of the reaction vessel (drum) and the weight of hide/skin in the drum are important factors that influence chrome tanning.

Generally, the bath temperature is raised about 10°C to 20°C by the rotation of the drum until the drum stops. Special care must be exercised about temperature control, particularly in the initial phase of tanning, because leather quality can be adversely affected.

(4) Drum rotation

The drum is widely used for soaking, washing with water, liming, deliming, bating, pickling, chrome tanning, neutralization, dyeing, oiling, etc. in leather factories.

Gear, V-belt, or flat belt is used to transmit motor power to the drum. Gear has a high efficiency of power transmission and does not take much space, but makes noise and requires an accurate mechanism. V-belt is a good means of power transmission without noise, but should be kept running at least at 2 meters/second. If belt speed goes down, the tension increases to result in a shorter belt life. Therefore, V-belt is suited to a drum operating at high peripheral speed. Flat belt has advantages that it makes little noise, does not require to fix the distance between the drum and motor, and is easy to adjust. However, flat belt tends to slip and does not transmit power so well.

(5) Dyeing speed

It can be said from comparison of leather with woven fabric that leather has ramifying collagen fibers, and a porous structure with a relatively large surface area. Thus, leather can be dyed in a far shorter time than woven fabric if the fibers are in a loose, separate state. Leather does not need high temperature for dyeing.

As dyeing temperature increases, the dyestuff is absorbed faster and dyeing tends to be uneven and superficial. At low temperature, however, dye fastness decreases.

(6) Drying temperature, feeling, conditioning

Leather that is dyed, oiled, squeezed, and set has a water content of 50% to 60%. It is dried to a final water content of about 17% to 20%.

By drying leather, the tanning agent, dyestuffs, oiling agents, etc. are fixed in the leather. This is an important process for not only energy conservation but also quality because the softness, fullness, and other quality characteristics of leather depend on it.

There are various drying methods. Generally, two or more methods are combined to dry leather in many cases. For example, vacuum drying may be followed by hang drying.

(a) Hand drying

For hang drying, a drying room that can be adjusted to a suitable temperature, humidity, and air flow is used. Hot air is used as a heat source. Mainly, air is indirectly heated by the latent heat of steam.

Leather is hang-dried normally at 35°C to 50°C, but higher temperature is used if leather is required to have a better grain and elasticity. On the other hand, low temperature drying is suited to producing leather soft but less elastic. High drying temperature requires great care because it may deteriorate the physical properties of leather, such as hardening, degradation, less yield in terms of area, and grain embrittlement.

(b) Drying on glass plate

After squeezing, leather is tacked to a glass plate or an enameled iron plate to dry it.

Hot air is used as a heat source. Air is indirectly heated by the latent heat of steam, or directly heated by electricity. Drying temperature ranges from 40°C to 60°C.

(c) Vacuum drying

Water has a boiling point of 100°C under normal atmospheric pressure, but easily vaporizes in a vacuum. Vacuum drying is based on this fact.

Leather is set on a smooth metal board, and is covered with a head. The space between the cover and metal board is sealed airtight with rubber, and the press load on the leather and inner pressure can be adjusted. The hot plate temperature ranges from 70°C to 90°C, and drying time is 2 to 3 minutes.

(d) Hot plate drying

Leather is set on the surface of the hot plate to dry it. The hot plate has a tank filled with hot water that is directly or indirectly heated by steam to keep tank at constant temperature. Working temperature ranges from 70°C to 90°C.

(e) Other types of drying and heat using points

Other drying methods include one by which hide/skin is tacked to a net board to dry it in the form of a dry sheet, and another that dries leather after spraying. Generally, hot air is used for drying.

Conditioning is intended to adjust dried leather to a state of uniform moisture. One conditioning method is to hold dried leather in sawdust containing about 35% moisture, and another is to immerse dried leather in hot water of 40°C to 60°C for a short time.

Conditioned leather is softened by a staking machine, and then dried on a net to prevent the leather from shrinking.

7.2 Rationalization of the Use of Heat Energy

7.2.1 Producing Hot Water

Leather factories consume a large quantity of hot water. Many of the factories that use steam to heat water blow steam directly into the hot water tank. This method produces much loss of steam because, when water temperature rises above about 60°C, steam runs away from the water surface without full condensation.

Energy can be saved by indirect heating and recovering the condensate from steam traps to the hot water tank.

7.2.2 Squeezing Before Drying

It is better to remove as much water from leather as possible by squeezing before drying because a heat energy of 539 kcal is needed to remove 1 kg of water by vaporization. However, the results of organoleptic tests on leather show that leather deteriorates in the feeling, grain condition, fullness, etc., becomes more flat, and hardens as the degree of water removal by squeezing is raised. This is especially true if leather is squeezed to a water content of less than 50%. Therefore, squeezing is limited to a water content of 50%. This is shown in the results of the test conducted by Sugita, Oda et al. Table 7-1 shows the test results.

In addition, there are other effects of squeezing leather as shown below.

(1) Leather will be more resistant to shrinkage by drying, and increase in area.

(2) Leather thickness will decrease.

(3) The tensile strength, tear strength, and other mechanical strength of leather will increase.

As described above, squeezing before drying involves not only energy conservation but also the matter of quality and product yield.

Table 7–1 Apparent Quality of Leathers

Degree of dehydration	Tightness	Fullness	Surface of grain	Softness
	Total	Total	Total	Total
70%	3 3 5 3 14	5 5 5 5 20	3 5 5 3 16	5 5 5 5 20
60%	3 3 5 3 14	5 5 5 5 20	3 3 5 5 16	5 5 3 5 18
55%	3 3 3 3 12	5 5 3 3 16	3 3 3 5 14	3 3 5 5 16
50%	1 1 3 3 8	3 1 1 3 8	1 3 3 1 8	1 1 3 1 6
45%	1 1 1 3 6	1 1 1 1 4	1 1 1 1 4	1 1 1 1 4

1 : bad, 3 : good, 5 : excellent

∴ Degree of dehydration is shown as the moisture content of leather after samming.

7.2.3 Drying

(1) Hang drying

Generallv. a drying room where temperature, humidity, and air flow can be adjusted is used for hang drying. Attention must be paid to the following for energy conservation.

(a) Hot air flow and leather moving direction must be counter to each other.

(b) Adjust the air flow rate and velocity to increase the difference in relative humidity between incoming air and outgoing air.

(c) Take care not to let hot air flow unevenly.

(2) Vacuum drying

(a) Provided that the degree of vacuum is the same, water vaporizes faster as hot plate temperature and as press load increase and as leather thickness and inner pressure decreases.

The final water content of leather decreases as drying temperature and pressure on leather increase.

(b) Area shrinkage increases as hot plate temperature increases and as load decreases.

(c) Partial overheat will not occur while leather retains sufficient moisture in it, but caution must be exercised because quality will lower due to partial overheat when the water content of leather decreases to less than 20%.

(d) A skirt should be mounted around the hot plate to prevent heat dissipation loss from the lower exposed part of the hot plate.

(3) Dry thermic plate

(a) Pay attention to water level in the hot plate so that there will be no uniformity of temperature. Be careful not to raise water level so much as to cause hot water to overflow, or to lower water level excessively.

(b) The hot plate comes in two types: vertical and horizontal. The vertical type can be used on both sides, while the horizontal can be used only on one side. This means that the unused side of the horizontal type hot plate must be heat-insulated.

(4) Glass drying

(a) Use hot air not for one pass only, but by recirculation.

(b) The temperature and humidity of hot air for drying should be adjustable at the air inlet and outlet of the heater.

7.2.4 Overdrying

If leather is overdried, it will become less fullness and softness and easily crack in the grain. Particularly, in the case of vacuum drying, leather quality will be seriously affected if water content decreases to less than 20%. It also means evaporation of water more than necessary, and thus fuel loss. An example of how the weight and water content of cow leather change in the process of producing chrome tanned leather are shown in Table 7-2.

Table 7–2 Example of Changes in Weight and Moisture in the Process of Producing Chrome Leather from Cow Hide

Process	Weight kg	Moisture %	Anhydride	
			kg	%
Raw hide	1,000.0	37.4	626.0	100.0
Chrome tanning	702.4	66.4	236.0	37.7
Drying	265.8	20.4	211.6	33.8
Toggling	256.2	18.9	207.8	33.2
Product	245.0	19.2	198.0	31.6

The relationship between atmospheric humidity and equilibrium moisture is shown in Figure 7-2. As shown, chrome-tanned calf skin contains about 18% moisture as measured 32 days after keeping it at a relative humidity of 60% and an ambient temperature of 25°C. If relative humidity is kept at 40%, the same calf skin has a water content of 16%.

Thus, if leather is left under ambient conditions of 40% to 60% in relative humidity and 25°C in temperature, its water content will be about 17%, so drying the leather beyond that point will result in waste.

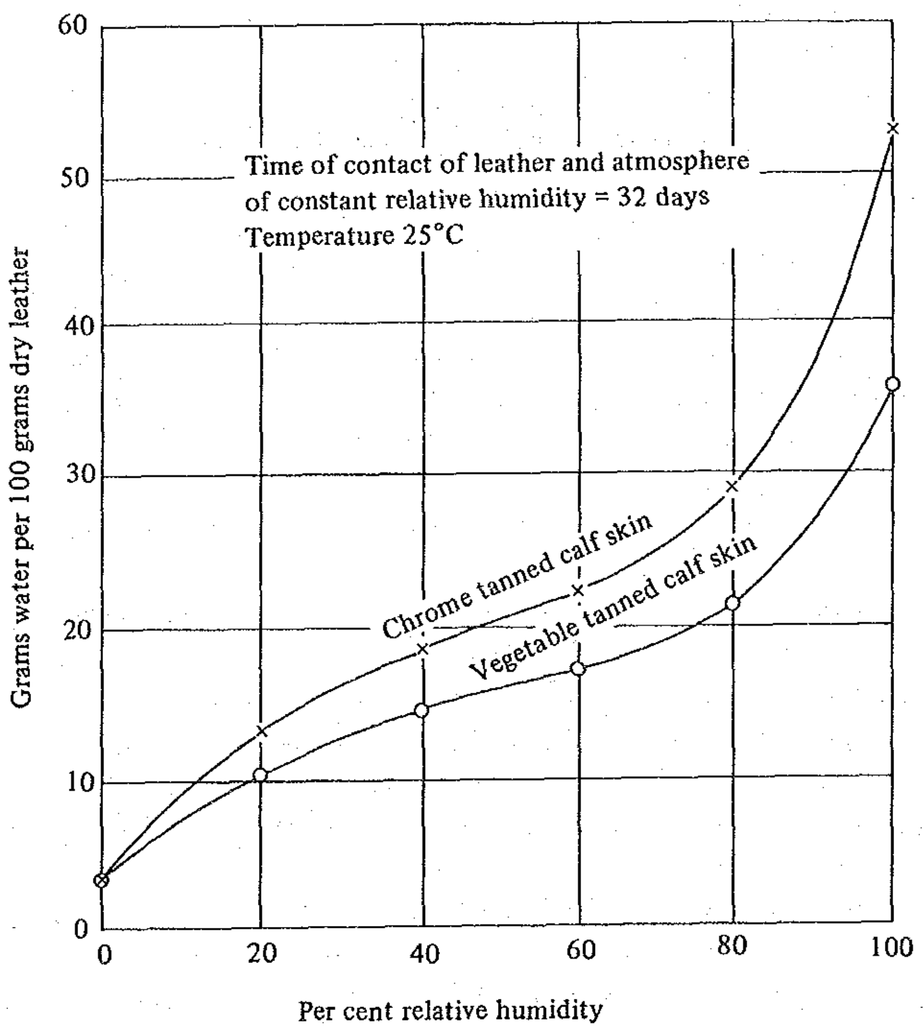


Figure 7–2 Showing Effect of the Relative Humidity of the Air upon the Water Content of Chrome and vegetable-Tanned Calf Leathers.

Managing the drying process to prevent overdrying is important for both energy conservation and quality control.

7.2.5 New Drying Techniques

Generally, quick drying in a short time will adversely affect the feeling of leather, it has been said. Perhaps because of it, the drying process has been left behind in technological innovations. As the processes before and after the drying process in painting have become automated in recent years, it has come to be necessary to apply rapid drying techniques in order to perform highly efficient, integrated continuous operations.

(1) Microwave drying

As can be seen from the wide spread use of microwave ovens, microwave energy has come to be increasingly used as heating energy also for industrial purposes.

Microwave heating is based on the theory that the water molecules of a drying object (insulator) vibrate and rotate to generate heat when exposed to microwaves of 300 MHz to 30 GHz, so that the drying object rises in temperature and evaporates water.

Temperature distribution is such that the inner layer is rather hotter than the surface, making water dissipation easy from inside. Microwaves are absorbed largely in parts containing water so that leather can be uniformly dried in a short time. Microwave drying is already used in some leather factories as a promising leather drying method.

The results of a microwave drying test conducted by Oda, Sugita, et al are summarized as follows:

(a) Although the drying conditions of microwave drying were more severe than those of natural drying, it did not adversely affect the mechanical properties of leather in particular, and area shrinkage was smaller than in the case of natural drying.

(b) Microwave drying, it is said, makes leather soft because it internally heats it, but the staking process cannot be omitted. It may be possible, however, to omit the conditioning process.

(2) Far infrared ray drying

Generally, paint and other high-molecular compounds well absorb far infrared rays (wavelength: 1 μm to 1 mm).

If far infrared rays are used for paint drying, the paint coat is quickly and uniformly heated by selective absorption of radiation energy. This offers such advantages as shortening of the process, energy conservation, and paint coat quality improvement.

According to the results of the test conducted by Oda, Sugita, et al, ill effects on the physical properties of leather were not observed in the test which involved hang drying, staking, and far infrared ray net drying but omitted the conditioning process.

(3) New system in using new techniques

Because omission of the conditioning process does not make difference in the physical properties of leather as mentioned above, a continuous drying system which combines hang drying with a microwave dryer, vibration staking machine, and far infrared ray net drier is considered as a possible effective means of shortening and integrating the drying processes, energy conservation, and labor saving.

7.2.6 Water Saving

Leather factories around the world are trying to save water. In a typical chrome leather factory, the quantity of water discharge per kilogram of wet salted hide is 60 liters, of which 24 liters is discharged from the wetting process and the remaining 36 liters from the washing and other processes. To reduce water consumption, the possibility of saving water in the washing process, omission or combination of processes, improvement of machines for the wetting process have been taken up as problems, and some practical means for the above purposes have been developed.

(1) Comparison of water consumption between running-water washing and batch washing

If running-water washing consumes 100, batch washing consumes only 25.

(2) Comparison of water consumption in the wetting process by machine

If the drum which has been used in the wetting process is replaced with a hydroprocessor, water consumption can be sharply reduced.

An example of hydroprocess is shown in Figure 7-3.

A report (by Kubo) says that water consumption decreased from 19.6 liters per kilogram of wet salted hide to 8.4 liters because of replacement of the drum with a hydroprocessor.

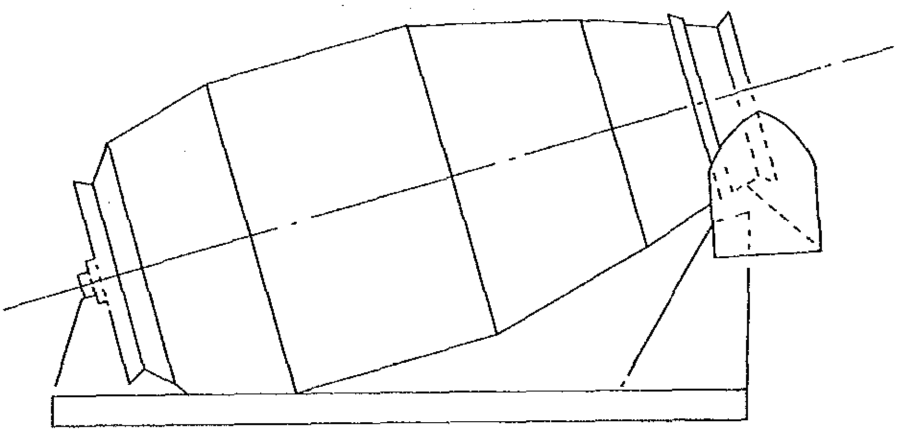


Figure 7–3 Hide Processor

(3) Combining/omitting processes

1) Combining soaking and unhairing/liming
2) Combining pickling and chrome tanning
3) Combining neutralization and oiling
4) Omitting washing after soaking
5) Omitting washing after neutralization
6) Omitting washing after dyeing and oiling

(4) Others

Because waste water in leather production differs in constituents from one process to another, it would be inappropriate to gather waste water from the different processes and reuse it after general treatment.

Waste water from the preliminary soaking and the liming and unhairing process in particular has a high degree of pollution with residues on evaporation, dissolved solids, total nitrogen, COD, etc. Waste water from the soaking process contains large quantities of chlorine ions, calcium ions, insoluble calcium salts, etc. so that it is undesirable to reuse it or bring it to a general treatment process as it is.

However, waste water from other processes, particularly, water from the washing processes, has a low level of pollution, and should be reused effectively.

It is recommended that a closed system be developed for waste water from the chrome tanning process for the purpose of reducing chrome consumption and preventing waste water contamination by recirculation of waste water.

8. Chemical

8 Chemicals

8.1 Characteristics of the Use of Energy in Chemical Industry

The chemical industry is an industry in which the raw materials are processed through chemical changes by utilizing chemical reactions in the production processes.

In addition to this main production process, it may be said that the chemical industry is an equipment industry in which the whole production process will be completed by adding pre-treatment of raw materials, and treatment processes based on physical, chemical, and mechanical separation operations for separation and refinement of the manufactured products.

The chemical reaction speed is influenced by the temperature, and in general, the higher the temperature, the faster the reaction. In most cases the chemical equilibrium is influenced by the pressure. In the case of exothermic or endothermic reactions, in order to maintain the optimum reaction temperature, cooling or heating of the reactor portion will become necessary, and in many cases, the raw materials are also heated so that they may be supplied at the optimum temperature.

Consequently, in chemical industry processes, the energy consumption is great. Since the amount of heat that is released out of the system in the form of sensible heat and latent heat is also quite significant, energy control is a very important issue, and rational heat use and recovery of waste energy will be one of the pre-conditions for improving productivity.

If we take an ethylene manufacturing plant as an example of heat energy consumption of chemical process, the raw material naphtha is cracked at a temperature of about 80 – 850°C to form ethylene, and large amount of heat energy such as 6×10^6 kcal per 1 ton of ethylene will be required.

In case of an ethylene plant that is making efforts to save energy, for the fuel of cracking furnace, self-producing cracked gas and cracked heavy oil are used. The high temperature gas from the cracking furnace gives heat to some waste heat boilers in the quenching process, and steam having varying temperature and pressure are recovered.

As a result, after 17% of the heat added to the cracking furnace is used for cracking reaction, 68% is recovered. Cooling loss and heat released from the stacks account for merely 15%.

In the chemical industry, since the production process and the energy consumed are specific to the products and the raw materials used, and since exothermic reactions and endothermic reactions are involved, it is difficult to argue uniformly on energy conservation in the case of the chemical industry.

However, among the various processes, in the case of unit equipment conducting so-called unit operation, in spite of the differences in the process, similar one is used generally, and there are many common points in the energy use. Thus, in this guideline, the writer would like to select some typical unit equipment which are used in the chemical industry, and discuss them.

8.2 Rationalization of Heat Energy Use

8.2.1 Combustion Equipment

Refer to "Metal Processing" for fuel and burners.

A) Lowering of excess air ratio

In the heat balance of an equipment, the heat quantity removed by the combustion waste gas is greatly influenced by the amount of waste gas as mentioned in Item (2), and the waste gas amount is directly related to the excess air ratio.

Since the heat loss based on waste gas increases linearly with the increase in the excess air ratio as shown in Fig. 8–2, theoretically, the heat loss will be smaller if the excess air ratio becomes small.

However, actually, if it becomes less than 1.1, fuel loss based on incomplete combustion occurs, so the maximum value of heat efficiency exists between an excess air ratio of 1.02 and 1.10.

However, in general combustion equipment, normally there will be fluctuation of load, and if combustion is done at low excess air ratio at that time, black smoke will be exhausted frequently by incomplete combustion. Thus, in actual equipment, a little allowance is considered and the operation is done at an excess air ratio of about 1.3 (Table 8–1).

However, recently, computer control is being conducted by a cross limit method in which the each flow amounts of air and fuel are measured directly, and the specified excess air ratio is always maintained even in case of load fluctuation. As a result, it has become possible to maintain the excess air ratio within the range of 1.02 – 1.10 at all times, and the effective energy saving has been obtained.

Table 8–1 Standard Air Ratio for Various Facilities

Classification	Standard air ratio
Melting furnace for metal casting	1.3
Continuous billet furnace	1.25
Other metal furnaces than continuous billet furnaces	1.3
Continuous heat treating furnace	1.3
Gas producer and gas heating furnace	1.4
Petroleum heating furnace	1.4
Thermal decomposition furnace and reforming furnace	1.3
Cement calciner	1.3
Alumina kiln and lime kiln	1.4
Continuous glass melting furnace	1.3

B) Recovery of waste heat

Even when the excess air ratio is 1.2, if the waste gas temperature at the furnace outlet is 1,000°C, the waste gas loss will be close to 50%, and the energy saving based on the recovery of waste gas retention heat will be effective.

a. Pre-heating of raw materials

Normally, the raw materials are mainly charged at ordinary temperature.

Thus, a pre-heating chamber is made at the raw material charging point, and the raw materials are heated by introducing the waste gas into the chamber. The suspension preheater system of the cement manufacturing plant is a good example of this method. (Refer to Fig. 8–1)

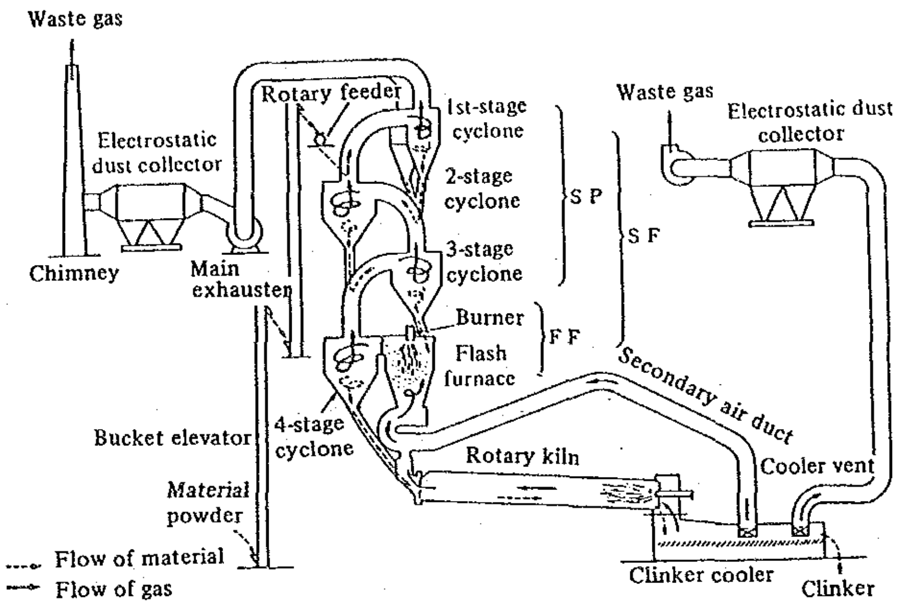


Figure 8–1 New Suspension Preheater System Cement Factory

b. Pre-heating of combustion air

In case the temperature of the combustion air is raised by using heat exchanger, as it is clear from the heat balance calculations, the amount of fuel consumed will decrease. As an example, the relation between the fuel economy (saving) rate and pre-heating temperature of air in case the excess air ratio is 1.3 is shown in Fig. 8–2. The point which we must mind here is the corrosion caused by sulfur contained in the fuel. Sulfur is contained in the waste gas in the form of SO_2, and part of this is converted into SO_3. The SO_3 will further combine with the steam in the combustion gas and form sulfuric acid vapor, which in turn will reach dew point at low temperature and condense. This will corrode the heat exchangers. It is difficult to obtain the dew point temperature theoretically, but it is obtained as a rule of thumb, and in case of heavy oil combustion, it is said to be in the range of 110 – 160°C, in general. (Refer to the item on boilers which is described later on.)