high temperatures, it may be practicable to provide a heat exchange chamber and let heat exchange take place between product prior to and after firing.

(4) Standard for exhaust gas temperatures

Set the standard temperature at 250° C considering an acid dew point concerning the exhaust temperature of combustion exhaust gas from the tunnel kiln. However, in the ceramic manufacturing kiln some part of waste heat is of no use, it is necessary to consider the economy as a whole.

4.2 Glass Industries

4.2.1 Melting kiln

(1) Appropriate air ratio and standard for the ratio

Glass is melt at a high temperature of approx. 1,500°C. At such a high temperature, heat transfer through radiation plays a dominating role. The quantity of heat Q radiated from an object at absolute temperature T_1K to an object at absolute temperature T_2K, is expressed by the following equation:

$$Q = 4.88\ \epsilon \{(\frac{T_1}{100})^4 - (\frac{T_2}{100})^4\}\ \text{kcal/m}^2\text{h}$$

Value ϵ is within the range of 0.5 to 0.8 in terms of flame from heavy oil. This equation is suggestive of a fact that the higher the flame temperature, the higher the heat transfer value becomes. Since the flame temperature is decreased in proportion with an increase in the excess air volume, it is required to lower the air ratio to such an extent that an incomplete burning should not occur.

Next, it is important to reduce the exhaust gas amount because even a combustion exhaust gas after the recovery of waste heat is still at approx. 500° C.

Suppose that the actual wet exhaust gas amount is G, the theoretical wet exhaust gas amount Go, the theoretical air volume Ao and the air ratio m. Then the following equation will be established.

$$G = Go + (m - 1)\ Ao\ \text{m}^3\text{N/kg} - \text{fuel}$$

Thus a reduction of the air ratio is helpful for minimizing the exhaust gas amount. The Go and Ao values should be calculated based on a fuel composition. In a similar way, however, it is possible to obtain the Go and Ao values by an equation of Table III-1-28 (Rosin equation) based on the fuel calorific value H/kcal/kg. The calorific value of each different kind of fuel is as shown in Table III-1-29.

When the exhaust gas amount has been reduced from G_1 to G_2 as a result of an improvement of the air ratio, the exhaust gas amount is further decreased by a decrease in the fuel quantity caused by a reduction of the exhaust gas loss. In this case, the fuel conservation rate will be as shown by the following equation:

$$\text{Fuel conservation rate} = \frac{100R\,(1 - \frac{G_2}{G_1})}{100 - R\frac{G_2}{G_1}}$$

(R means the exhaust gas loss percentage prior to modification)

Table III-1-28 Relationship between low calorific value Hℓ and Go, Ao (by Rosin)

Fuel	Go	Ao
Solid fuel (Hℓ : kcal/kg fuel)	$\frac{0.89\ H\ell}{1{,}000} + 1.65\ m^3{}_N/kg$ fuel	$\frac{1.01\ H\ell}{1{,}000} + 0.5\ m^3{}_N/kg$ fuel
Liquid fuel (Hℓ : kcal/kg fuel)	$\frac{1.11\ H\ell}{1{,}000}\ m^3{}_N/kg$ fuel	$\frac{0.85\ H\ell}{1{,}000} + 2.0\ m^3{}_N/kg$ fuel
Low calorific value gaseous fuel (Hℓ = 500 to 3,000 kcal/$m^3{}_N$ fuel)	$\frac{0.725\ H\ell}{1{,}000} + 1.0\ m^3{}_N/m^3{}_N$ fuel	$\frac{0.875\ H\ell}{1{,}000}\ m^3{}_N/m^3{}_N$ fuel
High calorific value gaseous fuel (Hℓ = 4,000 to 7,000 kcal/$m^3{}_N$ fuel)	$\frac{1.14\ H\ell}{1{,}000} + 0.25\ m^3{}_N/m^3{}_N$ fuel	$\frac{1.09\ H\ell}{1{,}000} - 0.25\ m^3{}_N/m^3{}_N$ fuel

Table III-1-29 Calorific value of fuel (Low calorific value Hℓ)

Solid fuel	Bituminous coal Lignite Coke	5,800 to 8,000 kcal/kg 2,500 to 5,500 kcal/kg 6,500 to 7,000 kcal/kg
Liquid fuel	Kerosene Light oil Total range of heavy oils "A" heavy oil "B" heavy oil "C" heavy oil	10,400 kcal/kg 10,300 〃 9,850 〃 10,200 〃 9,900 〃 9,750 〃
Gaseous fuel	Natural gas Propane Butane	9000 to 11,000 kcal/$m^3{}_N$ 22,350 kcal/$m^3{}_N$ 29,610 kcal/$m^3{}_N$

A measurement of the tank kiln in Japan revealed that the fuel consumption was the least within the range of m = 1.07 to 1.16. In the Kingdom of Thailand, 2 factories of the total 4 were within this range. According to the standard set by the notification of the Japanese government, the guide line for air ratio control in the continuous glass melting kiln is set at 1.3.

As for air for burning, in addition to the primary air conducted to the burner for atomizing heavy oil, preheated air for burning and air intrusion from the opening are pointed out. It is difficult to directly measure the volume of air for burning. Therefore, it is obtained by measuring an oxygen concentration or a carbon dioxide concentration in the exhaust gas and then calculating a material balance. In case the nitrogen content of fuel is small and completely burned, and the nitrogen content of air for burning is equivalent to 79%, the following equation is established:

$$m = \frac{21}{21 - (O_2)}$$

(O_2)........................ Oxygen concentration in the exhaust gas %

$$m = \frac{(CO_2)\ max}{(CO_2)}$$

(CO_2) .... CO_2 concentration in the exhaust gas %

(CO_2) max .... maximum CO_2 concentration in the theoretical dry exhaust gas %

$$(CO_2)\ max = \frac{1,867C}{G'o} \times 100\%$$

$(G'o = Go - (11.2\ h + 1.244W)$

Where, h: represents kg of hydrogen in 1 kg of fuel.
W: represents kg of moisture in 1 kg of fuel.
C: represents kg of carbon in 1 kg of fuel.

The following value may be used as a value of (CO_2) max. Coal 18.5%, heavy oil 15.7%, natural gas 12% and LPG 14.5%.

In order to maintain an appropriate air ratio, attention needs to be given to the following items:

a) Maintenance of appropriate fuel oil temperature.
Preheat the fuel so that it may fall within the viscosity range of 20 to 45 cst. It is necessary to preheat heavy oil at 80 to 100°C as shown in Fig. III-1-22.

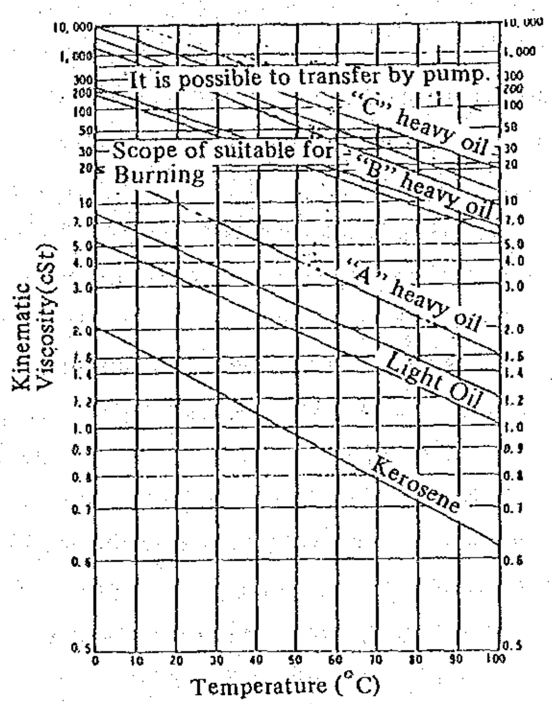


Fig. III–1–22

b) Inspection and tune-up of burners.
Inspect and tune-up the burner on the following so that burning equipment may function normally.

- Clogging of oil strainer.
- Clogging, wear and mounting condition of burner tip.
- Holding direction of the burner and distance from burner tile.
- Damage and carbon deposit on burner tile.
- Oil leaks from oil valves and pipe joints.

c) Maintenance of appropriate air pressure for atomization.
Adjust so that the air pressure may keep the specified level by burner.

d) Prevention of air intrusion
The air suction from the dog house, burner surroundings, peephole, etc. not only helps increase the exhaust gas amount but also lowers the intrakiln temperature because of the low temperature of the said air.
In order to minimize the intruding air volume, the following procedures should be taken:

- Reduce the opening dimensions. For instance, make sure that the wall joints are clogged perfectly, minimize a clearance around the burner, by water cooling of burner seal the dog house with batch.
- Maintain an appropriate kiln pressure by adjusting the damper.

e) Control
Control the secondary air volume in proportion to the fuel volume. The proportional control is also computerized for further precise control including the adjustment of an oxygen concentration in the exhaust gas, compensation of secondary air temperature fluctuations, etc.

f) Selection of burner
Determine the appropriate number and capacity of burners according to the shape and size of kiln. In addition, select the burner of such a type as to maintain stable combustion, even if the low-temperature primary air volume were small. Recently, natural gas began to be used for fuel atomization instead of air. In this case, it was reported that the unit fuel consumption rate had been improved by approx. 2%.

(2) Reinforcement of insulation and standard for adoption

Refractories of the melting tank are under extremely severe conditions in terms of temperature and erosion by a charged material. So far, no sufficient heat insulation was provided and the bricks of surface level of molten glass also was air-cooled. However, as is apparent from the heat balance chart, the heat release from the kiln wall accounts for a large percentage of the total loss. Therefore, a higher insulation effect is now being sought by using high-quality refractories. That is, the superduty silica brick containing a low percentage of alkali or alumina is used for the ceiling, and the electrocast brick of alumina, zirconia and silica is used as lining for the side walls and kiln floor, externally covered by refractory brick, insulating brick or ceramic fiber. Compared with the kiln of the conventional brick construction type, these kilns having a higher insulation effect showed, in a certain case, a decrease in the external surface temperature of the side walls from 304 to 173°C and a decrease in a heat release amount from 6,152 kcal/ m^{2}h to 2,092 kcal/ m^{2}h. The case of measurement of a newly built tank in Japan is shown in Table III-1-30.

Table III–1–30 Amount of heat release of modern-type kiln

Spot where heat is released.	Amount of heat release
Ceiling of melting furnace	1,050 kcal/m^2 h
Bottom of melting furnace	1,900
Sides of melting furnace	2,020
Ceiling of regenerator	920

The standard for heat insulation on the newly built industrial kiln published by the Japanese government shows a referential value for the external surface temperature of the kiln walls by intrakiln temperature. However, as to the kiln at higher than 1,300° C of intrakiln temperature, a uniform referential value is not indicated because the problem "erosion of kiln material" is involved. In addition, for the same reason, the kiln whose walls are forcibly cooled is not subjected to the standard.

Accordingly, in the Kingdom of Thailand, it seems to be some problems involved in setting a uniform standard. Only as far as newly established kilns are concerned and also excluding some parts susceptible of erosion, the surface temperature of the kiln walls shall be set at lower than 200° C as a standard when the atmospheric temperature stands at 30° C.

The regenerator is, in many cases, thermally insulated with rock wool sprayed on the external surface, because its insulation conditions are less severe than the kiln's. It is suggested that a standard for surface temperature be set when it gets possible to insulate by glass wool economically in the Kingdom of Thailand.

(3) Recovery of waste heat and standard for the recovery

Since the melting tank requires high temperatures, the waste heat of combustion exhaust gas is recycled for preheating the secondary air for burning. As a waste heat recovery device, either the regenerator or the recuperator is employed. However, except for the small size kiln, generally the regenerator is used.

The rate of heat recovery at the regenerator can be improved by reducing the thickness of a checker brick, expediting the velocity of gas running between checker bricks and increasing a checker amount with a taller regenerator provided (refer to Fig. III-1-23 and Fig. III-1-24). Normally, the secondary air is preheated at approx. 1,250 to 1,300° C. If the checker brick is used for a long time, it would collapse by a reaction with dust in exhaust gas, resulting in the clogging of a clearance and the subsequent diminishing of heat exchange area. For this reason, bricks of highly corrosion proof quality are used to match the life of the melting tank.

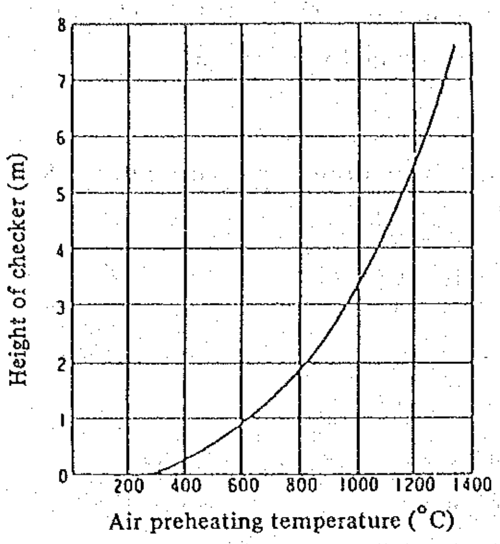


Fig. III-1-23 Relationship between height of checker and air preheating temperature

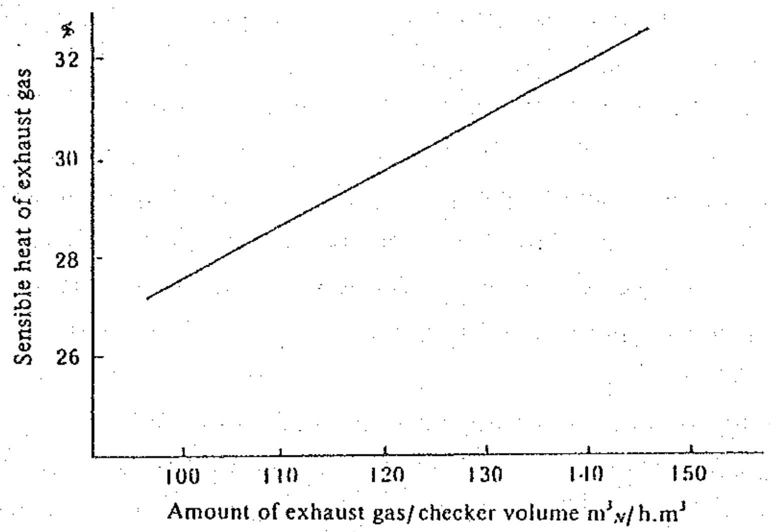


Fig. III-1-24 Relationship between amount of Exhaust gas/Checker volume and sensible heat of exhaust gas

As to the recuperator, the radiation type free from dust clogging is extensively used. The multi-ceramic tube type is also employed. A certain type can be proof an exhaust gas temperature of approx. 1,500° C, but the preheated air temperature is 800° C max. or a low heat recovery rate. Despite this fact, equipment cost is low and large space is not required. Therefore, the recuperator is used for the small capacity tank.

To make sure that the use of a preheated air is maximized, it is necessary to minimize the primary air volume at a low temperature or the intrusion air volume from the opening as far as possible. In addition, sufficient insulation needs to be applied so that the temperature of preheated air may not drop.

As the recovery rate for waste heat is almost determined by equipment, only the new kiln is eligible for the standard when it is established. Besides the waste heat recovery equipment for the glass melting tank requires large space which is a bottleneck for increasing the waste heat recovery rate. When setting the standard, these points need to be considered.

Under the standard in Japan, for the kiln whose exhaust gas temperature at the kiln outlet exceeds 1,000° C, the standard waste heat recovery rate is set as follows: 40% for the rated capacity of more than 20×10^6 kcal/h, 30% for that of 5 to 20×10^6 kcal/h and 25% for that of not more than 5×10^6 kcal/h.

In addition, under this standard, the kiln having a rated capacity of not more than 1×10^6 kcal/h or not exceeding 1,000 hours of annual operating time is not eligible.

In the case of the Kingdom of Thailand, all the regenerators excepting the metallic recuperator have satisfied the above-mentioned values. Therefore, it is suggested that the standard be established based on these values.

(4) Compounding of raw materials

The high compounding rate of cullet or lime to such an extent that it does not affect the quality of the finished product adversely can reduce a melting energy. The relationship between the cullet addition rate and the required heat is shown in Table III-1-31 and Table III-1-24.

Table III–1–31 Heat required for production of various kinds of glass at 1,400° C and pull temperatures (Theoretical value), q

Kind of glass	Temperature °C	Heat required for melting glass q (kcal/kg glass)					
		Cullet addition rate %					
		0	20	40	60	80	100
Tableware glass	1,400	576	543	510	477	444	411
	1,250	530	497	464	431	398	365
Sheet glass	1,400	666	615	563	512	460	409
	1,150	571	520	468	417	365	314
Laboratory appliances	1,400	508	482	455	429	402	376
	1,300	477	451	424	398	371	345
Lead glass	1,400	496	472	448	424	400	376
	1,100	391	367	343	319	295	271

For your reference, the use ratio of cullet in the Japanese bottle manufacturing industry was 42% in 1982. In the case of a diagnosed factory in the Kingdom of Thailand, the cullet consumption ran as high as 40 to 80%. The cullet compounding ratio has something to do with cullet availability and the quality standard of finished product. Therefore, a uniform standard cannot be established. Efforts to increase should be made independently by each factory.

The clarifying agent, if used, will shorten the clarifying time, resulting in energy conservation. It is necessary to select the type and quantity of raw material according to the condition of the tank.

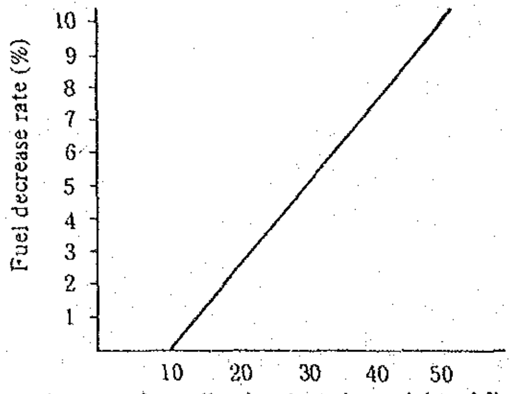


Fig. III–1–25 Consumption rate for cullet and fuel saving rate

(5) Electromelting

As glass becomes a conductor at 800° C, this method is to insert an electrode into the melting tank and directly heat glass through its electrification. This method used as an auxiliary means for the heavy oil heating kiln to increase the pull or adjust the intrakiln temperature, is called "booster". Power consumption required for increasing the pull by more than 1 ton per day is approx. 29 kw. Supposing that the efficiency of conversion from heavy oil to electric power is 35%, then the booster used will help save the energy, if the unit fuel consumption rate is more than 175l/ton.

Table III-1-32 shows an example of a heat output ratio of the electric melting kiln. Electric melting is sometimes economical even after considering energy cost and incidental facilities, when it comes to the small size tank. In addition, the electric melting tank is characteristic of causing less air pollution, controlling temperature easily and producing high-quality products.

Table III–1–32 Heat output ratio of electric melting furnace

	Heat output (kcal/h)	Ratio (%)
Heat release from ceiling	28	(0.07)
Heat release from furnace bottom	5,883	
Heat release from throat side wall	5,200	
Other walls	7,850	
Total	18,961	44.1
Loss by water cooling for electrode	10,455	24.3
For glass heating	13,584	31.6

(Capacity 750 kg, pull quantity 400 kg/day)

	Heat Output (kcal/h)	Ratio (%)	
Ceiling	1,800	2	30
Side wall	10,700	15	
Bottom	9,300	13	
Cooling water for electrode	1,400	2	2
Calorific value required for vitrification	2,200	3	68
Soaring temp. of glass	46,600	65	
Total	72,000	100	100

(Pull quantity 60 t/day)

4.2.2 Forehearth

This is a tank for adjusting the glass temperature to fit bottle manufacturing operation. As is the same as the melting tank, air ratio control and installation of high-efficiency insulation are items for energy saving counter-measures.

Of these items, air ratio control requires our attention regarding the numerous number of burners and the use of air for cooling and other points. It is considered that cooling by stirring and the adoption of electric heating will be effective for energy conservation.

4.2.3 Annealing furnace

In the case of diagnosed factories in the Kingdom of Thailand, all were of the continuous type (Lehr), so explanation is made of this type only.

(1) Increase in heat brought in

The temperature of the finished product that has been molded is at higher than 600° C. Therefore, if this heat is brought into the annealing furnace without any heat release, heating is almost unnecessary. In order to realize this measure,

- the distance between the molding machine and the annealing furnace shall be shortened,
- the finished product passing through the molding machine shall promptly be loaded into the annealing furnace

(2) Prevention of heat release and standard

While at a high temperature level, the finished product needs to be slowly cooled. So give attention to the following points:

- Insulation measure for the hot part and prevention of hot air leakage.
- Restriction of cold air intrusion from the charging port.
- Kiln cross-section shape matching the size and output of finished product.
- Charging finished products densely.

The external wall temperature of the hot part shall be 100°C of standard temperature at 30°C of ambient temperature.

(3) High efficiency-type kiln

- Adoption of the direct heating method.
- Forced circulation of intrakiln hot air.
- Reduction of heat capacity of mesh belt (weight reduction per unit area)
- Preheating of return mesh belt by waste heat (intrakiln return of belt).

The following is an example of an unexpectedly high heat requirement for heating a mesh belt.

Finished product processing quantity: 630 kg/h

Average specific heat of finished product: 0.252

Temperature at which finished product is loaded into the annealing furnace: 400° C

Annealing temperature: 550° C

In this case, the heat requirement for product is: $Q_1 = 0.252 \times (550 - 400) \times 630 = 23{,}814$ (kcal/h)

Suppose that the aforementioned finished product is carried into the furnace by means of 1,500-mm belt. Then

Belt weight: 20 kg/m^2

Belt travelling speed: 380 mm/min.

Temperature before running into the furnace: 15° C ambient temp.

Max. temperature inside the kiln: 550° C

Average specific heat: 0.132

In this case, the heat requirement Q_2 for heating the belt will be:

$Q_2 = 0.132 \times (550 - 15) \times 20 \times 0.38 \times 1.5 \times 60 = 48{,}304$ (kcal/h)

More than double the heat required for heating the finished product is consumed for heating the belt. In order to save this, the conceivable way will be to narrow the wire diameter of the belt or widen the pitch of the wire, thus reducing the weight per unit area of this belt.

The unit fuel consumption rate of the annealing furnace changes significantly depending on the charging temperature, shape, thickness of finished product and frequency of variation, operating time, processing amount, type of furnace, etc. For instance, to look at a few examples in Japan, most of the furnace are within the range of 380 to 830 kcal/kg with regard to the unit fuel consumption rate. However, a certain type of the large-size kiln has an extremely low fuel consumption such as 50 kcal/kg.

4.2.4 Reduction of weight of finished product

Decrease of the glass quantity required for manufacturing a fixed number of finished products is helpful for the reduction of manufacturing energy. For the maintenance of bottle strength with a small amount of glass, it is required to carry out the following:

Improvement of shape design, thickness distribution, thorough surface treatment, severe management of manufacturing condition, etc.

4.2.5 Enhancement of productivity

Glass bottle manufacturing is a hot temperature operation, so that even during production suspension, a large quantity of heat is consumed. Accordingly, it is necessary to prevent the interruption of operation by trouble, shortening of a mould replacement time for the molding machine, and reduction of mould changing frequency.

Further, in the glass melting tank, the fixed heat loss ratio is high, so that the larger the output, the lower the unit fuel consumption rate becomes. Therefore, efforts should be made to increase the output while preventing quality degradation by promoting an intrakiln stirring.

4.2.6 Prevention of defective product.

If the finished product is defective and, as such, is recycled into raw material as an off-spec product, all the energy spent during the production will be wasteful. Therefore, the production of defective products must be prevented by controlling the quality of raw material, operating conditions of each manufacturing process, and maintaining equipment in secure condition.

III Guideline for Rationalization of Energy Use

2. Paper

Contents

1. Character of Guide Line

This Guide Line is a summary of technical matters considered important for the promotion of energy saving at the factories of the paper industries. The Guide Line is to be used for the following purposes.

1) (1) As technical reference for factory's engineers when they plan to rationalize use of energy in the factory.
   (2) As a diagnostic guidance manual.
   (3) As referential data for determining the progress of rationalization.
   (4) As a text for seminars.

2) Descriptive level which should be understandable by engineers having only 4 to 5 years' experience of actual service after college graduation, but not actually working in the subject industries.

3) In consideration of the present industrial status of the Kingdom of Thailand, the descriptive coverage is limited to the process-related matters of the factories which we diagnosed. Also, the basic items and numerical values regarding this process —energy-saving techniques and referential instances or actual records — are described.

   It is hoped that the Guide Line prepared here will be further supplemented and substantiated by the addition of information obtained in future through NEA's own factory diagnosis and other means.

   For information, the Guide Line contains standard values published by the Japanese Government (Ministry of International Trade and Industry) as a basis for judgement in promoting energy saving for factory managers through its notification.

(1) The standard values are the most frequent values (refer to Fig. III-2-1) of statistical distributions of numerous examples. As such they represent a realistic level for factory managers to attain without difficulty from the technical and economic points of view.

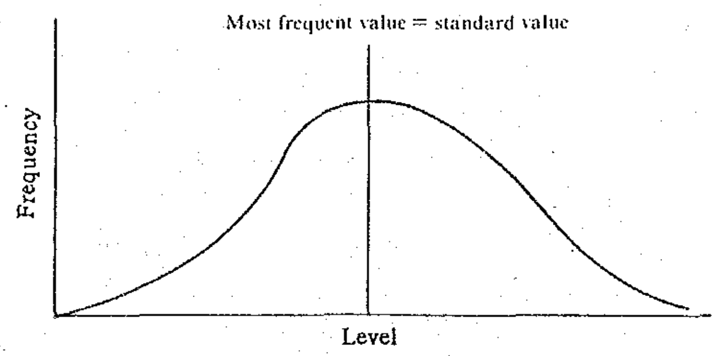


Fig. III–2–1

(2) The standard values do not necessarily represent the values which factory managers should be satisfied with after reaching them and also the minimum values which it must reach by all means. These values are rather those designed to improve the inferior value toward an average level, thus shifting the whole distribution of values into a better direction. Therefore, the most frequent value will be resought and a new standard value established after the elapse of a certain period.

The standard value establishment plan described in the report was prepared based on these standard values considering the present industrial status of the Kingdom of Thailand.

These standard values will be a starting point for the establishment of standard values for the rationalization of energy use in industry of the Kingdom of Thailand. It is recommended that the Kingdom of Thailand itself accumulates data during factory diagnosis to be put into practice, and evaluates it periodically and revises or newly establishes standard values.

2. Characteristics of Energy Consumption

2.1 Manufacturing process and main equipment

The flow of the paper making process is as shown in Fig. III-2-2. Fig.

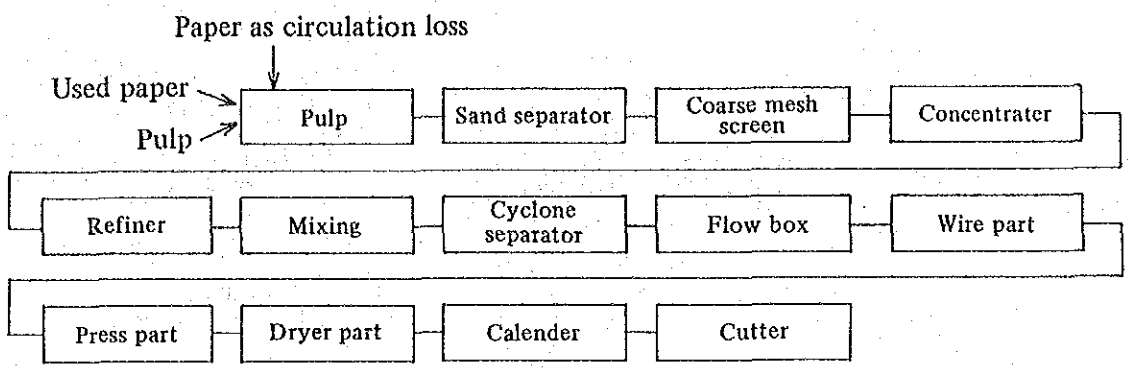


Fig. III–2–2

In order to make wooden fiber sheets, the fiber is carefully selected and beaten in preprocessing procedures, and is gradually dehydrated in uniform dispersed condition. In the final stage, moisture approx. twice as much is evaporated and dehydrated 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 industry consuming a large amount of energy.

2.1.1 Press part

(1) Theory of water squeezing on the press

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 has a capillary structure, elasticity and surfacial flexibility. The number and configuration of presses used vary according to the paper machine. However, the long net paper machine having 2 to 3 sets of presses is generally most popular. However, recently the squeezing capacity of the 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 past 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 Fig. III-2-3 was advocated.

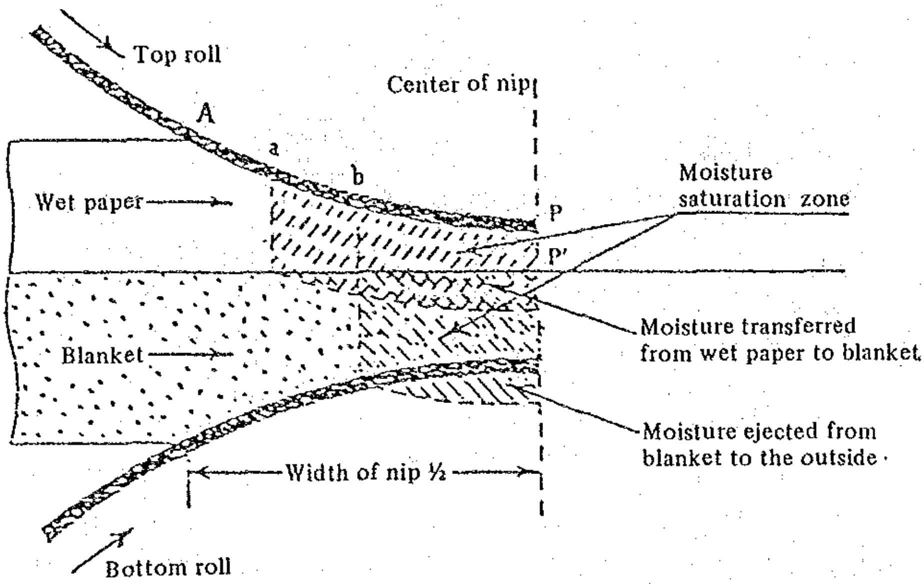


Fig. III–2–3 Water movement in press nip

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 decompressed 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

If the moisture content after pressing could be decreased, that 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 Fig. III-2-4.

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.

- 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.

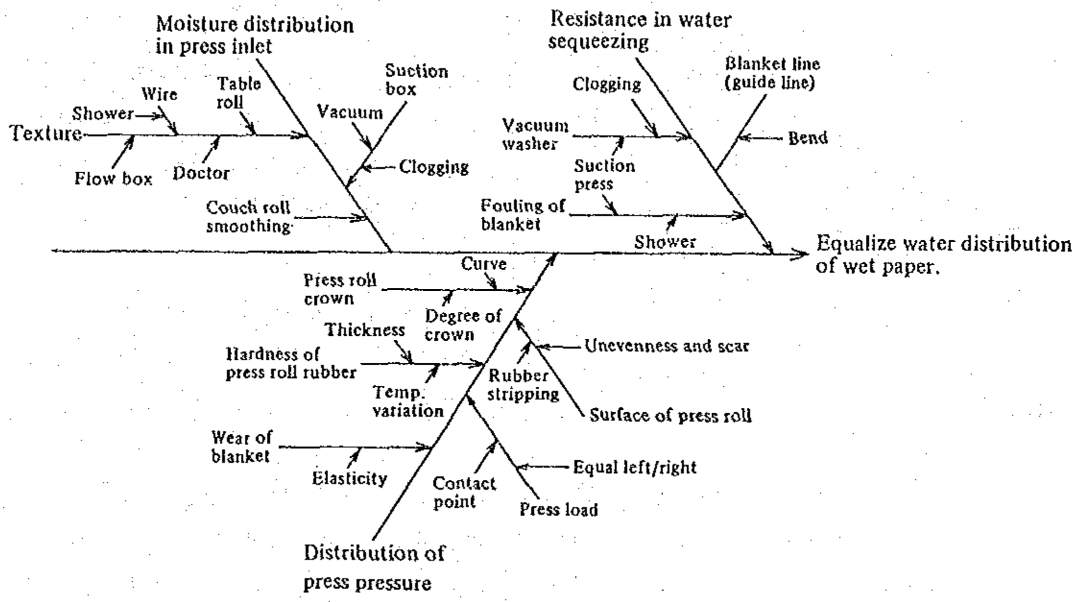


Fig. III–2–4 Chart for characteristic factors

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 Fig. III-2-5. Accordingly, the change of the linear pressure on the same conditions signifies the change of the average nip pressure as follows:

$$\bar{P} = \frac{P_L}{k\sqrt{P_L}} = k'\sqrt{P_L}$$

$\bar{P}$: 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 with 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 Fig. III-2-6).

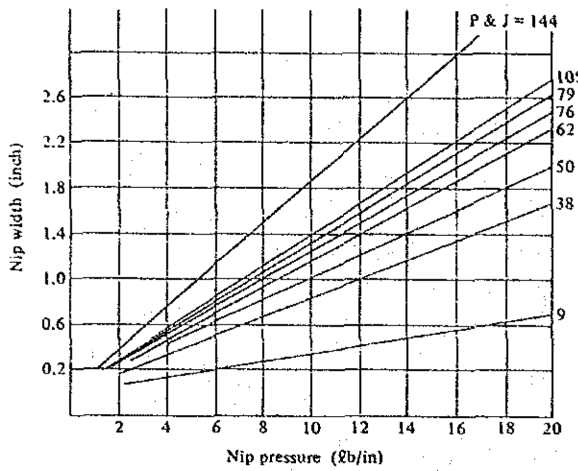


Fig. III–2–5 Nip pressure and nip width

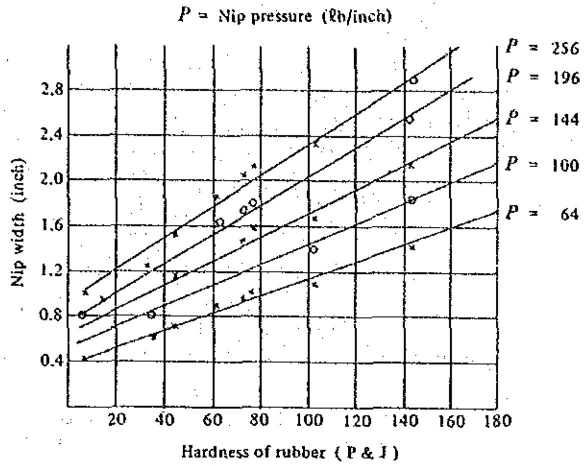


Fig. III–2–6 Nip width and rubber hardness

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 system 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 III-2-1.

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 III–2–1 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 regrinding the rubber-coated suction roll every 3 to 6 months considering the hardness of rubber or the pressure of press nip. The rubber roll should be used by repeating its grinding until the thickness is 13 to 15 mm.

When carrying out the grinding, consider the crown. The roll is in the form of a beam whose ends are supported, so it sags by its own weight. To think 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 on the journals of both ends is generally more significant (refer to Fig. III-2-7).

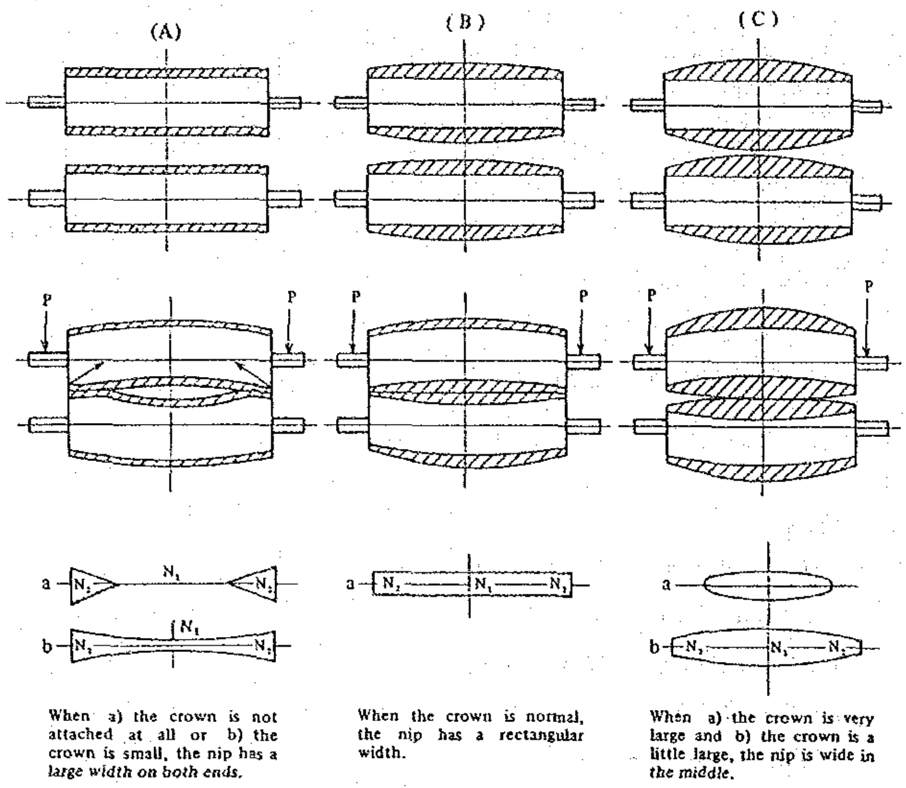


Fig. III–2–7 Crown and nip width

Consequently, the center creates a clearance, 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. As a simple visual determination way for the crown state, insert the undermentioned objects between the rolls and make use of their marks or traces.

a. Carbon and tracing paper

b. Pressure-sensitive paper products manufactured by Fuji Film Inc. and sold on the market.

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, in addition to the mark as shown in Fig. III-2-7, that means that a load on the front 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:

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

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, that signifies the necessity to reduce the crown value by this negative amount. Here attention should be given to the fact that the difference of $\frac{1''}{10}$ of the nip width appears as a change of $\frac{15''}{1000}$ 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.

2.1.2 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 is increased, extra energy (power) for the raw materials is required to remove it. If the removal of foreign matter is insufficient, the consumption of steam energy will be increased, or production efficiency will be reduced by the occurrence of trouble with the manufacturing process.

Nevertheless, it seems that generally, little concern is given to foreign matter from the viewpoint of energy conservation. The idea persistently prevails that in processing raw materials for paper, foreign matter and admixture are removed by the machinery. 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 alone on the ground and no concern was shown abont the soiling of used paper by tires or dirty feet. Soiled used paper necessitates extra expense for removal of dirt 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 materials and manage the inventory should:

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 due to putrefaction.

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 data on the actual status of foreign matter, its samples, etc. be made available periodically for referential purposes.

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 blast. 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, tatters, 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. Primary 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 an 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 cohesion 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 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 for paper flowing facing downwards may be turned upward by the baffle, and to also curve the inverter.

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:

$$h/u \geqq l/V$$

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

therefore, $h/u \geq \dfrac{l\cdot b\cdot h}{Q}$

$$u \leqq \frac{Q}{l\cdot b}$$

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, and mix in the slow stream of the boundary layer along the circumferential 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 periodically 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 the reject is flowing in an embrella-shaped spray fashion by the production of an air core in the center of the cyclone due to the release of tail into the atmosphere as seen in the conventional centricleaner, 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 discharge tube is too large, the reject volume is increased, diminishing the yield. On the contrary, if the diameter of the tail discharge tube is small, the fluidity may sometimes be decreased on account of the entanglement of separated foreign matter with some quantity of fiber, resulting in the clogging of the pipe.

2.1.3 Dryer part

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

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

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 soars and consequently the partial pressure of the internal steam also climbs. Then the canvas instantaneously evaporates moisture absorbed by the former in the free space from the cylinder to the other.

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 steam pressure is so high that the evaporation action on both surfaces of the paper is very effective with the accompanying sharp temperature drop.

g. The evaporation rate at that time is in proportion to the differential between the partial pressure of steam in the surface of the paper (almost matches the saturated steam at the temperature of paper surface), and the partial pressure of steam 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 a drain condensed inside the cylinder is resident or formed into a water film ring, the thermal efficiency drops so that the drain 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.

ts : Temperature of steam in the dryer

ti : Temperature of the internal surface of dryer shell

to : Temperature of the external surface of dryer shell

td : Temperature of the internal surface of paper

tp : Temperature of the external surface of paper

tf : Temperature of the internal surface of felt

ta : Temperature of the external surface of felt

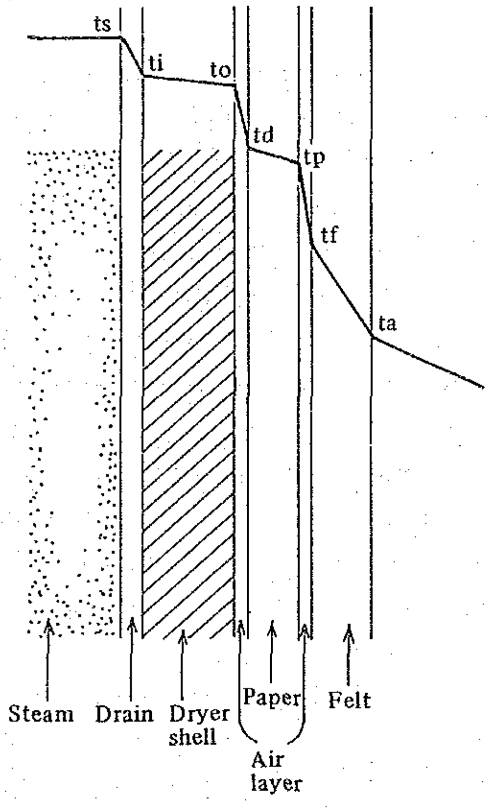


Fig. III–2–8 Resistance and temperature grade in drying process

(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 Fig. III-2-9.

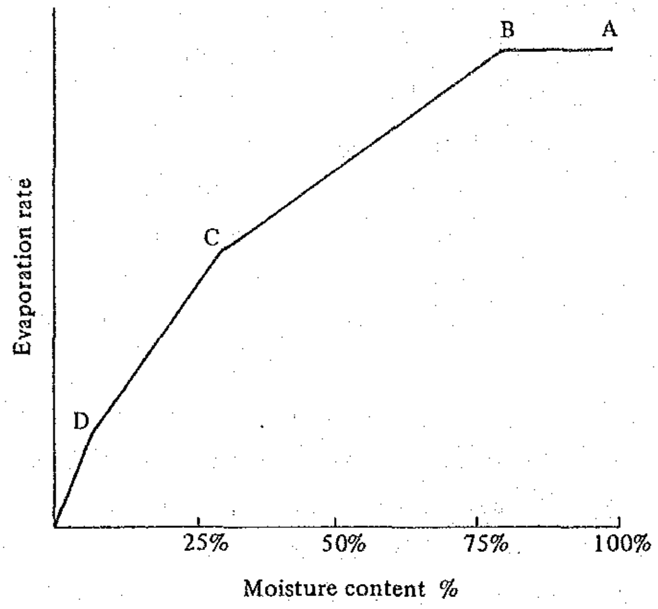


Fig. III–2–9 Drying curve of paper

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 gradually 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 in the internal clearance, when coming out onto the surface of the paper layer, becomes gradually stronger and the evaporation 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 displacement point indicating the initiation of evaporation 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 fibrous flocks 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) Thermal transmission resistance (contact resistance) on the contact surface between the surface of dryer and paper.

With regard to Item A) if the discharge of drain 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 Fig. III-2-10.

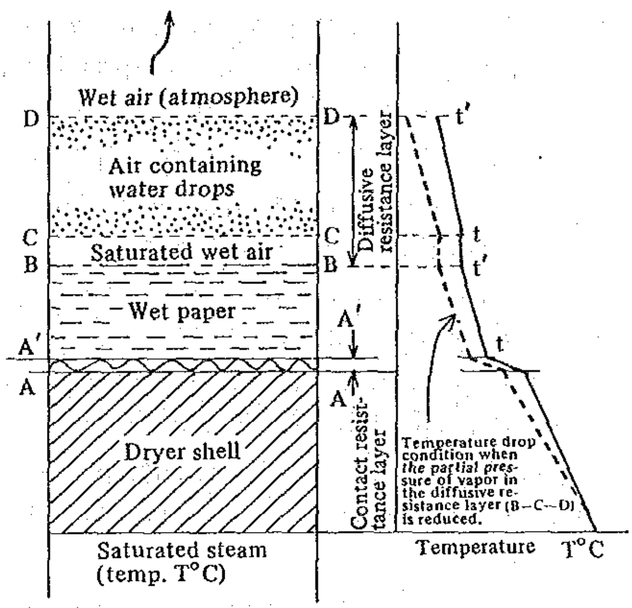


Fig. III–2–10

Fig. III-2-10 shows the state of air contacting the wet paper, the essential point is how rapidly the evaporation heat (heat of vaporization) required for the evaporation of moisture in the wet paper should be supplied to the wet paper. However there is a principle that heat transmission speed between two points is proportional to the temperature differential between two points. Accordingly, in order to expedite the transmission speed, the differential between the cylinder's surfacial temperature and the wet paper's temperature must be significant. In order to realize such a difference, a) the surfacial temperature T °C of the cylinder shall be increased or b) the temperature t °C of wet paper shall be decreased.

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 of b) and its effect. The moisture of the wet paper shown in Fig. III-2-10 is vaporized, taking a heat of vaporization from the wet paper and then is released into the atmosphere (wet air) 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 differential between the wet paper and steam becomes significant, increasing the thermal transmission rate. The environmental conditions around the wet paper influence the drying speed of the wet paper and, in turn, the dryer gives its influence to the thermal transmission rate of the wet paper. Thus the drying speed is secondarily affected. Accordingly, the environmental conditions around the wet paper (temperature, humidity, wind velocity) are an important causes for affecting the drying speed and for the unevenness in drying in the width direction.

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

a) Film resistance on the internal surface of the cylinder.

b) Resistance of cylinder wall.

c) Air film resistance between the cylinder wall and paper.

d) Resistance of the paper layer itself.

With regard to the above, the item to which attention must be given is b), because of the uncertainly and severity beyond expectation. Also, be careful about the air layer contacting the paper surface.

For the elimination of abnormal elements, the leading dryer is sometimes installed. Fig. III-2-11 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 operating procedures, namely, a) maintenance and check of the doctor, and removal of refuse to keep the cylinder's surface always clean, b) removal of clogging in the canvas and humidity, and c) prevention of the flow of cold and wet air to the dryer.

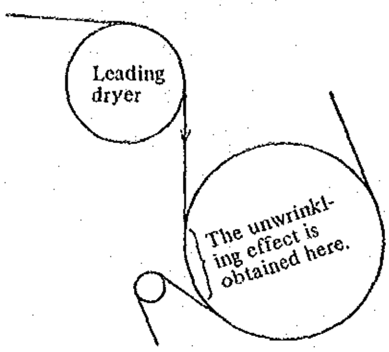


Fig. III–2–11

(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 be gradually increased from the wet end to the dry end. This requirement agrees with a condition that the drying resistance increases in accordance with a decrease in the moisture of paper and, at the same time, the thermal transmission rate of the cylinder decreases. Accordingly, the dryer part should be divided into 2 to 3 dryer groups to change the steam draft value. In other words, it should be arranged so that steam consumption may be increased for the dryer groups of the dry end, and steam consumption may be decreased for the dryer groups of the wet end.

As a standard for the grouping of cylinders, the ratio of the number of cylinders should be 1:2:4 from the wet side, for instance, in the case of 3 groups.

Fig. III-2-12 shows the typical drainage system of 3 groups called "blow through systems".

(Explanation of Fig. III-2-12)

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').

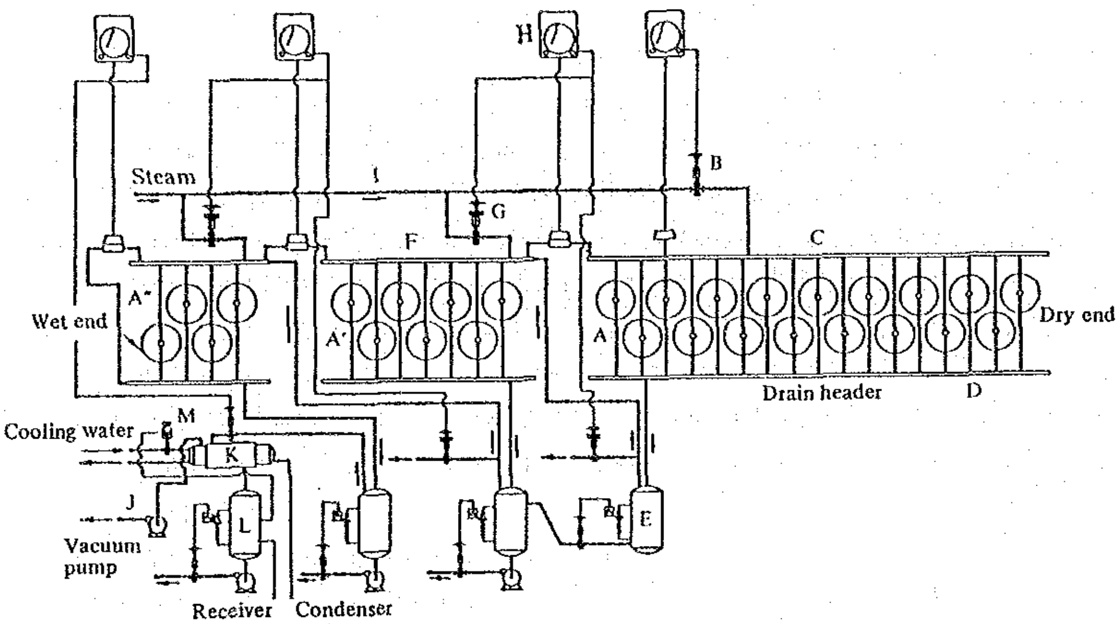
Between the steam headers of (A) and (A'), the control valve (G) and the controller (H) are provided for keeping constant differential pressure. This differential pressure is set so that the drip trap for (A) may be in the most ideal state. However, if the differential pressure is higher than the set 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 condenser 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 may always be kept at a constant level.

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



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 drain header

E : First group drain 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

Fig. III–2–12 Typical third group drainage system (Blow through system)

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

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 is provided to play 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, the dryer hood should have from the structural point of view, the following design considerations:

a. The width of the hood and the depth (height) of the side wall should be of sufficient dimension for capturing wet air. In the case of the open hood, it is necessary that the height of the side wall be at least 2 m and the location be almost at 30 to 35° against the internal surface of the sole plate as a distance from the machine frame (refer to Fig. III-2-13). This is from the operational point of view and sufficiently absorbs 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 allow the flow-down of condensed water drop in the interior. The upper space capacity should also be large enough.

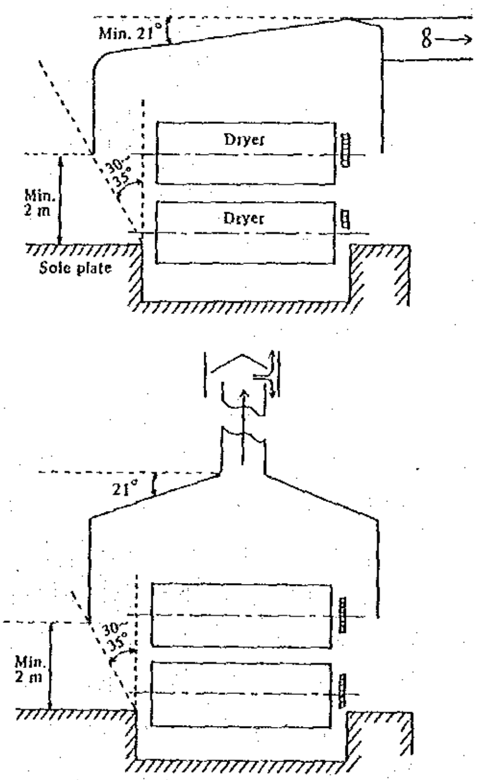


Fig. III-2-13 Design of open hood

b. The location, size and shape of the exhaust port should be satisfactory enough to eject wet air without fail. At the same time, the exhaust port also should be less susceptible of deflected air current which could be a cause for uneven drying in the paper width direction. In case the exhaust port is connected directly to the hood ceiling, it should be provided at an air equivalent to 3/4 of the wet end of the dryer part. This is because most of the steam is generated in the drying zone at a rate of max. approx. 15%, i.e. the drying zone at a constant rate.

c. The dryer hood shall be of such a structure as not to stand in the way of paper feed operation.

d. The hood also should be of such a design as to allow easy access to the operator for the maintenance, repair and cleaning of the dryer.

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

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

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

When developing the high-speed paper machine of high productivity the drying performance was reevaluated. Then the said machine was improved by the following procedures. The adoption of forced exhaust, introduction of hot blast supply equipment, complete sealing of the hood and building-in of the 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 suitable production pattern through actual operation.

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

$$E = P \times \frac{W_1 - W_2}{100 - W_1} \quad \cdots\cdots (1)$$

$$G = \frac{E}{X_2 - X_1} \quad \cdots\cdots (2)$$

E : Evaporation amount kg/h

P : Paper feed amount kg/h

W_1 : Moisture at inlet

W_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, that is the maintenance of the dew point of exhaust at high level contributes toward the decreasing of 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 logical and effective to hang a transparent film curtain from the side wall end of the open-type hood. The measure also will 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

Each time the hood device is improved, less air consumption is required, and subsequently, the unit steam consumption rate is reduced. Fig. III-2-14 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.

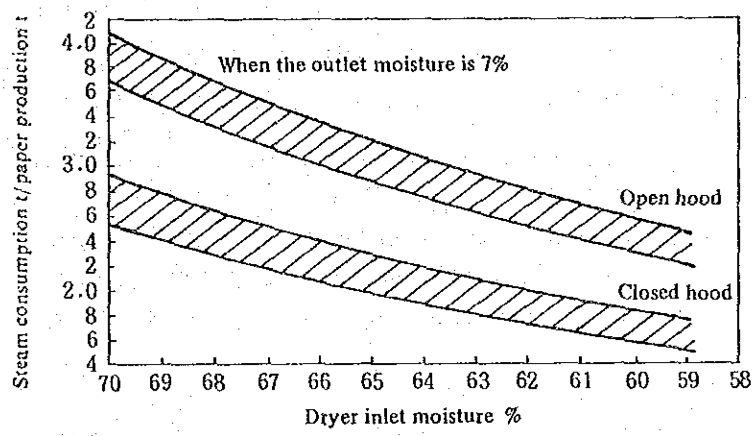


Fig. III–2–14 Unit steam consumption rate for open hood and closed hood

2.2 Status of energy consumption

2.2.1 Places where energy consumption is required.

The places at the paper mill where energy is consumed are as shown in Table III-2-2. 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 pulper for the purposes of drying after coating in the continuous sheet-making and coating unit, and beating and fibrellation acceleration by promoting the defiberize and 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, dusting 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 refining 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 pre-treatment process is not arranged with the paper machine in series as a systematized line.

For instance, 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 raw material processing 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.

Table III–2–2 Equipment and energy of paper mill

Name of equipment	Purpose	Energy source
Pulper	Pulp disintegration	Electricity and steam
Yanson screen H.D. 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

In the raw material section 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 pulper for used paper disintegration, dye dissolution and the gelatinization of 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 making 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 turned to friction heat which in turn, increases the system temperature or is released into the atmosphere. Although it is not easy to control the release of this heat into the atmosphere, white water should at least be recycled and the aforementioned friction heat 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 sheet making process be maximized. The direct measure for the saving of electric energy is to maintain the highest concentration of raw materials 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. The case realizing the above was actually noticed.

Almost all of the mills checked, take 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 layer formation. It seems that researches on the process at high concentration are underway. Yet it is strongly suggested that total concerted efforts of the whole industry be made regarding the improvement of the concentration.

2.2.2 Ratio of energy by heat and electric power

To look at the total energy consumption for paper mills in the Kingdom of Thailand by heat and electricity, the former accounts for approx. 82% and the latter for approx. 18%.

The energy ratio of steam and electricity for fiscal 1980 in Japan is as shown in Table III-2-3.

Table III–2–3 Ratio of energy by kind of paper
(Actual records in 1980)

	Steam	Electricity
Printing paper	71%	29%
Kraft paper	69	31
Liner	74	26
Painted white cardboard	80	20
White board paper	71	29

The consumption ratio of steam in Japan is lower than that of the Kingdom of Thailand. Despite the atmospheric temperature differential of approx. 10°C, the consumption ratio of steam in the Kingdom of Thailand is higher than that of Japan. This is the reverse situation and is suggestive of there being sufficient room for improvement. The energy ratio of the SKPC (Siam Kraft Paper Co.) in 1978 was 85% for steam and 15% for electricity. However, five years after the enforcement of measures for energy improvement, the said company showed the improved energy consumption ratio of 78% and 22%.

2.2.3 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 "K" mill capable of 40 tons per day in Bangkok.

Temperature of fresh water for mill's use	27 to 28°C
Temperature of mill's waste water	37 to 38°C
Consumption of fresh water for mill's use	150 m^3 ton of paper (assumption)
Heat input of fuel	204 × 10^6 kcal/d
Electric power consumption	50,000 kWh/day × 10^6 kcal/d
Calorific value lost into waste water	10°C × 150 m^3 × 40 = 60 × kcal/d

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 75 to 80% of the total energy input, and the majority of it is consumed in the drying process. The drying process 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.

2.2.4 Unit energy consumption rate

In Japan, the standard unit energy consumption rate of the sheet making section, including the mixing process, in 1976, and 1979 to 1980 is as shown in Fig. III-2-4. The grouped and rounded values based on the figures of Fig. III-2-4 are as shown in Fig. III-2-5.

In June, 1983, the symposium "Energy Saving in the Paper Pulp Industry" was held in Tokyo under the sponsorship of the Asian Productivity Organization. Then the actual results of the energy saving drive performed at the Ban Pong mill of the Siam Kraft Paper Co. in the Kingdom of Thailand, were introduced. The progress of improvement in unit energy consumption rate is shown in Table III-2-6.

The significant improvement of energy consumption is highly evaluated. However compared with the unit energy consumption rate for kraft paper shown in Fig. III-2-5 the unit consumption rate for steam of SKPC is slightly higher than that when steam of SKPC is lower.

Since the atmospheric temperature differential between Japan and the Kingdom of Thailand is approx. 10°C. The latter should be more advantageous than the former by 0.2 in terms of unit steam consumption rate. Consequently, there is room for further improvement. With regard to unit electric power consumption rate the Japanese paper manufacturers also should follow this set example.

In 1982, the comparison of the total energy consumption rate of 8 paper manufacturing mills with that of SKPC (refer to Table III-2-6) and the average energy consumption rate of Japan (refer to Table III-2-5) is shown in Table III-2-7. For reference, information on these total energy consumption rates was collected when the initial survey was concluded under the energy project for the Kingdom of Thailand in 1982.

Table III-2-4

	Steam (t/t)				Electricity (kWh/t)			
	1979 Oct. ~ 1980 Sep.		1976 May ~ 1977 March		1979 Oct. ~ 1980 Sep.		1976 May ~ 1977 March	
	Range	Typical value	Range	Typical value	Range	Typical value	Range	Typical value
Printing paper A (high quality)	1.6~5.0	(3.2)	1.9~4.5	(3.37)	320~1,280	(775)	510~970	(780)
Printing paper B (intermediate quality)	1.9~3.6	(2.75)	1.8~3.7	(2.95)	480~940	(710)	540~890	(710)
Printing paper C (high groundwood paper)	1.9~3.1	(2.45)	1.7~3.2	(2.53)	440~950	(665)	510~810	(870)
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)	2.2~3.5	(2.87)	490~1,080	(770)	540~1,220	(810)
Kraft paper	2.1~4.2	(3.00)	2.4~4.6	(3.46)	420~1,450	(855)	600~1,320	(920)
Other wrapping paper	1.8~3.8	(2.95)	1.9~5.3	(3.29)	200~1,210	(750)	370~1,270	(860)
Kraft liner for external fitting	1.4~4.1	(2.60)	2.1~3.8	(2.78)	350~750	(540)	450~900	(650)
Jute liner for external fitting	1.6~2.9	(2.15)	1.7~3.6	(2.53)	300~700	(490)	400~900	(630)
Pulp core	1.7~2.9	(2.20)	1.7~3.0	(2.36)	30~600	(295)	200~500	(340)
Coated Manila cardboard	1.9~3.9	(2.90)	2.5~5.1	(3.71)	250~1,150	(700)	450~1,500	(750)
Coated white cardboard	1.8~3.4	(2.55)	2.1~4.6	(3.12)	220~650	(895)	300~800	(560)
Non-coated white cardboard	2.4~2.7	(2.55)	2.1~3.9	(2.95)	390~440	(420)	450~600	(490)
Core paper or Tube board	1.9~2.5	(2.20)	2.4~3.0	(2.70)	180~700	(430)	350~750	(550)
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

Table III-2-5

	Steam (t/t)		Electricity (kwh/t)		Improvement rate (%)	
	1976 May ~ '77 March	1979 Oct. ~ '80 May	1976 May ~ '77 March	1979 Oct. ~ '80 May	Steam	Electricity
Printing/writing	3.0	2.8	770	690	5	10
Kraft	3.2	2.8	860	810	12	6
Wrapping	3.3	3.0	860	750	10	10
Liner	2.7	2.4	640	520	11	18
Width core	2.4	2.2	340	300	8	12
Coated cardboard	3.4	2.8	650	550	18	15
Board	2.8	2.4	520	440	14	15

Table III-2-6 Energy consumption rate of S.K.P.C.

	1978	1979	1980	1981	1982	Improvement rate (%)	Energy ratio (%)	
						'82-'78/'82 x 100	1978	1982
Steam (t/t)	5.7	5.1	4.2	3.5	3.0	47	85	78
Electricity (kWh/t)	880	855	860	800	770	12	15	22

Table III-2-7 Comparison of total energy ($X10^3$ kcal/t)

	Surveyed Mills under Energy Saving Project in the Kingdom of Thailand	SKPC		JAPAN	
		1978	1982	1976~1977	1979~1980
Printing and writing paper	7,500 ~ 20,000	—	—	2,600	2,400
Card board Kraft	2,000 ~ 4,200	Kraft 4,400	Kraft 2,600	Kraft 2,800 Liner 2,300 Card board 2,250	2,500 2,000 1,920

Steam: Standard steam 639 kcal/kg

Electric power: 860 kcal/kWh

3. How to Manage Energy

In order to improve the efficiency of energy consumption, productivity and product quality as well as raise their overall level, it is essential first to use facilities well adjusted and maintained to the purpose and to operate them correctly. It is most effective for energy conservation to reduce the incidence of equipment failure and increase product yield. Secondly, it is required that those engaged in energy management study the possibilities of further improving the existing facilities and operating method and pursue better means through repeated surveys and factory experiments.

Accordingly, it is not exaggerating to mention that the consciousness and willingness of the total factory employees would influence the actual performance of the factory. And it is important to raise the level of factory management which encourages the employees to have such consciousness and willingness. It is defined that energy management is a systematic effort to achieve energy conservation.

3.1 Clarification of Management Policy

Following the soaring of energy prices, the factory owner and manager have grown more concerned about energy conservation. In order to promote this tendency on a company level instead of letting it merely stay within the frame of the owner's mind as a desire, it needs to be clarified toward all the employees that the top management has the intention to tackle the energy conservation problem seriously as a company policy. In positive terms, the target should be clarified quantitatively; such as what percentage of energy consumption per ton of finished product should be reduced. Simultaneously the restrictions such as the ceiling of annual investment and deadline for pay back time should be clarified.

As explained above, the top management should clearly show the way to proceed on to the employees. Then in turn, the latter become confident about their jobs meeting the direction set by the former. Further, both can develop a smooth collaborative relationship because everybody involved is spiritually aligned in a unified direction.

Since the target of the top management is shown as a comprehensive one for the whole factory, each section and department should set concrete subtargets which do not require too much time and try their best effort to achieve these subtargets. These subtargets should be set concerning items for which any counter-measures can be taken by section and department personnel within their own responsibility range to attain the target set by the top management. As the said target is shown in a familiar and understandable form, it is easy to expect even employees of the lowest rank to fully understand the subtargets and extend their cooperation in attaining them.

When setting subtargets for each section and department, it is suggested that the committee described later or others study if such subtargets would be appropriate for achieving the overall target.

3.2 Arrangement of System for Promotion

In a campaign, for energy conservation where various classes of people take part, persons who play a part to promote the activities of all as a nucleus. If the factory is small, an individual person may be a promoter, but if the factory is large, a section for promotion is sometimes established.

This position should be occupied by a top-notch person and he should always be careful about a progress in energy conservation status and look into a cause, if there is a delay, then try to treat problem.

In concrete terms, the assignments of the position are as follows: the grasping of actual energy consumption, comparison of actual energy consumption with plans, invitation and checking of ideas about improvement, budgetary distribution, management of work progress and evaluation of actual works, mapping-out of education programs, preparations for committee meetings, etc.

The committee is effective for adjustment so that inter-disciplinary understanding may be realized among sections and departments such as manufacturing, sales, raw material purchasing, equipment maintenance and servicing, and accounting, and countermeasures may be put into practice smoothly. At the committee meeting, any possible influence of energy conservation measures to be performed on each section and department should be studied to make sure that no profit is reduced on an entire factory basis.

It is important that a general manager of the factory or a person next to the former in rank who has responsibility and authority in production assume the chairmanship of the committee. Otherwise, no decision would be made, neither would such a decision be implemented.

Even if certain energy measures were based on an excellent idea, any fruitful results would not be expected unless the operator fully understands what the measures mean and applies them to the actual work. There are many cases where the QC (quality control) circle which is effective for quality control is utilized successfully for energy conservation with noteworthy results. The QC circle is an activity of improving human relationship in the job, stimulating people to become more conscious about independence endowed intrinsically to humans and providing them with the pleasure of working actively. However, it is necessary to prepare conditions which make the operator find it easier to conduct activities such as education and incentive granting before he can recognize the advantages and necessity of the circle activities. It is the operator on the front line that is always in touch with energy consuming equipment and sensitive enough to grasp any phenomenon appearing according to a change in the operating conditions. It is extremely effective for energy conservation to make the best of information obtained by the operator and to squeeze out a good idea for improvement.

3.3 Scientific and Systematic Activities

It is an indispensable condition to obtain an exact status of energy consumption when energy conservation is carried out. If data such as change of the unit consumption rate per production, difference in the unit, variation of product grade and difference in raw materials are not available, it would be impossible to formulate plans which guide you toward an area requiring the implementation of immediate procedures. In other words, it is factory data that provide numerous ideas for improvement. If studies are made of these data with a consciousness about problems, it would be able to find something leading to such ideas. Therefore, it is suggested that a measuring instrument be installed at necessary spots, record its readings and obtain information through their periodical arrangement. In this case, such data should be processed from the viewpoint of mathematical statistics to determine if the difference is significant.

Next, it should be made sure that the results are followed up, if improvement plans were implemented. Efforts should be made to enhance the quality of operations according to the PDCA circle advocated by Dr. Deming. The function of the PDCA circle is such as explained below as shown in Fig. III-2-15:

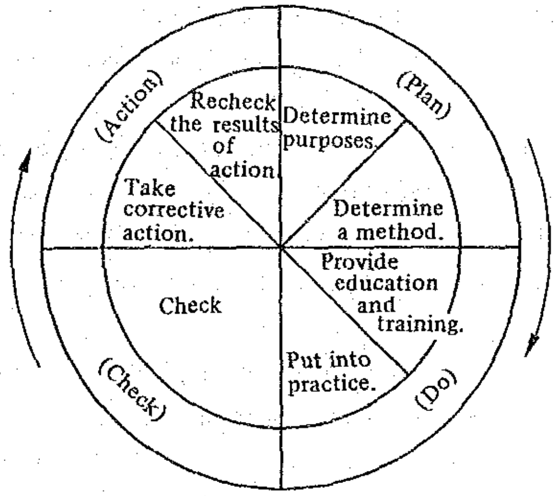


Fig. III–2–15 Deming circle

First, plans should be formulated; that is, a purpose will be set for a certain theme and means decided. This represents "P" for PDCA. People will be trained concerning how to perform these means and given an opportunity to actually do them. This represents "D". The results of the performance will be checked. This represents "C." Results of the check will be evaluated to determine if they are satisfactory. Action will be to standardize the results, if they are satisfactory and to take corrective measures if there is still a problem yet to be resolved. If one step was completed, the function of "PDCA" will be set to work towards a target of higher level. In this way, people proceed with their assignments. This method will be helpful for not only energy conservation but also heightening the quality of jobs in every field.

With regard to the part concerned with "Plan," it is recommended that "improvement plans invitation system" be actively utilized because items to propose can be found rather easily during an early stage. It should be so arranged that proposals may be made by whosoever he may be, an individual or a member of a working place, the QC circle or staff. Proposals presented should not be left alone, but should be examined promptly by the committee and others. The proposals presented should be adopted as far as circumstances allow after being modified on advice depending on the occasion. It is also suggested that a prize be presented to people for their proposals and further, a commendation be given to those whose proposals brought about fruitful results. These measures will be an incentive for people to deepen their consciousness about participation. For proponents whose proposals were not adopted, it is suggested that they be explained about the reasons why the proposals were not taken up and at the same time, be properly guided over better ideas.

In the stage of "D", it is suggested that satisfactory explanation be provided to employees of the lowest rank regarding an intention for improvement, and their cooperation in an effort toward the improvement be solicited. They are also encouraged to report even on minor abnormalities during operation so that they may be able to make scrupulous adjustments. This consideration is necessary to eliminate any possible cause for error.

"Check" should be conducted periodically and at the same time, the results be reported to the committee and the senior official. Along with this procedure, the results also should be made known to the operator so that he may deepen his concern. In this case, it is important to clarify an evaluation criterion from the beginning; it is not desirable to change it easily halfway.

If satisfactory results can be expected following the implementation of an improvement plan, they should be incorporated into the operation standard. Simultaneously necessary measures for the improvement of equipment should be taken so that any extra load may not be brought to bear on the operator. This is a condition for continued favorable results of energy conservation.

In case considerable results have been accomplished continuously as a result of the above, their summarized processes should be published as references. At the same time, those concerned should be officially commended so that they may be motivated for next activities.

3.4 Furnishing of Education and Information

Even if employees are willing to cooperate, any improvement can hardly be expected, unless they have knowledge as to how they should do it. They would become more positive to participate in the energy conservation campaign, if they are capable of presenting their own improvement proposal without being limited to merely pointing out problems. In order to realize this target, an internal education program sponsored by the company itself is important; that is, programs such as seminars and distribution of guide books should be provided. In the Kingdom of Thailand, a considerable number of companies are enthusiastic about education and also numerous cases where their staffers are sent for participation into external seminars are noticed. To our regret, however, such staffers sent for the external seminar tend to keep their acquired knowledge only to themselves instead of passing it on to other staffers or general operators. If it is arranged so that those who received external seminar training become lecturers for internal education and provide training to other people based on their acquired knowledge, it is expected that the entire level of employees' professional quality will be raised and staffers participating in the external seminars will be able to make sure that their obtained knowledge is practically useful.

Next, it is desired that information exchange with other companies of the same industry or raw material suppliers or finished product buyers be activated. Although it is naturally important that competition should take place among different companies of the same industry, it is recommended that technical information be exchanged to some extent on a give and take basis. This is because the technical level of the entire company can be heightened resulting in stronger international competing power and subsequent mutual benefit. For instance, the publishing of actual unit consumption rates will be instrumental for the motivation of commercial competition.

4. Rationalization of the Utilization of Thermal Energy

4.1 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 III-2-8.

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 a 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.

4.2 Items of measures for energy conservation

The contributing factors for energy conservation, expected results and points of equipment requiring care at the paper manufacturing mill are as shown in Table III-2-9.

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 III-2-10.

4.3 More effective dehydration by 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 an extra 1%, it will be possible to save the steam quantity in the dryer part 3 to 5%.

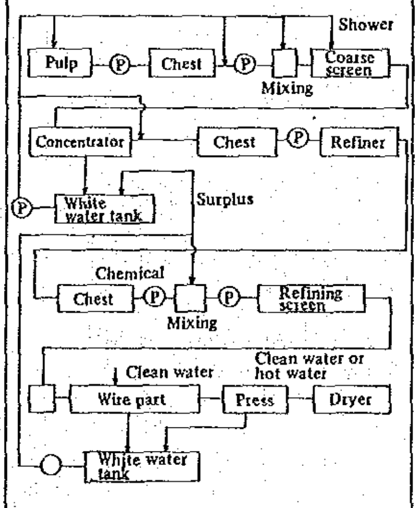
The key point of drying the wet paper is whether it is possible to dehydrate moisture evenly in the total width direction and as much as possible in the press part. If the change in the dehydrated moisture amount of the paper machine is examplified referring to printing, paper, it will be as shown in Table III-2-11.

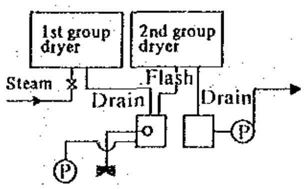
This Table III-2-11 shows the comparison of the dehydration values between the case of "K" company in the Kingdom of Thailand and the case of "E" mill in Japan when paper of the same use is made. Yet, the moisture content of wet paper in the case of "K" company is the value alleged by the section manager at site. Actually it seems that the dehydration value should be higher. Besides it was estimated that the concentration of liquid at the slice output should be higher and it may stand at approx. 0.8%. Further, it was estimated that the moisture content of paper manufactured by "K" company should be less than 2%, considering the static condition of the reel take up.

Table III–2–8 Example of step-wide promotion plans

Step	Equipment	Others
First step Effective utilization of and sufficient management of existing equipment.	Maintenance of various equipment Yanson screen and rotary screen Cyclone separator and pressure gauge Refiner and pressure gauge Concentrator Wire, slice, table roll, suction box, Nash pump, pressure-reducing gauge, blanket washing machine (shower, squeeze and whipper) Installation of insulation, repair of steam leakage and installation of steam flow meter.	Keeping a daily report in order . . . data collection. Setting qualitative standard. Setting operating standard. Carrying out quality and process tests (introduction of testers). Setting standard for equipment and management. Checking the quality of blanket and canvas.
Second step Recovery of waste heat and re-evaluation of electric motors.	Repair of press Maintenance of dryer Drain recovery system. White water circulating system Improvement of ventilation for dryer part. Adoption of appropriate electric motor. 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.	

Table III–2–9

		Energy saving and factors	Effects	Equipment
Pulp dissolution disintegration	Pulp	1. Use of white water. (try to avoid use of fresh water as far as circumstances allow) 2. Appropriate high concentration. (standardize the concentration)	1. Maintenance of temperature. 2. Effective use of electric power.	
Removal of dirt	Coarse screen In the case of Yanson and rotary screens.	1. Maintenance of appropriate concentration. 2. Determination and retaining of appropriate liquid quantity. 3. Use of appropriate quantity of white water for shower.	1. Quality control in following refining process. Reduction of electric power load. 2. Maintenance of temperature. 3. Prevention of paper break by improvement of dust removing efficiency.	Adjustment of mesh, slit and plate for normalization.
	In the case of cyclone screen.	1. Determination and retaining of appropriate liquid quantity. 2. Maintenance of appropriate pressure at inlet and outlet.	the same as above.	Internal smoothness. Adjustment of pressure gauge
Beating	Refiner Beater	1. Beating at high concentration (if the concentration is at low level, the fiber cut will be frequent. 2. Retaining of proper freeness (set the standard value by paper quality).	1. Beating in viscous condition for retaining paper strength. 2. Retaining of paper strength by refining sheet formation (prevention of paper break) and uniform drying (prevention of overdrying).	Refiner Adjustment of pressure gauge, rubber stone and blade. Beater Adjustment of drum and blade.
Use of white water by circulation.		Circulation of white water in the wire part of concentrator (filter) for saving fresh water.  Only clean water for wire part and clean water or hot water for washing blanket are fresh water. It is suggested that blanket washing water for high-quality paper such as printing paper be transmitted to the white water chest for material reconditioning process.	Maintenance of temperature. (prevention of temperature drop) Saving of fresh water consumption. Saving of pollution control cost following the saving of factory waste water.	o Thorough cleaning of each equipment during shutdown. Slime stickings increase in every part following the use of white water. Be careful about qualitative degradation and paper cut by the drop of stickings.

		Energy saving and factors	Effects	Equipment
Dehydration	Wire part	1. Refining of sheet formation.	Stabilization of paper strength.	o Keeping the wire in operating condition
	(Fourdrinier)	2. Effective utilization of suction box.	Fixed quantity of moisture.	o Keeping the suction box in good operating condition.
		3. Effective utilization of table roll.		o Keeping the table roll in good operating condition.
	(Cylinder)	4. Washing of blanket.		o Keeping the blanket washing shower, and squeeze roll in good operating condition.
	Press	Thorough washing of blanket. Clean the blanket and retain elasticity.	Improvement of dehydration rate for wet paper. If the dehydration rate is improved one percent, steam consumption will be saved approx. 4 percent.	o Blanket quality. o Keeping the press in good operating condition. o Keeping the press in good operating condition. o Careful washing with detergent and rinsing of blanket during shutdown.
		Perfect function of press Pressure increase Surface of press roll Crown of press roll		o Adjustment of press roll surface and crown. o Keeping the press mechanism in good operating condition. o Checking and cleaning of mesh and the interior in the case of suction press.
Drying	Steam	Insulation of steam pipe, drain pipe and valve.	Prevention of radiant heat loss.	Insulation and repair. Repair of steam leakage.
		Effective utilization of steam. Ventilation system adjustable to the degree of dryness. Recovery of drain and utilization of flush steam.  Installation of steam flow meter.	Effective utilization and saving of steam. Improvement of boiler efficiency by drain recovery.	Determination of drain pump characteristics.
	Dryer clinder (including canvas dryer)	Improvement of thermal transfer by smoothing and cleaning the surface of dryer. Improvement of thermal transfer with effective ejection of drain inner the dryer.	Effective utilization and saving of steam.	Keeping the doctor in good condition. Adjustment and checking of siphon

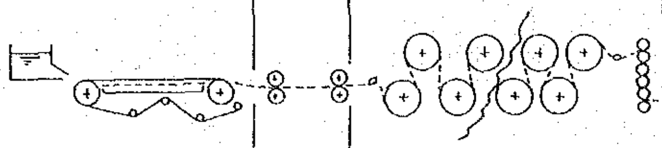
		Energy saving and factors	Effects	Equipment
	Ventilaction	Appropriate ventilation and control of fresh air.	Election of wet vapor.	
			Consideration over heating with the radiant heat of fresh air.	Consideration over the installation of half-closed hood.
		Elimination of delay in drying by vapor pocket in the center of dryer.	Even drying of entire paper width (prevent overdrying of both ends)	Measures for pocket ventilation.
		Retaining of clean canvas	Containment and release of moisture.	Shall be gas-permeable and not be fouled.

Table III–2–10 Check list for operation

		Process	Item				Record	Frequency	Remark
Operation at site	Screening process for raw materials	Pulping	For each pulper	disintegration time (min.) disintegration frequency (per day)			Pulper log		
			Each raw material charge (t/day)						
		Screen-related	For each coarse mesh screen and each time-mesh screen	Temperature Concentration PH			Screening log	Twice/shift (6 times/day)	
			Determination of dirt	For hand sheet made, refer to "standard for sheet making."			Preserve samples.	Once/shift (3 times/day)	Determine visually the refining performance of screen.
	Refining process	Refiner	For each system	Inlet	Outlet	Each unit	Refining log	2 to 3 times/shift	
			Temp.	O	O	Pressure			
			Concentration	O	X	Electric power			
			PH	O	X				
			Freeness	O	O				
		Cyclone separator	Inlet pressure Outlet pressure Concentration				Refining log	Twice/shift	
		Mixing box	Temperature PH Freeness				Refining log	Twice/shift	
	Paper making process	Stuff box	Stock gate Opening for white water				Paper making log	Every change	
		Head box	Head				Paper making log	Every change	
		Wire part	Degree of suction vacuum				Paper making log	Every 2 hrs	
			Life of wire					Cumulative hrs	
		Press part	Pressure				Paper making log	Every change	
			Frequency of breaking wet paper					Frequency/shift	
			Life of blanket					Cumulative hrs	
		Dryer part	Speed				Paper making log	Every change	
			Steam, pressure, flow and exhaust pressure					Every 2 hrs	
			Frequency of breaking paper					Each time	
			Weight and thickness					Per reel	
			Paper moisture					Once/shift	
			Paper strength					Twice/shift	Based on running tests.
			Size					Per reel	

		Process	Item		Responsible party	Frequency	Remarks
Periodical test	Check raw materials and equipment function	Raw material test	Purchased pulp	Make sheets according to "standard test" and carry out quality test.	Tester	Once/month	Monthly test report. The standard test method conforms with TAPPI and JIS methods. However, it is modified by the branch.
		Raw materials after screening	By sampling	Measure concentration, temperature, PH and freeness. Then make sheets and carry out quality test.			
		Raw materials after refining process.	By sampling	the same as above.			
		Dust removing rate	By sampling	According to "standard test method."	Tester	Once/month	the same as above.
Inspection of equipment	Preparatory procedures for perfect operation and maintenance to equipment operating efficiency. Keeping high operating efficiency.	Screen-related	Screen mesh Concentrator wire	Check clogging and breakage, and clean	Site	Once/month	
		Dust catcher related	*Cyclone separator*	*Pressure gage*	*Site*	*During shut-down.*	
				Check the smoothness of the interior, repair and replace.			
				Check and clean the reject tail.	Site		
		Wire part	Wire	Check clogging in holes, and repair.	Site	During shut-down.	
			Table roll	Check deformation and level, and adjust.	Site	"	
			Bat	Check clean and polish the interior.	Site	"	
			Suction box	Check the smoothness of upper surface, and polish.	Part requiring maintenance services.	"	
				Clean the interior.	Site		
				Adjust seals.			
			Breast roll Couch roll	Clean and check.	Site	"	
		Press part	Press roll	Check, adjust and replace the crown	Part requiring maintenance services.	During shut-down.	
				Check and adjust the press.	"	"	
			Blanket washer	Clean and check.	Site	"	
			Shower	Clean and check.	Site	"	
		Dryer	Interior of dryer	Check repair and adjust the siphon.	Part requiring maintenance services.	During shut-down.	
			Dryer doctor	Check, repair and adjust.	"	"	
			Steam injection	Check and repair.	"	"	
			Hood	Check and repair.	"	"	
			Air heater	Check and repair.	"	"	
			Trap	Check and repair.	"	"	

Table III–2–11 Dehydration rate for paper machine
(In the case of printing paper)

		Wire part	Press part	Dry part	
					
(Thailand) "K" company	Concentration	0.7% 20%	40%	98%	(Paper moisture 2%)
	Quantity of dehydrated moisture/ 1 kg of paper	137.86 kg	2.50 kg	1.48 kg	141.84 kg
	Dyhydration rate	97.2%	1.8%	1.02%	100%
	Dehydration rate for the interior of part	97.2%	62.5%	98.7%	–
(Japan) "E" factory	Concentration	0.6% 20%	44%	93%	(Paper moisture 7%)
	Quantity of dehydrated moisture/ 1 kg of paper	161.67 kg	2.73 kg	1.19 kg	165.60 kg
	Dehydration rate	97.6%	1.7%	0.7%	100%
	Dehydration rate for the interior of part	97.6%	68.2%	93.7%	

The test results of "E" mill's laboratory in Japan for the finished product of "K" company and those for the similar finished product of "E" mill are shown in Table III-2-12.

Based on this data, it is apprent that printing and writing paper of "E" mill has the following advantages over the finished product of "K" company.

(1) Higher density and air permeability (it is presumed that the pressure applied by the press is high).

(2) Higher smoothness

(3) Less dust

(4) Higher moisture content

Table III-2-12 Quality of printing and writing paper

		Actual results of quality test and standard value (at 20°C 65% RH)						Actual operating conditions and targets	
		Weight (g/m^2)	Thickness (mm)	Density (g/m^2)/ mm x 100)	Smoothness (sec.)	Air permeability (sec) Felt side/ wire side	Dust (mm^2/m^2)	Reel moisture %	Paper break frequency/ day
"K" co. of Thailand white paper		49.1	0.074	0.66	32/24	6	29.7	1 ~ 2	9 ~ 10
"E" factory of Japan printing paper		50.8	0.062	0.82	75/60	25	1	6.3	1
"K" co. of Thailand white paper		62.4	0.113	0.55	6/4	13	17.3	1 ~ 2	9 ~ 10
"E" factory of Japan drawing paper		62.3	0.114	0.55	6/4	13	2	6.2	1 max.
"E" factory Standard quality value	Basis weight 50 g/m^2 printing paper		0.065 ±0.004	—	75±20	20±5	2 max.	6.0	2 max.
	Basis weight 64 g/m^2 printing paper		0.079 ±0.004	—	75±20	20±3	2 max.	6.0	2 max.
	Basis weight 65 g/m^2 printing paper		0.120 ±0.004	0.54	15 max.	10±5	2 max.	6.0	2 max.

The high moisture content of paper means the lower level of steam consumption for the dryer. This signifies that the texture composition of paper in the wire part is satisfactory and sufficient water squeezing on the press is carried out uniformly across the entire width of wet paper.

If the density of wet paper having satisfactory texture and uniform quality across the entire width is increased through pressing, the strength of wet paper will be improved. In addition, the tension for paper feed is also even on account of the uniform quality across the entire width. If the frequency of paper break is reduced, and the dust content is lessened, the concern about paper break will be further eliminated.

Further, the high content of moisture in paper helps improve the degree of smoothness on the calender, and maintain the high quality easily.

The high content of moisture of paper means an advantage not only in the area of energy but also in the domain of production efficiency, yield and quality.

In the dryer of "E" mill, it is arranged so that the drying speeds of the dryer groups in the front, middle and back rows may be automatically controlled by paper shrinking tension.

The feed rate of "K" company's paper machine is 130 to 140 m/min and that of "E" company's paper machine 500 to 600 m/min. The requency of paper break is approx. 9 to 12 times/day for "K" company and approx. 1 time/day for "E" mill.

Table III-2-11 shows the difference of approx. 20% in the water vaporization rate of the dryer part and the significant difference in the steam consumption (the water vaporization rate is 15%, even when compared to the moisture content of paper at both mills estimated at

2%). This means that the dehydration capacities of these mills in the press part must be different. 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 the paper machine and sheet formation in the wire part. If there are large amounts of fibrous flocks and foreign matter, it is impossible to expect the formation of high-quality sheets in the wire port. 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, fibrous flocks and foreign matter darken the paper, i.e. causing fish eyes. In order to prevent this phenomenon, overdrying tends to be carried out. But contraction often follows the former 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. The improvement of productivity is also impossible. It is said that paper is made by the beater (refining machine), and also that paper is made by the roller, doctor and shower.

The former signifies the satisfactory pre-treatment of raw materials for paper, and the latter, the perfect maintenance of sheet-making equipment. If paper-making technology, equipment maintenance and service procedures from the raw material mixing process to the drying process are soundly established, it is possible to promote energy conservation at the paper mill to a considerable extent. When putting an emphasis on refining process, the removal of foreign matter, elimination of shieves and fibrillation can be realized. If the sheet is formed, its texture should be made of smooth and tightly binding fibers.

As to the equipment such as roller, doctor and shower, make sure that those well maintained to the design for their purposes are always used. To cite a few examples, when the center of the table roll in the wire part is deviated, raw materials would spatter, causing an uneven texture. And also the wet paper after pressing would show a quantitative unevenness on account of uneven moisture distribution, and steam consumption at the dryer would increase. On top of that, paper break would occur due to irregular shrinkage caused by non-uniform drying.

In the press part, if the doctor touches incorrectly, water around the doctor moistens the blanket, resulting in the uneven distribution of moisture in the wet paper. On the other hand, in the dryer part, refuse would be mixed into the paper, causing its qualtitative degradation or paper break or increased steam consumption.

If the spray is irregular because of clogging in the shower holes or scales accumulated inside the pipe spout that would cause the following:

- In the wire part, partial wire mesh is clogged and the texture matching that portion becomes thin.
- In the press part, the blanket is heavily soiled and that portion dehydrates moisture unsatisfactorily. This situation brings about uneven drying and paper break.

In conclusion, the wet paper shall have the least possible percentage of fibrous flocks and foreign matter and a required fibrous strength with a uniform sheet formation. This wet paper shall be uniformly dehydrated across its entire width as far as circumstances allow. In the dryer part, the effective thermal transmission and the uniform vaporization of moisture shall be realized. The above represents energy conservation technology at the paper mill.

To look at the test results for paper in the Kingdom of Thailand, the values of density, smoothness and air permeability are low, and this fact means the press pressure is apparently low. The presumable reasons for this insufficient pressure are the mixing of foreign matter, low-quality sheet formation, unsatisfactory blanket conditions, and inadequate maintenance of equipment.

In the dirt of white paper shown in the paper quality test chart of Table III-2-12, ink-like substance originating from old paper is seen scattered. This does not have to do with paper break. However, particles shaped like scales or metal pieces, sand or shieves (such as knots and saw dust) and slime or lump of starch powder would cause paper break. It is possible to separate scales, metal pieces and sand by means of the cyclone separator. Fibrous flocks also can be unravelled by a refiner and removed by a screen.

4.4 Improvement of dryer ventilation

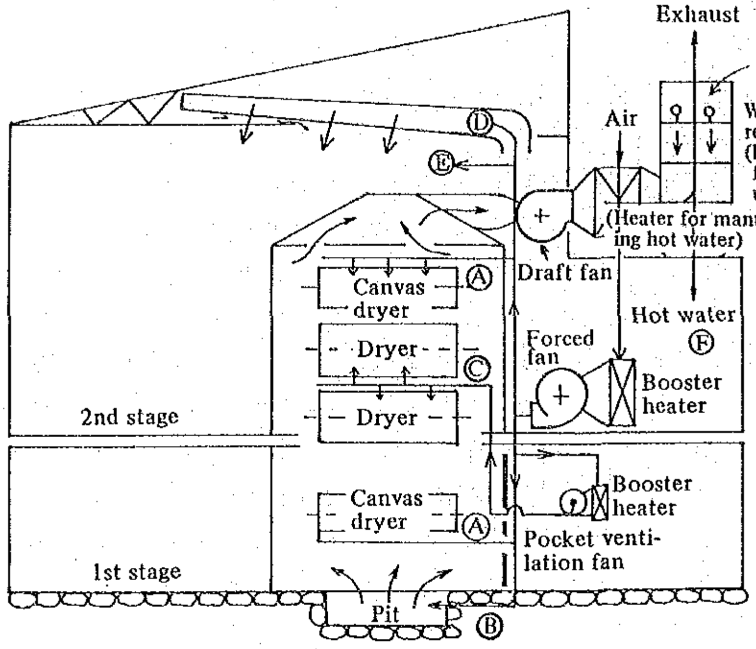
In the case of the closed hood, it is suggested that the ventilation system be built into the paper machine with the dryer. Otherwise, the drying effect would be reduced. The well-balanced air supply and exhaust, and appropriate temperature will be contributing factors toward the effective consumption 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 wash and pulp wash 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 Fig. III-2-16. The waste heat recycling flow and the ventilation control system are shown in Fig. III-2-17.

The pocket ventilation system is effective for equallizing 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 yet to be resolved. The devices such as PV roll and Grewin nozzle incorporated in the canvas roll are also available. It may be required that a device to inject air into a part where vapor is stagnant be fabricated by an individual company according to its equipment at work.

It is further conceivable for energy conservation in the dryer part of the paper machine to suspend polyethylene film from the side wall of the hood to form a semi-closed hood for controlling excess air. This is considered a duty on the part of a vapor machine tender.



A) Draft for canvas drying

B) Draft for pit

C) Draft to auxiliary dryer (PV roll or Grewin nozzle for pocket ventilation)

D) Draft for paper chamber ceiling (for prevention of dewing and for chamber ventilation)

E) Draft for press part (for prevention of dewing)

F) For hot water of pulp section and blanket wash (for washing pulp)

Fig. III–2–16 An example of "Closed Hood Ventilation System"

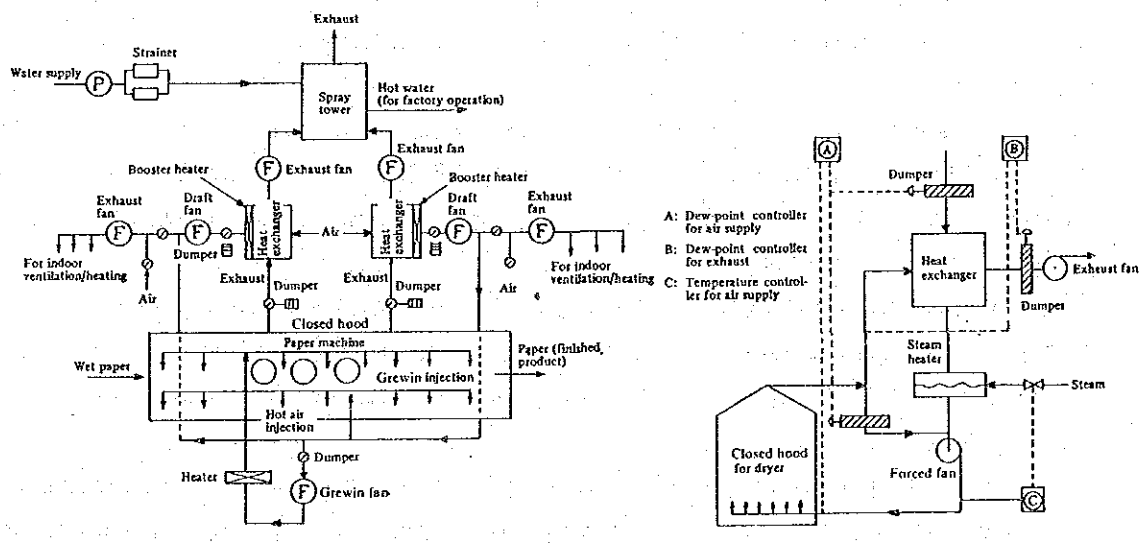


Fig. III–2–17
Waste heat recovery flow for closed hood ventilation system and control system

4.5 Others

4.6 Improvement target for unit energy consumption rate

4.6.1 Target unit energy consumption rate for printing and writing paper

With regard to the paper mills subjected to the at-site survey for fiscal 1982 in the Kingdom of Thailand, printing and writing paper mills showed an abnormally low unit energy consumption rate. Not only the energy saving measures but also steps for the improvement of the entire sheet making technology shall be performed preferentially.

It is suggested that techniques for quality and equipment control be actively adopted together with sheet making technology to promote energy conservation step-wise. The target unit steam and electric power consumption rates in each step are shown in Table III-2-13.

Table III–2–13

	Unit consumption rate of total energy $\times 10^3$ kcal/t	Unit consumption rate of steam t/t	Unit consumption rate of electric power kWh/t
First step target value	6,000	7.5	2,100
Second step target value	4,500	5.5	1,500
Third step target value	3,000	3.5	1,000

Steam: electric power = 70%:30%
Steam: (standard steam) 639 kcal/kg
Electric power: 860 kcal/kWh

The ratio of energy consumption is based on the present ratio of 70% for steam and 30% for electric power.

The third step target is not necessarily at a high level, but is at the lowest level of the existing paper making industry.

4.6.2 Target unit energy consumption rate for kraft paper

Regarding kraft paper for the multi-ply bag of approx. 70 to 80 g/m^2 and packs, the remarkable performance of setting and attaining the target unit energy consumption rate by the Siam Kraft Paper Co. is pointed out. Table III-2-14 shows the target unit energy consumption rate based on the above-mentioned performance and available data of the Japanese paper making industry.

Kraft paper requires qualitative strength, so the consumption ratio of virgin pulp for this paper is high. Accordingly, the consumption ratio of electric power at the refiner is slightly high.

4.6.3 Target unit energy consumption rate for core and board

The consumption ratio of used paper is high. Accordingly, the electric power consumption for beating is lower than for kraft paper. The consumption ratio of electric power for the core and board is low as whole. The target unit energy consumption rate is shown in Table III-2-15.

Table III–2–14

Unit consumption rate of total energy $\times 10^3$ kcal/t	Unit consumption rate of steam t/t	Unit consumption rate of electric power kWh/t
2,800	3.2	850

Steam: standard steam 639 kcal/kg
Electric power: 860 kcal/kWh
Steam: electric power = 74% : 26%
(energy consumption ratio)

Table III–2–15

Unit consumption rate of total energy $\times 10^3$ kcal/t	Unit consumption rate of steam t/t	Unit consumption rate of electric power kWh/t
2,000	2.6	400

Steam: standard steam 639 kcal/kg
Electric power: 860 kcal/kWh
Steam: electric power = 83% : 17%

III. Guideline for Rationalization of Energy Use

3. Textile

Contents

1. Character of Guide Line

This Guide Line is a summary of technical matters considered important for the promotion of energy saving at the factories of the textile industries. The Guide Line is to be used for the following purposes.

1) (1) As technical reference for factory's engineers when they plan to rationalize use of energy in the factory.

(2) As a diagnostic guidance manual.

(3) As referential data for determining the progress of rationalization.

(4) As a text for seminars.

2) Descriptive level which should be understandable by engineers having only 4 to 5 years' experience of actual service after college graduation, but not actually working in the subject industries.

3) In consideration of the present industrial status of the Kingdom of Thailand, the descriptive coverage is limited to the process-related matters of the factories which we diagnosed. Also, the basic items and numerical values regarding this process —energy-saving techniques and referential instances or actual records — are described.

It is hoped that the Guide Line prepared here will be further supplemented and substantiated by the addition of information obtained in future through NEA's own factory diagnosis and other means.

For information, the Guide Line contains standard values published by the Japanese Government (Ministry of International Trade and Industry) as a basis for judgement in promoting energy saving for factory managers through its notification.

(1) The standard values are the most frequent values (refer to Fig. III-3-1) of statistical distributions of numerous examples. As such they represent a realistic level for factory managers to attain without difficulty from the technical and economic points of view.

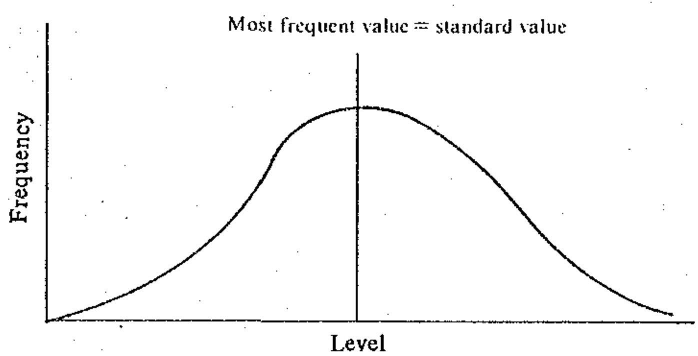


Fig. III–3–1

(2) The standard values do not necessarily represent the values which factory managers should be satisfied with after reaching them and also the minimum values which it must reach by all means. These values are rather those designed to improve the inferior value toward an average level, thus shifting the whole distribution of values into a better direction. Therefore, the most frequent value will be resought and a new standard value established after the elapse of a certain period.

The standard value establishment plan described in the report was prepared based on these standard values considering the present industrial status of the Kingdom of Thailand.

These standard values will be a starting point for the establishment of standard values for the rationalization of energy use in industry of the Kingdom of Thailand. It is recommended that the Kingdom of Thailand itself accumulates data during factory diagnosis to be put into practice, and evaluates it periodically and revises or newly establishes standard values.

2. Characteristics of Energy Consumption

2.1 Manufacturing process and main facilities

There are a wide variety of textile products and the process from material to product is divided: the process from chemical materials to synthetic fiber; spinning process to manufacture yarn from natural fiber and synthetic fiber; weaving process to manufacture woven textile from yarn; and dyeing process to dye yarn and woven textile. The products are divided into natural fibers such as cotton, silk, wool, etc., and man-made fibers into such as rayon and synthetic fibers. Many kinds of yarns are manufactured according to class and length of fiber, twisting method and fineness.

There are many weaving methods and finishing methods to give variety to the feel of woven textile, and different processes such as dipping dyeing and printing methods, etc. are selected for dyeing also.

Here, we will not refer to expertise, but describe only the product and process which are observed in the factories diagnosed by us in the Kingdom of Thailand and general matters.

(1) Synthetic fibers

In synthetic fibers, there are rayon, acetate, etc. manufactured by chemical treating of natural cellulose, and synthetic fibers manufactured by synthetic reaction from chemical materials. Synthetic fibers have many classes such as nylon, polyester, polyacrylnitrile, polyvinyl alcohol, etc.

Taking the case of nylon which was diagnosed by us, we explain. Manufacturing process of nylon fiber is shown in Fig. III-3-2. Although nylon has many classes, it is nylon 6 from caprolactam that is being manufactured in the Kingdom of Thailand. Adding water and catalyst to caprolactam and heating, it is polymerized into nylon 6. Since this contains water-soluble unreacted materials, extrude in the form of string into water, solidify, cut into chips and clean with hot water. After drying the chips, feed them into spinning equipment for melting, extrude through pores in the spinning nozzle, and solidify them into fibers by cooling in air for reeling. After spinning, stretch three to four times and put their molecular arrangement in order to increase the strength.

On the other hand, concentrate the unreacted materials extracted into hot water in evaporation and distillation towers and remove impurities for re-use as raw materials.

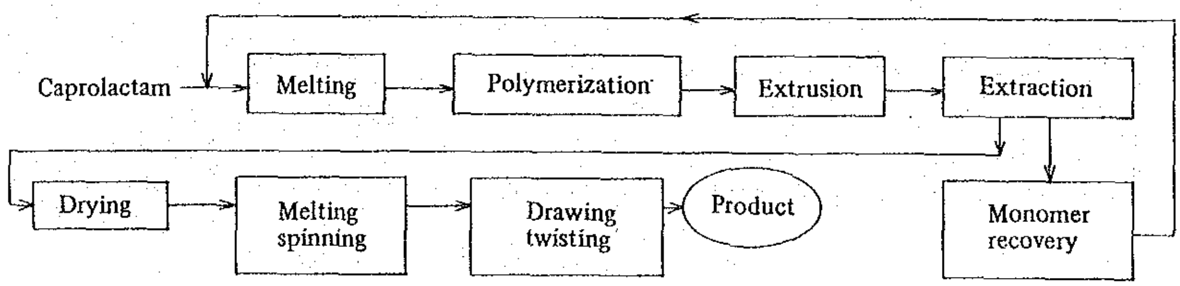


Fig. III–3–2 Manufacturing process chart for nylon filament

The abovementioned processes to entry of the spinning equipment are similar to the chemical industry and contain both equipments handling fluid consisting of tower, tank, pipe and pump, and equipment handling solids such as dryer, centrifugal separator, etc.

Since these equipments handle organic compounds and are easily damaged by local superheating, a jacket type steam heating is mainly used and thermal fluid and electric heater are partially used. A boiler and chiller for air conditioning in spinning process are used for utilities facilities.

(2) Spinning

Spinning is a process to manufacture cotton yarns from raw cotton and synthetic fiber, and is further divided into processes as shown in Fig. III-3-3.

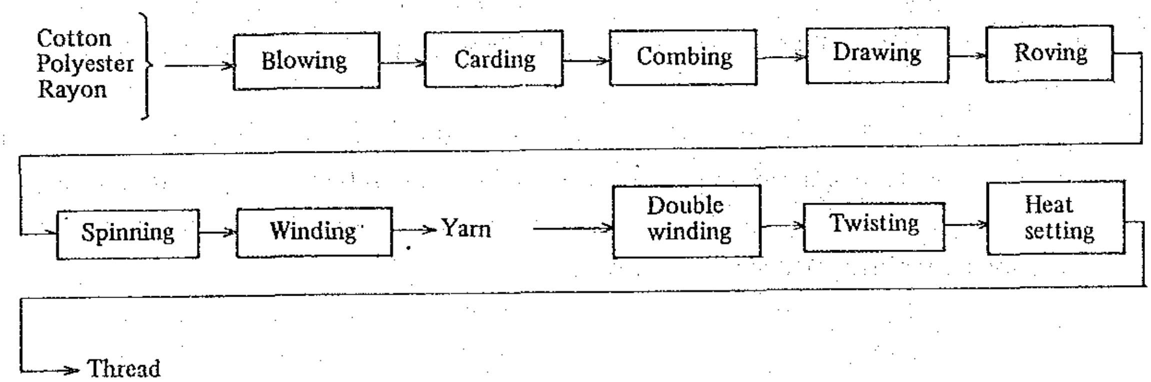


Fig. III–3–3 Manufacturing process for cotton spinning and weaving

Since raw cotton is sent in a firmly compressed state to facilitate transport, remove foreign matters and short fibers contained therein while beating with a roller having pins and beater to untie (See Fig. III-3-4).

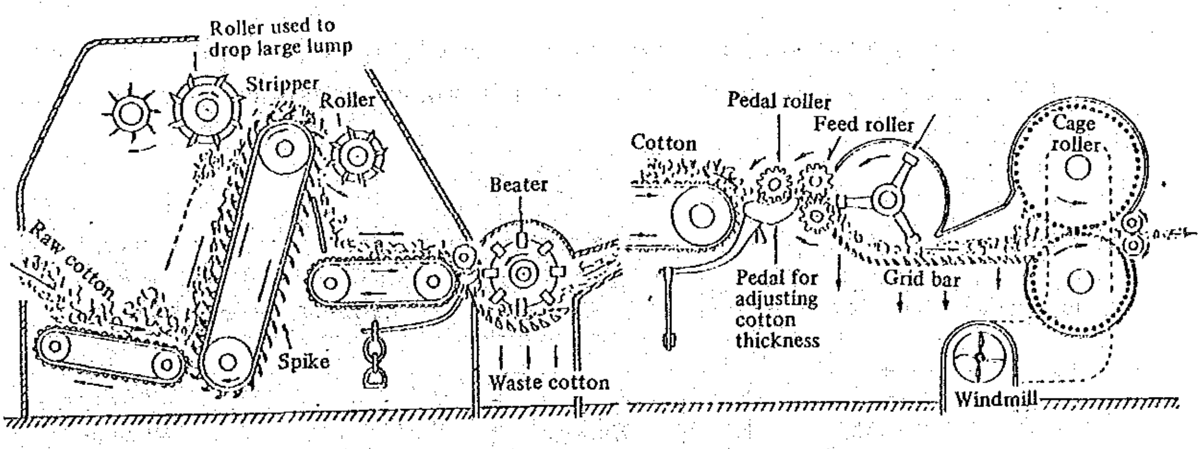


Fig. III–3–4 Blowing machine and beater

Since the cotton fed out from the beater still contains small lumps and fiber tangles and individual fibers are not stretched out, feed to the carding machine (See Fig. III-3-5) to further untie well, stretch out, and remove short fibers. Collect only the long fibers stretched out thus, arrange them in parallel and turn into string-like slivers 2 to 3 cm in diameter.

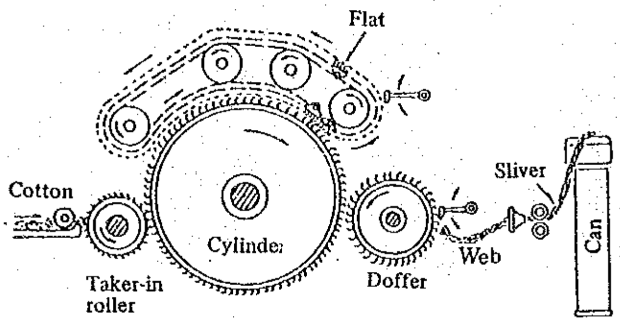


Fig. III–3–5 Carding machine

To manufacture better quality yarns or stronger yarns, apply to a comber to arrange the fibers with uniform length and remove short fibers and the remaining foreign matters. Next, to correct any unevenness in sliver fineness, bundle several pieces of them and apply a drawing frame to stretch them to the original thickness. Since about 8 pieces are usually bundled and stretched out to 8 times, the unevenness in fineness becomes almost 1/8. Repeat this further 2 to 3 times to lessen the unevenness.

Slivers with uniform fineness enter the roving process. These slivers are further stretched out, lightly twisted and are formed into yarns. After repeating this 1 to 2 times, they are fed to the next spinning.

One example of a ring spinning machine is as shown in Fig. III-3-6 and the yarn is fed out from E, passes through F, passes through B (traveller) travelling along ring A, and is rolled around D (bobbin). Since the bobbin rotates at a high speed of about 10,000 rpm and the traveller rotates in the same direction at a slightly slower speed, the yarn is twisted.

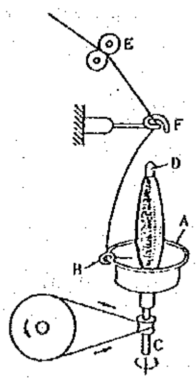


Fig. III–3–6 Ring spinning machine

A single yarn thus manufactured is used as-is or with 2 pieces or more twisted. Then, it enters the winding process and is wound in the form of hank, cheese, or cone according to the use application (See Fig. III-3-7) and applied to a heat setter to prevent the untwist.

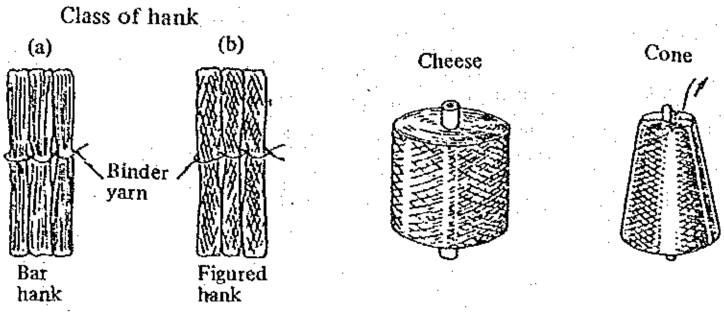


Fig. III–3–7

(3) Woven textile

Woven textile is cloth manufactured by crossing warp and weft perpendicular to each other, and various products are manufactured by respective yarn classes and different crossing methods (See Fig. III-3-8).

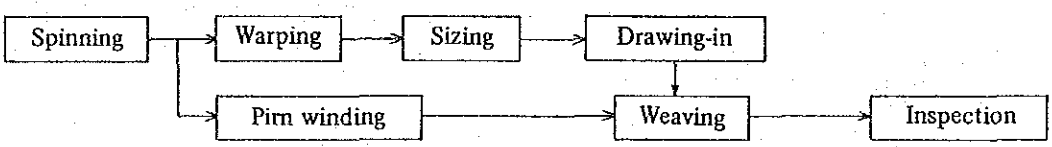


Fig. III–3–8 Weaving process

Mechanism of a loom is based on repetition of passing a weft through warp group divided into two; up and down and fastening with a reed.

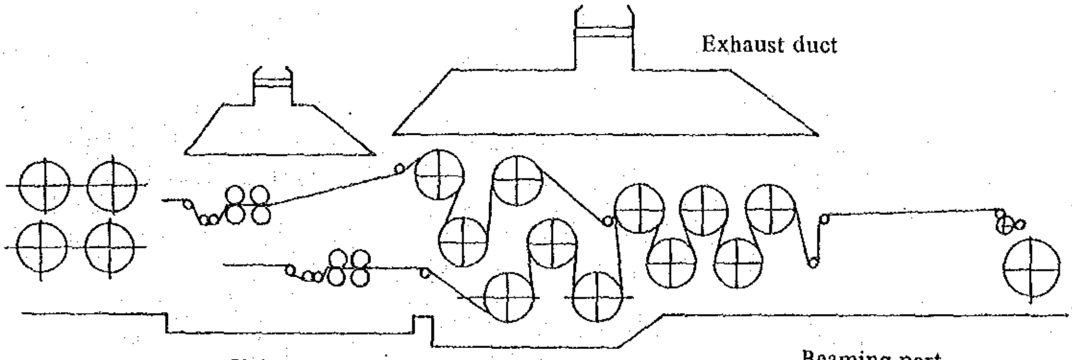
A mechanism of striking a shuttle mounted with a weft alternately in both directions to pass a weft through is generally used. Since this shuttle must be rapidly striked, rapidly stopped at the opposite end, and immediately striked in the reverse direction to increase the production speed, the energy consumption is great and the noise is severe.

Size the warp beforehand to prevent hairiness due to friction among yarns and to improve the weaving performance. The sizing machine consists of four parts as shown in Fig. III-3-9.

(4) Dyeing

Dyeing is performed during a stage of yarn in some cases and during a stage of woven textile in some cases. Also, the dyeing method is mainly divided into dip dyeing and printing, and only the dip dyeing method was used in all the diagnosed factories.

For dyeing, the working process varies with class of the fiber and class of the dye, but it is basically performed by repetition and combination of the following five functions:



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

Fig. III–3–9 Construction of sizing machine

A) Adding:

By dip dyeing, printing, etc. give dye, assistant to the fabric.

B) Washing:

Wash with water or hot water and remove the impurities, surplus dye and assistant.

C) Dehydration:

Remove moisture contained in the fabric by mechanical measures such as pressing, vacuuming, and centrifugalizing, etc.

D) Drying:

Remove moisture contained in the fabric by evaporation through conduction heat (Cylinder dryer), convection heat (Hot air dryer), radiation heat (Infrared dryer), etc.

E) Fixing:

Applying heat, firmly fix dye, pigment, etc. on the fiber.

In addition, in the case of woven textile dyeing, preparatory process such as singeing, desizing, scouring, bleaching, heat setting, etc. and special work finishing such as non-shrink, wrinkle resistant, waterproofing treatment, etc. are performed. The cheese dyeing machine for yarn dyeing is of a vertical and cylindrical type and is equipped with a steam coil for heating at the bottom, and the workpiece set in a dye-carrier is able to be put in and took out from the top. Dye liquor is circulated by a pump and jetted alternately from the outside and inside of the workpiece for dyeing.

Hank dyeing machine is of a horizontal type with an open door in front and a hank hung on a hanger is jetted with dye liquor for dyeing while being rotated at a specified time.

Cheese after dyeing is dried with carrier in a vertical and cylindrical dryer as shown in Fig. III-3-10 and Fig. III-3-11. The hank is dried in a hanger type hot air dryer.

For woven textile dyeing, various types such as a Wins dyeing machine shown in Fig. III-3-12 are used.

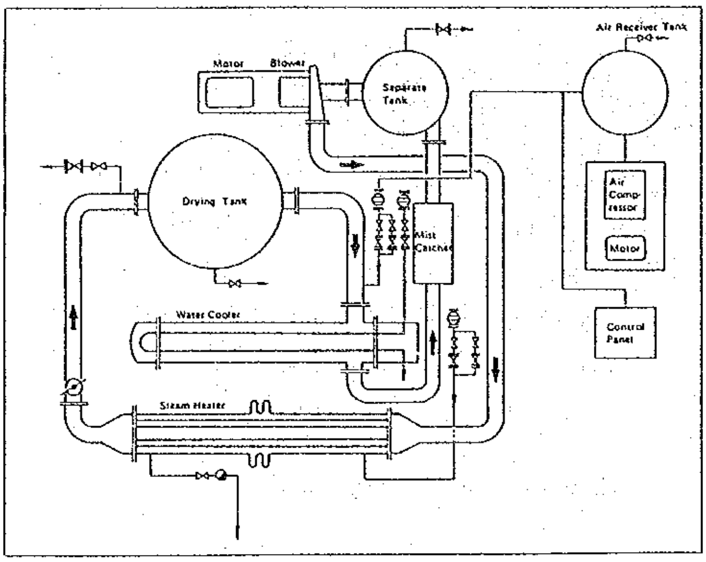


Fig. III–3–10

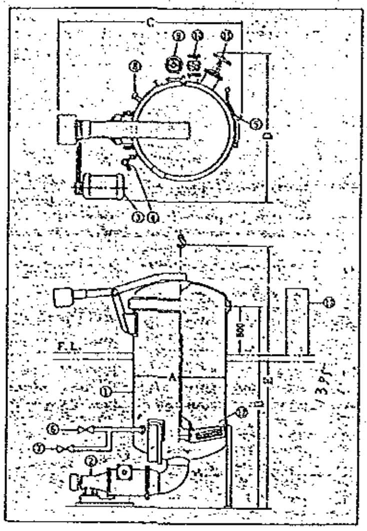
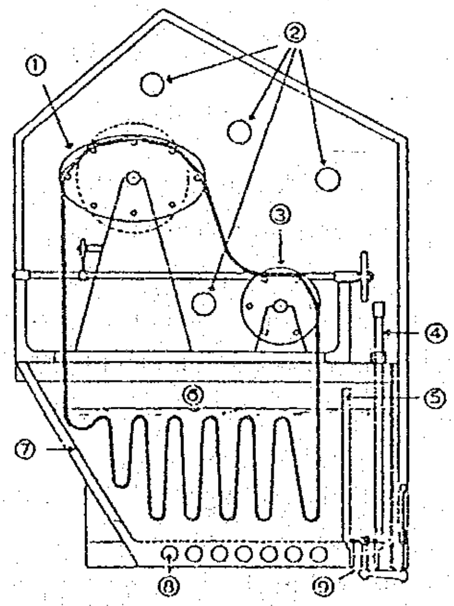


Fig. III–3–11



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

Fig. III–3–12 Internal construction of wins

2.2 State of use of energy

(1) Synthetic fibers

Energy in nylon factories is used as shown in Table III-3-1. Steam is considerably consumed (40 to 50%) for heating and pressure reduction in a monomer recovery process and electric power is mainly used for air-conditioning blowers and refrigerators.

Table III−3−1

Purpose	Equipment	Energy source
Caprolactam melting	Molten bath	Steam
Polymerization	Polymerization tower	Heating medium oil (electric heating)
Extraction	Extraction tank	Steam
Drying	Dryer, ejector	Steam
Monomer recovery	Distillation tower, ejector	Steam
Spinning	Molten spinning equipment	Heating medium oil (electric heating) · Electric power
Stretching	Stretching machine	Electric power
Air conditioning	Air conditioning plant	Electric power
Liquid transfer	Pump	Electric power
Dehydration	Centrifugal separater	Electric power

In the diagnosed factories in the Kingdom of Thailand, one is manufacturing nylon and polyester fibers and the other only nylon fibers, and it is meaningless to compare directly the consumption rate between the two. However, the consumption rate is about 500 l/t in fuel and about 4000 kWh/t in electric power for both.

Although the consumption rate for each product is not published in Japan, the trend of all the chemical fibers is shown in Table III-3-2. Also, the composition of chemical fibers on the said Table changed as follows:

Year	Viscose	Nylon	Acryl	Polyester	Others
1972	26.0%	18.4%	17.0%	23.9%	14.7%
1981	18.6	16.7	19.4	35.1	10.2

The changes in consumption rate contain this difference in product distribution, though the entire energy consumption rate lowers to about 60%.

(2) Spinning

Energy in the spinning process is consumed as shown in Table III-3-3 and electric power accouts for the greater part. Temperature and humidity of air are important

Table III–3–2 Transition of energy consumption and consumption rate in chemical textile industry in Japan

Year	Production thousand ton	Fuel oil			Purchased power					Total energy consumption rate converted in crude oil kl/t
		Consumption thousand kl	Consumption rate		Consumption million kwh	Consumption rate thousand kWh/t	Purchased power ratio %	Purchased power consumption rate		
			kl/ton	Converted in crude oil (x 1.05)				thousand kWh/t	Converted in crude oil (x 0.26) kl/t	
1972	1628.5	2372.5	1.46	1.53	4788.2	2.94	33.5	0.98	0.25	1.78
1973	1847.8	2576.0	1.39	1.46	5102.7	2.76	37.0	1.02	0.27	1.73
1974	1648.1	2372.6	1.44	1.51	4780.2	2.90	37.4	1.08	0.28	1.79
1975	1452.3	2168.5	1.49	1.56	4610.2	3.17	37.7	1.20	0.31	1.87
1976	1637.8	2278.0	1.39	1.46	4859.0	2.97	38.2	1.13	0.29	1.75
1977	1734.9	2121.0	1.22	1.28	4690.8	2.70	38.0	1.03	0.27	1.55
1978	1843.1	1947.0	1.06	1.11	4535.7	2.46	35.9	0.88	0.23	1.34
1979	1850.6	1845.0	1.00	1.05	4508.5	2.44	38.9	0.95	0.25	1.30
1980	1832.2	1630.9	0.89	0.93	4337.2	2.37	44.7	1.06	0.28	1.21
1981	1797.8	1417.4	0.79	0.83	3943.5	2.19	44.4	0.97	0.25	1.08

Note: Excluding kerosene, coal, etc.

Table III–3–3

Purpose	Equipment	Energy source
Cotton opening spinning	Spinning machine	Electric power
Twist fixing	Heat setter	Steam
Air conditioning	{ Blower Pump Refrigerator }	Electric power

factors in spinning mills to improve yarn slip, hold down cotton dust, and ensure good quality of yarns. Therefore, a value of optimum air condition according to class and fineness of yarns is determined as know-how in respective factories. The percentage of air conditioning to the electric power consumption depends upon the climatic conditions, and it is said to be 15 to 20% in the temperate regions, but it reaches 30 to 40% in the Kingdom of Thailand.

The electric power consumption rate in the spinning process is indicated per unit weight. Since the length per unit weight varies with fineness of the yarn and the value of the consumption rate will vary naturally. Therefore, to control the consumption rate in the mill, it is necessary to calculate the consumption rate for each fineness of yarn and also to determine the mutual conversion factor based on the actual results and control values converted to certain conditions.

For reference, energy consumption of all the spinning mills in Japan is shown in Table III-3-4.

Table III-3-4 Energy consumption of the whole spinning industry in Japan

Year	Production	Power consumption	Electric power consumption rate
	thousand t	million kWH	kWH/t
1979	1,319	4,509	3,418
1980	1,298	4,337	3,341
1981	1,183	3,944	3,334
1982	1,220	3,890	3,188
1983	1,173	3,846	3,279

Energy consumption of all the spinning mills in the Kingdom of Thailand is nearly 3,300 to 5,200 kWh/t and this is a high figure even if the difference in the climatic conditions is taken into consideration.

(3) Woven textile

Energy in the weaving process is used as shown in Table III-3-5 and electric power still accounts for the greater part. The weaving process is very similar to spinning in use of energy, and also in this case, the consumption rate depends upon the weaving method and width, etc.

Table III-3-5

Purpose	Equipment	Energy source
Weaving	Looms	Electric power
Sizing	Sizing machine	Steam
Air conditioning	Blower Pump Refrigerator	Electric power

For reference, electric power consumption of all the weaving industries in Japan is shown in Table III-3-6.

Fig. III-3-6 Power consumption of the whole woven textile industry in Japan

Year	Production	Power consumption	Electric power consumption rate
	million m^2	million kWH	kWH/m^2
1979	6,757	2,325	0.344
1980	6,737	2,285	0.339
1981	6,431	2,273	0.353
1982	6,270	2,181	0.348
1983	6,470	2,236	0.346

In examples in the Kingdom of Thailand, the production is indicated in length and the consumption rate is 0.4 to 0.5 kWh/yd.

(4) Dyeing

Energy in the dyeing process is used as shown in Table III-3-7 and the greater part of thermal energy is consumed in this process.

Table III–3–7

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

Although there are a wide variety of dyeing methods used, water nearly 100 times the weight of the fiber itself is used in all cases and heating, cooling and drying is repeated. Therefore, a lot of energy is consumed; energy accounts for more than 10% of the cost and requires most of the energy conservation.

We, in Japan, have strived to save energy as can be seen from the actual results of the woven textile dyeing in Table III-3-8 and saved fuel oil by 13%. However, the electric power consumption rather increased because of automatization and increased antipollution devices.

Table III–3–8 **Woven textile, etc. dyeing and finishing industry**

Item \ Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Fuel oil (thousand kℓ)	1495	1301	1380	1371	1353	1323	1263	1220	1273	1265	1281
Electric power (hundred million·kWH)	10.7	9.8	10.8	11.3	12.0	12.3	12.6	12.2	12.7	12.7	12.8
Processing amount (hundred million·m²)	72.9	61.3	69.4	71.0	71.7	71.4	71.4	71.3	73.4	71.0	73.1
Consumption rate											
Fuel oil ℓ/m³	0.205	0.212	0.199	0.193	0.189	0.185	0.177	0.171	0.173	0.178	0.175
(1973 = 100)	(100)	(103)	(97)	(94)	(92)	(90)	(86)	(83)	(84)	(87)	(85)
Electric power kWH/m²	0.147	0.160	0.155	0.159	0.167	0.172	0.176	0.171	0.173	0.179	0.175
(1973 = 100)	(100)	(109)	(105)	(108)	(114)	(117)	(120)	(116)	(118)	(122)	(119)

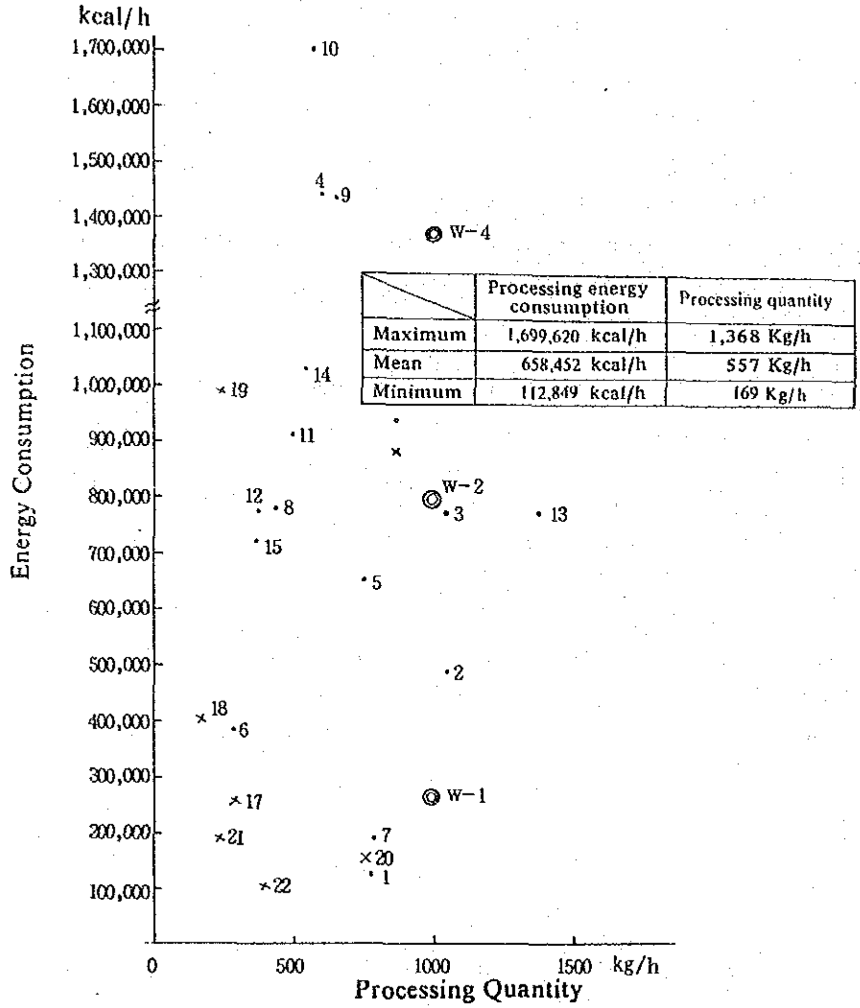
Since yarn dyeing is mostly used in the diagnosed factories in the Kingdom of Thailand, direct comparison with these figures cannot be made.

Energy consumption for dyeing depends upon various factors. For example, bath ratio, temperature and processing time vary with the class of fibers, width of cloth, light and shade, bleaching or no bleaching, class of dye, dyeing method, processing speed, etc. Therefore, they determine a specified conversion factor according to dyeing conditions and control is made by converting the consumption rate in some factories. Fig. III-3-13 to Fig. III-3-19 show the relationship between treating capacity and energy consumption for various dyeing machines investigated in Japan. Also, for reference, examples of the energy consumption rate for each process are shown in Table III-3-9. Since the dyeing conditions are different each case, the

Table III–3–9 Examples of energy consumption rate each process

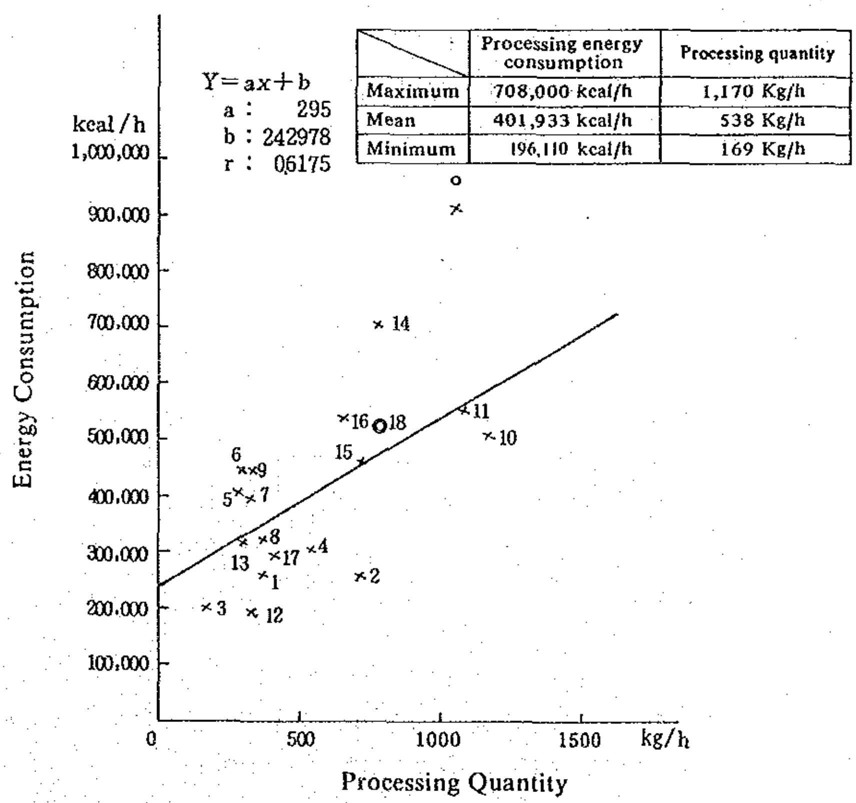
Process	Short fiber				Long fiber			
	Main material	Mean fabric weight	Energy consumption rate		Main material	Mean fabric weight	Energy consumption rate	
			Fuel	Electric power			Fuel	Electric power
		g/m²	ℓ/m²	kWH/m²		g/m²	ℓ/m²	kWH/m²
Preparation process	Cotton and cotton/synthetic fiber	110~ 180	0.085~ 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

dispersion of values is great. There are too many classes of dyed products and, therefore, it is impossible to establish a standard consumption rate uniformly for the dyeing process.



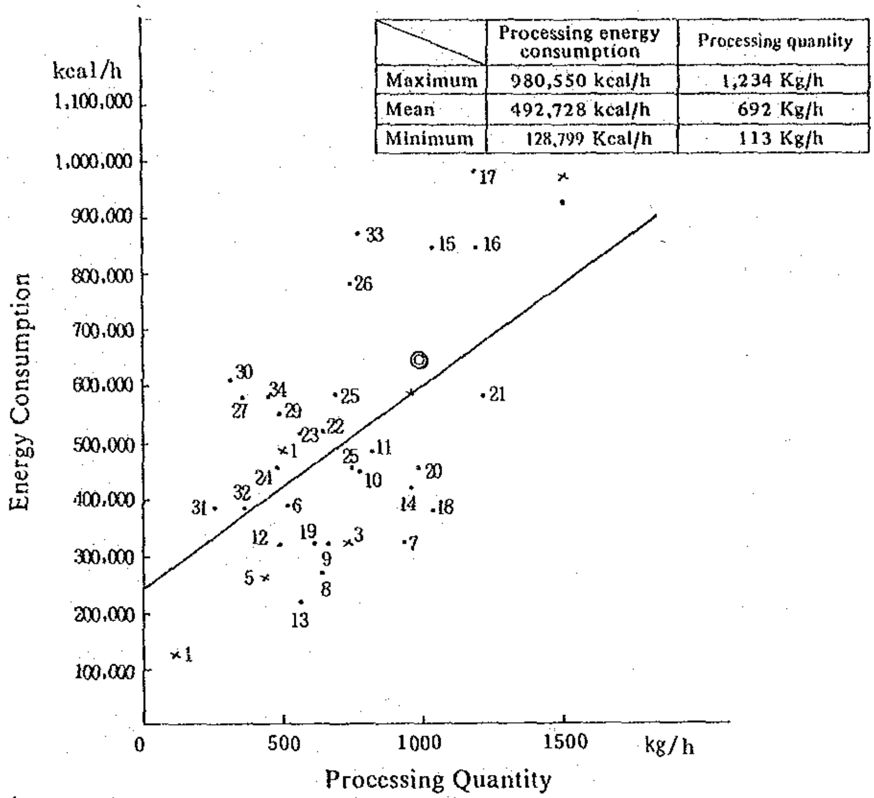
	Processing energy consumption	Processing quantity
Maximum	1,699,620 kcal/h	1,368 Kg/h
Mean	658,452 kcal/h	557 Kg/h
Minimum	112,849 kcal/h	169 Kg/h

Fig. III-3-13 Washer



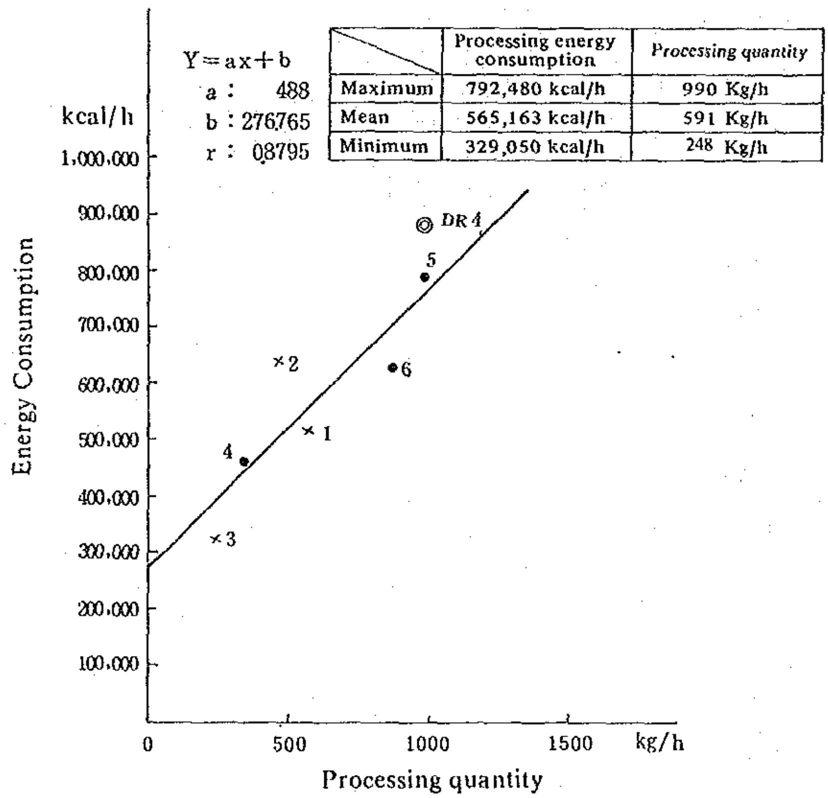
	Processing energy consumption	Processing quantity
Maximum	708,000 kcal/h	1,170 Kg/h
Mean	401,933 kcal/h	538 Kg/h
Minimum	196,110 kcal/h	169 Kg/h

Fig. III-3-14 Short loop dryer



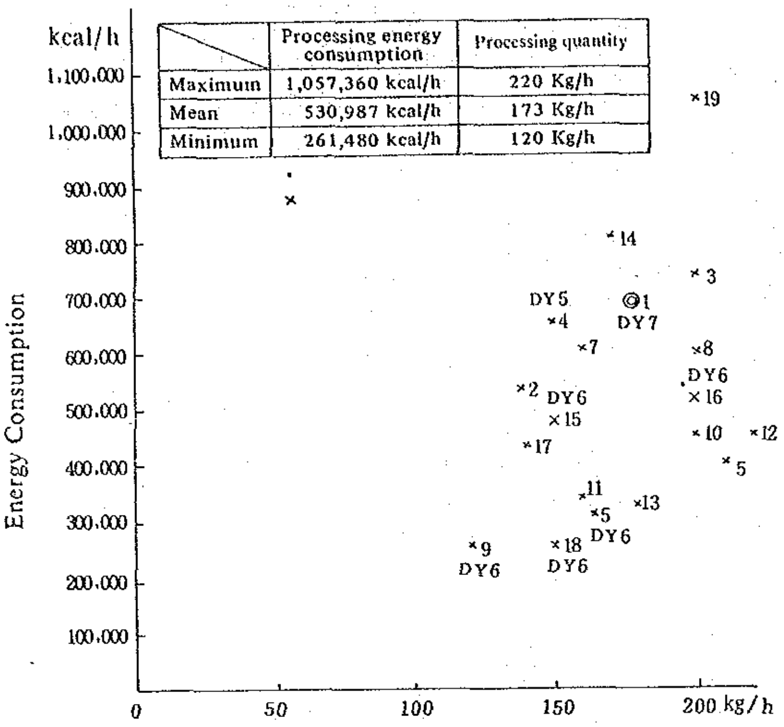
	Processing energy consumption	Processing quantity
Maximum	980,550 kcal/h	1,234 Kg/h
Mean	492,728 kcal/h	692 Kg/h
Minimum	128,799 Kcal/h	113 Kg/h

Fig. III–3–15 Cylinder dryer



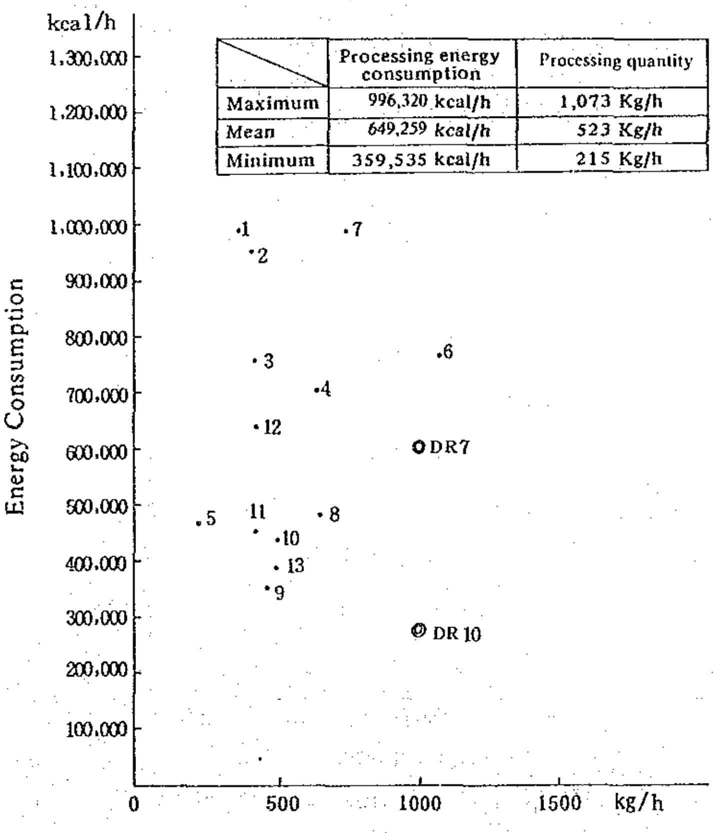
	Processing energy consumption	Processing quantity
Maximum	792,480 kcal/h	990 Kg/h
Mean	565,163 kcal/h	591 Kg/h
Minimum	329,050 kcal/h	248 Kg/h

Fig. III–3–16 Suction drum dryer



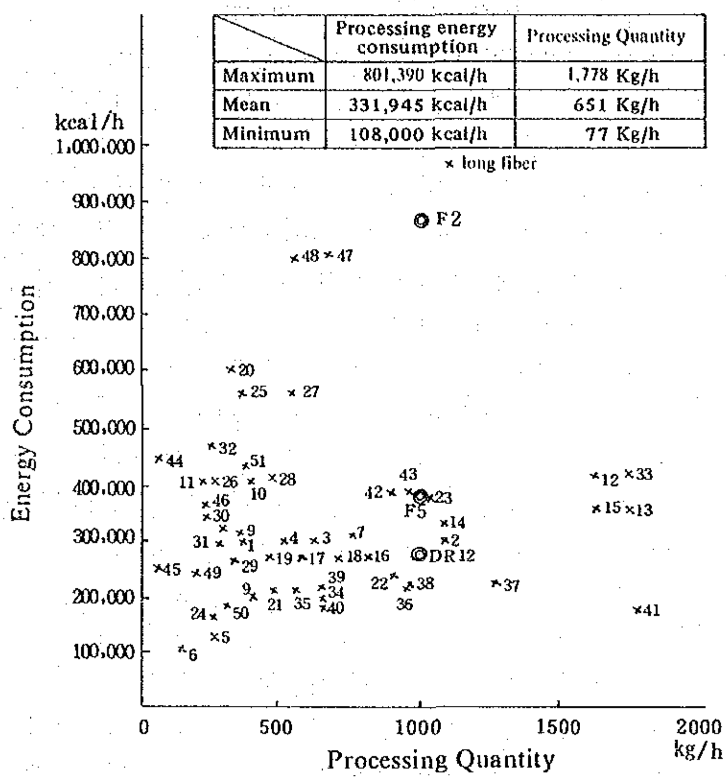
	Processing energy consumption	Processing quantity
Maximum	1,057,360 kcal/h	220 Kg/h
Mean	530,987 kcal/h	173 Kg/h
Minimum	261,480 kcal/h	120 Kg/h

Fig. III–3–17 Liquid flow dyeing machine



	Processing energy consumption	Processing quantity
Maximum	996,320 kcal/h	1,073 Kg/h
Mean	649,259 kcal/h	523 Kg/h
Minimum	359,535 kcal/h	215 Kg/h

Fig. III–3–18 Tenter dryer
(including multi-stage type)



	Processing energy consumption	Processing Quantity
Maximum	801,390 kcal/h	1,778 Kg/h
Mean	331,945 kcal/h	651 Kg/h
Minimum	108,000 kcal/h	77 Kg/h

Fig. III–3–19 Heat setter

3. How to Manage Energy

In order to improve the efficiency of energy consumption, productivity and product quality as well as raise their overall level, it is essential first to use facilities well adjusted and maintained to the purpose and to operate them correctly. It is most effective for energy conservation to reduce the incidence of equipment failure and increase product yield. Secondly, it is required that those engaged in energy management study the possibilities of further improving the existing facilities and operating method and pursue better means through repeated surveys and factory experiments.

Accordingly, it is not exaggerating to mention that the consciousness and willingness of the total factory employees would influence the actual performance of the factory. And it is important to raise the level of factory management which encourages the employees to have such consciousness and willingness. It is defined that energy management is a systematic effort to achieve energy conservation.

3.1 Clarification of Management Policy

Following the soaring of energy prices, the factory owner and manager have grown more concerned about energy conservation. In order to promote this tendency on a company level instead of letting it merely stay within the frame of the owner's mind as a desire, it needs to be clarified toward all the employees that the top management has the intention to tackle the energy conservation problem seriously as a company policy. In positive terms, the target should be clarified quantitatively; such as what percentage of energy consumption per ton of finished product should be reduced. Simultaneously the restrictions such as the ceiling of annual investment and deadline for pay back time should be clarified.

As explained above, the top management should clearly show the way to proceed on to the employees. Then in turn, the latter become confident about their jobs meeting the direction set by the former. Further, both can develop a smooth collaborative relationship because everybody involved is spiritually aligned in a unified direction.

Since the target of the top management is shown as a comprehensive one for the whole factory, each section and department should set concrete subtargets which do not require too much time and try their best effort to achieve these subtargets. These subtargets should be set concerning items for which any counter-measures can be taken by section and department personnel within their own responsibility range to attain the target set by the top management. As the said target is shown in a familiar and understandable form, it is easy to expect even employees of the lowest rank to fully understand the subtargets and extend their cooperation in attaining them.

When setting subtargets for each section and department, it is suggested that the committee described later or others study if such subtargets would be appropriate for achieving the overall target.

3.2 Arrangement of System for Promotion

In a campaign, for energy conservation where various classes of people take part, persons who play a part to promote the activities of all as a nucleus. If the factory is small, an individual person may be a promoter, but if the factory is large, a section for promotion is sometimes established.

This position should be occupied by a top-notch person and he should always be careful about a progress in energy conservation status and look into a cause, if there is a delay, then try to treat problem.

In concrete terms, the assignments of the position are as follows: the grasping of actual energy consumption, comparison of actual energy consumption with plans, invitation and checking of ideas about improvement, budgetary distribution, management of work progress and evaluation of actual works, mapping-out of education programs, preparations for committee meetings, etc.

The committee is effective for adjustment so that inter-disciplinary understanding may be realized among sections and departments such as manufacturing, sales, raw material purchasing, equipment maintenance and servicing, and accounting, and countermeasures may be put into practice smoothly. At the committee meeting, any possible influence of energy conservation measures to be performed on each section and department should be studied to make sure that no profit is reduced on an entire factory basis.

It is important that a general manager of the factory or a person next to the former in rank who has responsibility and authority in production assume the chairmanship of the committee. Otherwise, no decision would be made, neither would such a decision be implemented.

Even if certain energy measures were based on an excellent idea, any fruitful results would not be expected unless the operator fully understands what the measures mean and applies them to the actual work. There are many cases where the QC (quality control) circle which is effective for quality control is utilized successfully for energy conservation with noteworthy results. The QC circle is an activity of improving human relationship in the job, stimulating people to become more conscious about independence endowed intrinsically to humans and providing them with the pleasure of working actively. However, it is necessary to prepare conditions which make the operator find it easier to conduct activities such as education and incentive granting before he can recognize the advantages and necessity of the circle activities. It is the operator on the front line that is always in touch with energy consuming equipment and sensitive enough to grasp any phenomenon appearing according to a change in the operating conditions. It is extremely effective for energy conservation to make the best of information obtained by the operator and to squeeze out a good idea for improvement.

3.3 Scientific and Systematic Activities

It is an indispensable condition to obtain an exact status of energy consumption when energy conservation is carried out. If data such as change of the unit consumption rate per production, difference in the unit, variation of product grade and difference in raw materials are not available, it would be impossible to formulate plans which guide you toward an area requiring the implementation of immediate procedures. In other words, it is factory data that provide numerous ideas for improvement. If studies are made of these data with a consciousness about problems, it would be able to find something leading to such ideas. Therefore, it is suggested that a measuring instrument be installed at necessary spots, record its readings and obtain information through their periodical arrangement. In this case, such data should be processed from the viewpoint of mathematical statistics to determine if the difference is significant.

Next, it should be made sure that the results are followed up, if improvement plans were implemented. Efforts should be made to enhance the quality of operations according to the PDCA circle advocated by Dr. Deming. The function of the PDCA circle is such as explained below as shown in Fig. III-3-20:

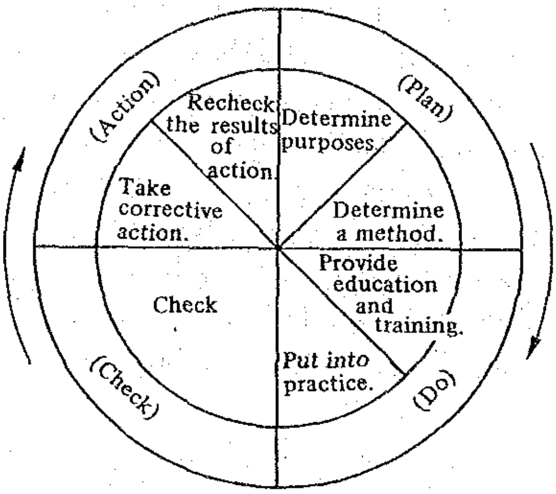


Fig. III–3–20 Deming circle

First, plans should be formulated; that is, a purpose will be set for a certain theme and means decided. This represents "P" for PDCA. People will be trained concerning how to perform these means and given an opportunity to actually do them. This represents "D". The results of the performance will be checked. This represents "C." Results of the check will be evaluated to determine if they are satisfactory. Action will be to standardize the results, if they are satisfactory and to take corrective measures if there is still a problem yet to be resolved. If one step was completed, the function of "PDCA" will be set to work towards a target of higher level. In this way, people proceed with their assignments. This method will be helpful for not only energy conservation but also heightening the quality of jobs in every field.

With regard to the part concerned with "Plan," it is recommended that "improvement plans invitation system" be actively utilized because items to propose can be found rather easily during an early stage. It should be so arranged that proposals may be made by whosoever he may be, an individual or a member of a working place, the QC circle or staff. Proposals presented should not be left alone, but should be examined promptly by the committee and others. The proposals presented should be adopted as far as circumstances allow after being modified on advice depending on the occasion. It is also suggested that a prize be presented to people for their proposals and further, a commendation be given to those whose proposals brought about fruitful results. These measures will be an incentive for people to deepen their consciousness about participation. For proponents whose proposals were not adopted, it is suggested that they be explained about the reasons why the proposals were not taken up and at the same time, be properly guided over better ideas.

In the stage of "D", it is suggested that satisfactory explanation be provided to employees of the lowest rank regarding an intention for improvement, and their cooperation in an effort toward the improvement be solicited. They are also encouraged to report even on minor abnormalities during operation so that they may be able to make scrupulous adjustments. This consideration is necessary to eliminate any possible cause for error.

"Check" should be conducted periodically and at the same time, the results be reported to the committee and the senior official. Along with this procedure, the results also should be made known to the operator so that he may deepen his concern. In this case, it is important to clarify an evaluation criterion from the beginning; it is not desirable to change it easily halfway.

If satisfactory results can be expected following the implementation of an improvement plan, they should be incorporated into the operation standard. Simultaneously necessary measures for the improvement of equipment should be taken so that any extra load may not be brought to bear on the operator. This is a condition for continued favorable results of energy conservation.

In case considerable results have been accomplished continuously as a result of the above, their summarized processes should be published as references. At the same time, those concerned should be officially commended so that they may be motivated for next activities.

3.4 Furnishing of Education and Information

Even if employees are willing to cooperate, any improvement can hardly be expected, unless they have knowledge as to how they should do it. They would become more positive to participate in the energy conservation campaign, if they are capable of presenting their own improvement proposal without being limited to merely pointing out problems. In order to realize this target, an internal education program sponsored by the company itself is important; that is, programs such as seminars and distribution of guide books should be provided. In the Kingdom of Thailand, a considerable number of companies are enthusiastic about education and also numerous cases where their staffers are sent for participation into external seminars are noticed. To our regret, however, such staffers sent for the external seminar tend to keep their acquired knowledge only to themselves instead of passing it on to other staffers or general operators. If it is arranged so that those who received external seminar training become lecturers for internal education and provide training to other people based on their acquired knowledge, it is expected that the entire level of employees' professional quality will be raised and staffers participating in the external seminars will be able to make sure that their obtained knowledge is practically useful.

Next, it is desired that information exchange with other companies of the same industry or raw material suppliers or finished product buyers be activated. Although it is naturally important that competition should take place among different companies of the same industry, it is recommended that technical information be exchanged to some extent on a give and take basis. This is because the technical level of the entire company can be heightened resulting in stronger international competing power and subsequent mutual benefit. For instance, the publishing of actual unit consumption rates will be instrumental for the motivation of commercial competition.

The referential value establishment plan described in the report was prepared based on these referential values considering the present industrial status of the Kingdom of Thailand.

These referential values will be a starting point for the establishment of referential values in deciding industrial rationalizaiton in the Kingdom of Thailand. It is recommended that the Kingdom of Thailand itself accumulates data for factory diagnosis to be put into practice, and evaluate it periodically and revise or newly establish referential values.

4. Rationalization in the use of energy

4.1 Synthetic fibers

(1) Combustion control for boilers, etc.

See III-7 Section for Boiler and Steam.

(2) Prevention of heat release

The manufacturing process up to melting-spinning is similar to those of chemical factories and a number of towers and tanks are connected with piping and their contents are heated to 100 to 300°C through a heating medium. Therefore, it is important to prevent heat release from the surface of these equipments. The main equipment is generally heat insulated well, but for the flange portion and small diameter piping at the ends, etc. the insulation tend to be incomplete.

(3) Utilization of flash steam

See III-7 Section for Boiler and Steam.

Since high-pressure steam is partially used in relation to heating temperature, it is necessary to effectively utilize low-pressure flash steam generated by feeding the condensate into the flash tank.

(4) Recovery of condensate

See III-7 Section for Boiler and Steam.

(5) Utilization of back pressure of steam

When steam at different pressures is used, this steam is generally obtained either by using two or more boilers to generate steam at respective pressure, or by reducing the pressure of a portion of steam from a high-pressure boiler with a reducing valve. In this case, electric power can be effectively obtained when all the boilers are changed into high-pressure boilers, a steam turbine is used instead of the reducing valve, and the steam turbine is used to drive the generator. Recently, small-sized, high-efficient turbines are manufactured and such cases are often seen.

<Example> Power generation by the existing boiler and economic efficiency

Let us consider one example when a steam turbine generator is installed instead of the reducing valve in a factory with a boiler = 10 kg/cm^{2}g × saturated 45 t/h and required process steam = 3.5 kg/cm^{2}g × 140°C × 40 t/h.

a. *Since the use of a reducing valve causes steam to make an isoenthalpic change*, the enthalpy retained by steam remains unchanged before and behind the reducing valve (A → B in Fig. III-3-21 Steam i-s Diagram). Fuel consumption at this point is, assuming that combustion heat of fuel (fuel oil C) = 10,000 kcal/kg, boiler efficiency = 80% and temperature of feed water = 80°C,

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

STEAM i-s CHART

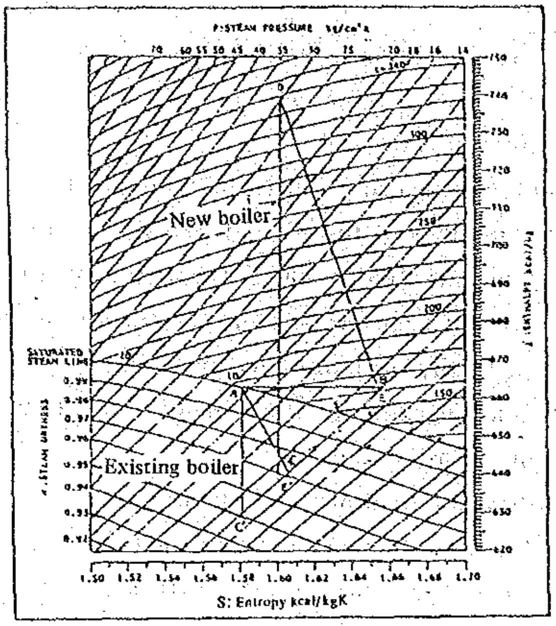


Fig. III–3–21

b. When power is generated with the steam turbine, the enthalpy of steam decreases (A → C' in the Steam i-s Diagram). Generated energy, heat balance and economic efficiency at this point are as follows:

* Generated energy: 967 kW from the following calculation:

①	Steam pressure at turbine inlet	8.5 kg/cm^{2}g
②	Steam enthalpy at turbine inlet	662.4 kcal/kg
③	Exhaust pressure at turbine outlet	3.5 kg/cm^{2}g
⑤	Theoretical adiabatic heat drop (A → C') (662.4 – 629.4)	33 kcal/kg
⑤	Select an optimum turbine from steam conditions and dimensions of the turbine.	
⑥	Ratoh double reduction turbine	
	• Internal efficiency	67.15%
	• Effective heat drop (33 × 0.6715)	22.2 kcal/kg
	• Exhaust enthalpy (662.4 – 22.2)	640.2 kcal/kg
⑦	Amount of required process steam	
	$40{,}000 \times \frac{662.4}{640.2}$	41,387 kg/h
⑧	Generated energy	
	• Overall efficiency of turbine including generator (η_o)	60.92%
	• Steam consumption $\frac{860}{\text{Theoretical adiabatic heat drop}} \times \eta_o$	42.8 kg/kw-h
	• Generated energy (Process steam amount consumption) ÷ (Steam conosumption)	97 kW

* Heat balance: Process steam must be fed 1,387 kg/h (See item (7)) more than when the reducing valve is used.

at turbine inlet $\begin{cases} Q = 41{,}387 \\ P = 8.5 \\ T = 177 \\ I = 662.4 \end{cases}$

at turbine outlet (Process inlet) $\begin{cases} Q = 41{,}387 \\ P = 3.5 \\ T = 147 \\ I = 640.2 \end{cases}$

* Fuel consumption: in the same manner as the reducing valve,

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

* Economic efficiency: ¥95,600,000 when determined from the cost difference between purchased power and house generated power and annual working hours in the following way

① Increase in fuel = Ft − Fv = 3,013 − 2,912 = 101 kg/h

② Unit price of fuel (differs from country to country, but the unit price in Japan is adopted) ¥60/kg

③ Generated electric energy 967 kW

④ Unit price of house generated power

$$\frac{\text{Increased fuel cost}}{\text{Generated electric energy}} \quad ¥6.27/\text{kW-h}$$

⑤ Purchased power unit price ¥20/kW-h
(differs according to the country and enterprise, but one example in Japan is adopted)

⑥ Annual saved electric energy charge ¥95,600,000
(Operating time assumed as 7,200 h)
(20 − 6.27) × 967 × 7,200 = 95,593,752

The foregoing is one example of electric energy charge saving by installing a power generation turbine utilizing steam pressure difference instead of the existing plant reducing valve. Its merit is so enormous that investment for equipment such as turbine generator, piping, foundation, etc. will be refundable within a year.

<Example 2> Power generation and economical efficiency by a newly-installed boiler

If the boiler renewal time is only a little while away, decisively install a new high-pressure and high-temperature boiler to increase the generated energy, thus increasing the economic efficiency by leaps and bounds. For trial, let us determine economical efficiency when a super-heatingboiler with 33 kg/cm^{2}g × 350°C × 45 t/h in the same process as Example 1 when newly installed.

* Generated energy: Calculating in the same manner as Example 1, = 3,300 kW

* Heat balance:

at turbine inlet $\begin{cases} Q = 40{,}000 \\ P = 30 \\ T = 340 \\ I = 738.7 \end{cases}$

at turbine outlet (Process inlet) $\begin{cases} Q = 40{,}000 \\ P = 3.5 \\ T = 160 \\ I = 662 \end{cases}$

* Fuel consumption: in the same manner as when the reducing valve is used,

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

(Newly-installed boiler efficiency is assumed as 85%)

* Economical efficiency: ¥394,000,000 from the following calculation:

Assuming annual working time as 7,200 h, and in the same manner as Example 1,

①	Increase in fuel (Fn − Fv = 3,099 − 2,912)	187 kg/h
②	Unit price of fuel	¥60/kg
③	Generated electric energy	3,300 kW
④	Unit price of house generated power	¥3.4/kW-h
⑤	Purchased power unit price	¥20/kW-h
⑥	Annual saved electric energy charge (20 − 3.4) × 3,300 × 7,200	¥394,000,000

(6) Distillation equipment

A lot of steam is consumed for heating and evacuation in a process to concentrate the unreacted monomer extracted into hot water from polymeric nylon.

To save the amount of steam for the ejector, it is necessary to give attention to the following points:

A) Periodically replace the packings and weld the flanges closed as far as possible so that air does not enter the vacuum system.

B) Endeavour to save the amount of feed water to the condenser while keeping the necessary temperature to maintain the vacuum.

C) Re-examine the vacuum condition and test to check whether the steam pressure can be reduced, or in the case of multi-stage, whether the final stage can be eliminated.

D) Study the merits and demerits of combined use with a vacuum pump or the replacement. If there is no problem of corrosion and dust, it is advantageous to replace and there are some examples that the equipment cost is refunded within a year.

E) Turn any evaporator into a double or triple effect evaporator (See III-5 Section for Chemical Industry).

(7) Change of process

When establishing a new plant, it is necessary to study adoption of the following energy conservation type processes.

A) Continuous polymerization spinning equipment

In a conventional process, molten polymer formed by a polymerizer is solidified by cooling and after removing the unreacted monomer by cleaning with hot water, it is dried and re-melted for spinning (See Fig III-3-22).

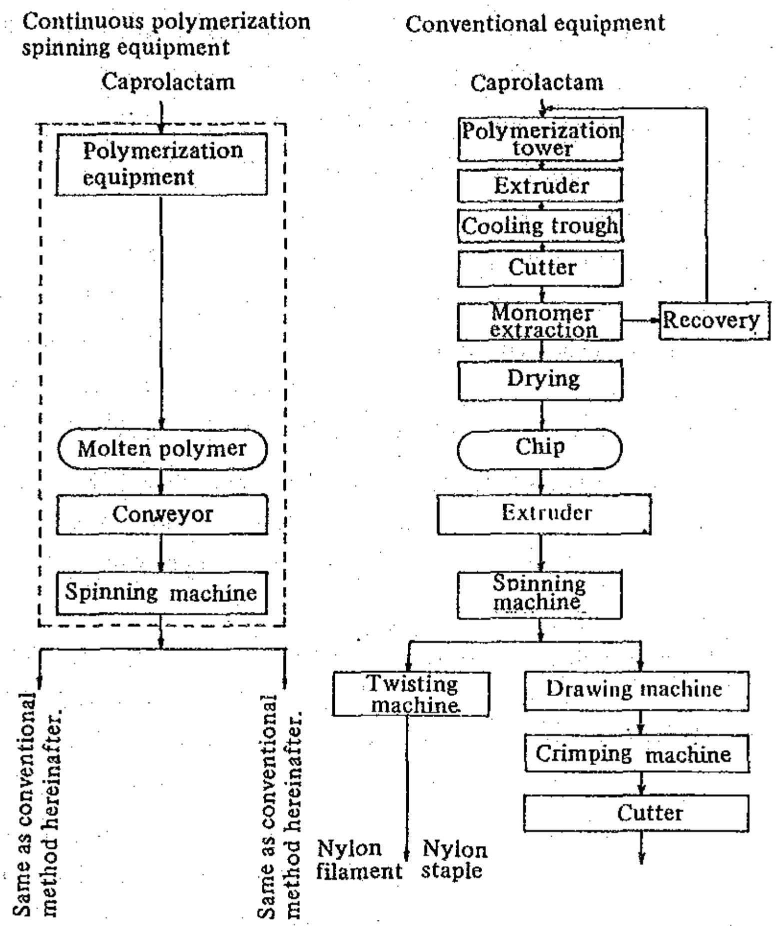


Fig. III-3-22

In a new process, since molten polymer formed by a polymerizer is carried as-is for spinning, a greater part of the process is omitted.

B) High-speed multi-thread yarn-making

In the past, yarn used to be manufactured by extruding molten polymer from a spinning head and once thread was obtained by cooling, then stretching by a drawing machine separately installed.

In a new process, spinning and drawing are performed at the same time by high-speed spinning and also multi-thread take-up is performed together. Therefore, power and heat loss can be saved because of the omitted drawing machine.
Spinning speed changes from 1,000 to 1,500 m/min, to 3,000 m/min or more and the number of threads will be 4 pieces or more when under 630 denier and 2 pieces or more at 630 denier or above. Although energy for spinning and drawing is consumed at the rate of nearly 3:2, this improvement saves the energy greatly, but it may not be applied to some yarn according to applications.

(8) Change of heating source for heating medium

Although electricity is used for the heating source for a heating medium boiler, the thermal efficiency at the power generation stage is only slightly over 35%. Therefore, in a certain factory having several electric type heating medium boilers, they changed these boilers into one fuel oil burning with the results that they could save annual expenses by ¥3,100,000 against the investment of ¥8,000,000.

(9) Air conditioning (See III-8 Section for Electricity)

A) Re-examination of air conditioning loads

Air conditioning conditions for the spinning process have an impact on the quality of yarn and respective conditions are set for each factory. However, it is necessary to re-examine them as occasion calls with technical development.

In a certain factory in Japan, they changed the temperature and humidity step-wise and determined limits beyond which problems will occur, by checking the quality of threads and operating circumstances in each step. As a result, they saved the refrigerating load by 14% and humidified, heating steam by 16% by changing the specified conditions set throughout the year into new conditions each season.

It is necessary for energy conservation to reduce the load by intensifying heat insulation for the building and heat-generating apparatus.

B) Change of spray nozzle

When air is directly cooled by chilled water spraying, the delivery pressure of water pump can be reduced by making the spray nozzle larger and reducing its quantity. This reduces the pump power and may reduce the number of pumps in some cases.

For example, in a certain factory in Japan, replacing 15,400 nozzles 4 mm in diameter in use with 212 nozzles 44 mm in diameter reduced the spray pressure from 3 kg/cm^2 to 2 kg/cm^2, thus resulting in saving of electric power of about 470,000 kWh annually.

C) Introduction of high-efficient refrigerators

Deteriorated refrigerators do not reach their designed performances.

For example, in a certain factory in Japan, a refrigerator with the design consumption rate of 1.28 kW/JRT (Note: 1 JRT = 79,680 kcal/d) was deteriorated into a consumption rate of 1.41 kW/JRT and they saved 750 kW by replacing it with a high-efficiency refrigerator with a consumption rate of 0.91 kW/JRT.

D) Control of refrigerator rotating speed

In factories with turbo compressors in use, it is effective to control the number of turbo compressors or the rotating speed when the load varies greatly. Examples of reduction in electric power are shown in Fig. III-3-23.

E) Control of blower rotating speed

See III-8 Section for Electric Power.

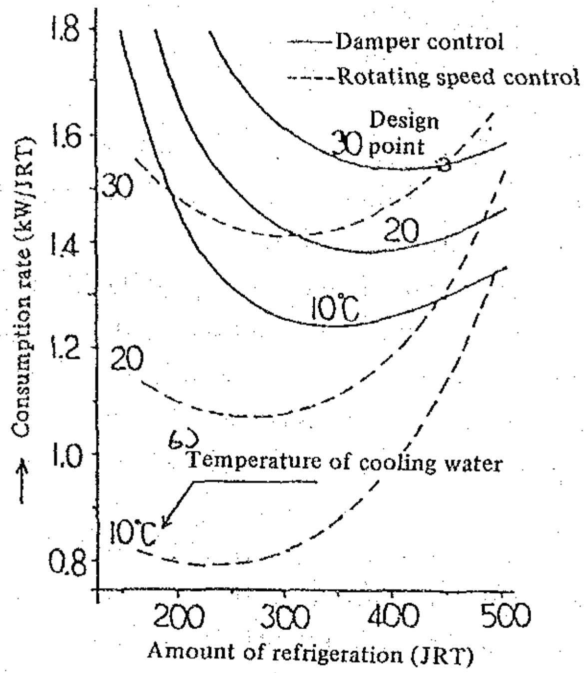


Fig. III–3–23 Characteristic comparison of capacity adjustment

4.2 Spinning and weaving

(1) Heat setter

See III-7 Section for Boiler and Steam.

Pay attention to strict enforcement of door closing while waiting, maintenance and control of trap, heat insulation, maintenance of packings for doors, etc. and recovery of condensate.

(2) Sizing

A) Intensification of heat insulation

Thoroughly heat insulate tanks, headers and piping.

B) Attachment of hood

This serves to keep temperature around the cylinder and also serves to expel vapor quickly.

C) High-pressure squeezing

For example, increasing the squeezing pressure after sizing from 350 kg to 1,500 kg reduced the amount of water to vaporize by 33%.

D) Change of glue

Glue can be made at low temperature and sizing also can be made at low temperature by changing the class of the glue. For example, lowering the compounding temperature from 130° C to 80° C saved steam by 13%.

E) Increase in number of sizing pieces

Increasing the number of sizing pieces saves energy as a whole, though the speed is slower.

F) Improvement of heat transfer of cylinder

Adjust the siphon and locate traps so that condensate within the cylinder is smoothly removed.