Report No. 15: Paper

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

- Industry Krungthai Co., Ltd. -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Industry Krungthai Co., Ltd. -

1. Outline of the Factory

Address : 72/2 Tivanon Rd., T. Bang Krachant
Town, District Pratumthani

Capital : 60 million bahts

Type of industry : Paper

Major products : Kraft paper, white paper, brown paper

Annual output : 12,000 t

No. of employees : 213

Annual energy consumption :

- Electric power : 16,800,000 kWh
- Fuel
  - Fuel oil : 900 kl
  - Sawdust : 36,000 m^3

Interviewees : Tamrong Trakulyuthachai, factory manager,
and Charal klinpuen, engineer

Date of diagnosis : Sept. 2 - 3, 1982

Diagnosers : A. Koizumi, K. Nakao, and K. Kurita

Industry Krungthai put its factory into operation fifteen years ago. Currently, the factory has a daily output of about 40 tons of paper from BKP, white waste paper, waste corrugated cardboard boxes, etc., with three paper machines:

No. 1 paper machine - 76" wide, 15 t/d, board

No. 2 paper machine - 76" wide, 13 t/d, machine-finished medium quality paper

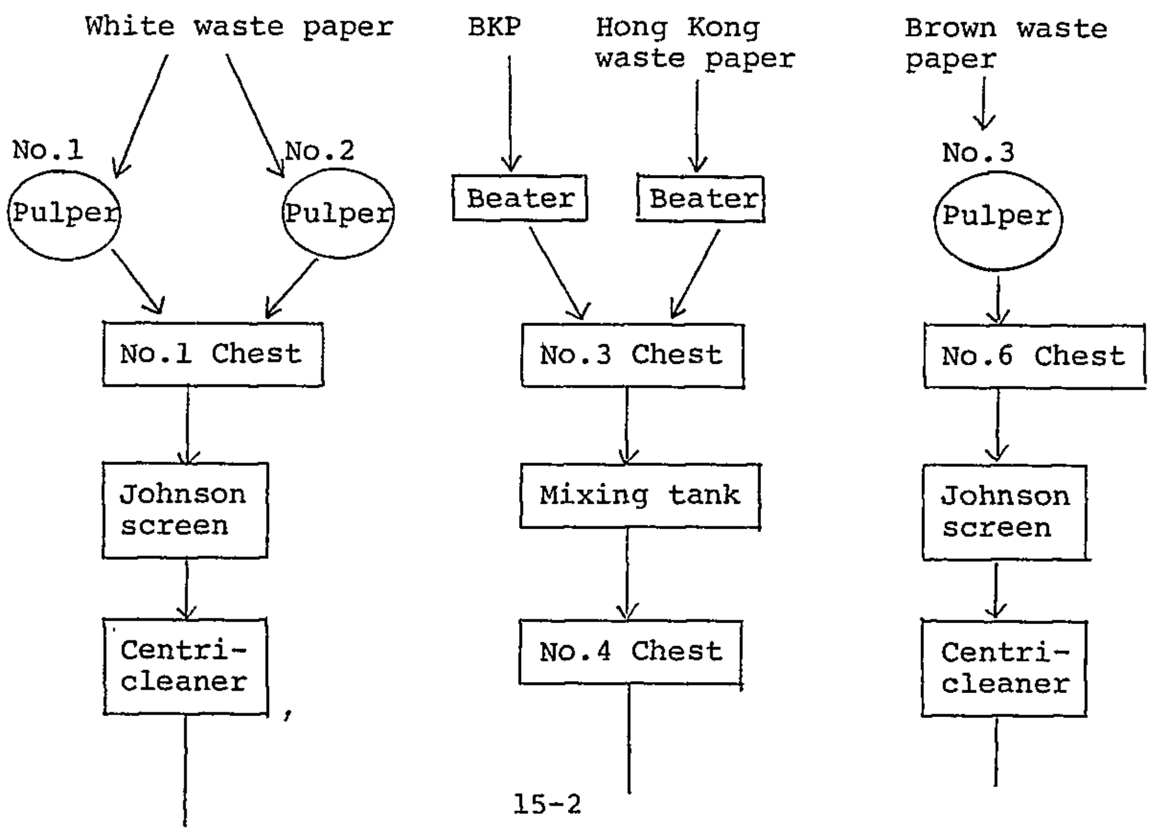
No. 3 paper machine - 76" wide, 13 t/d, white paper

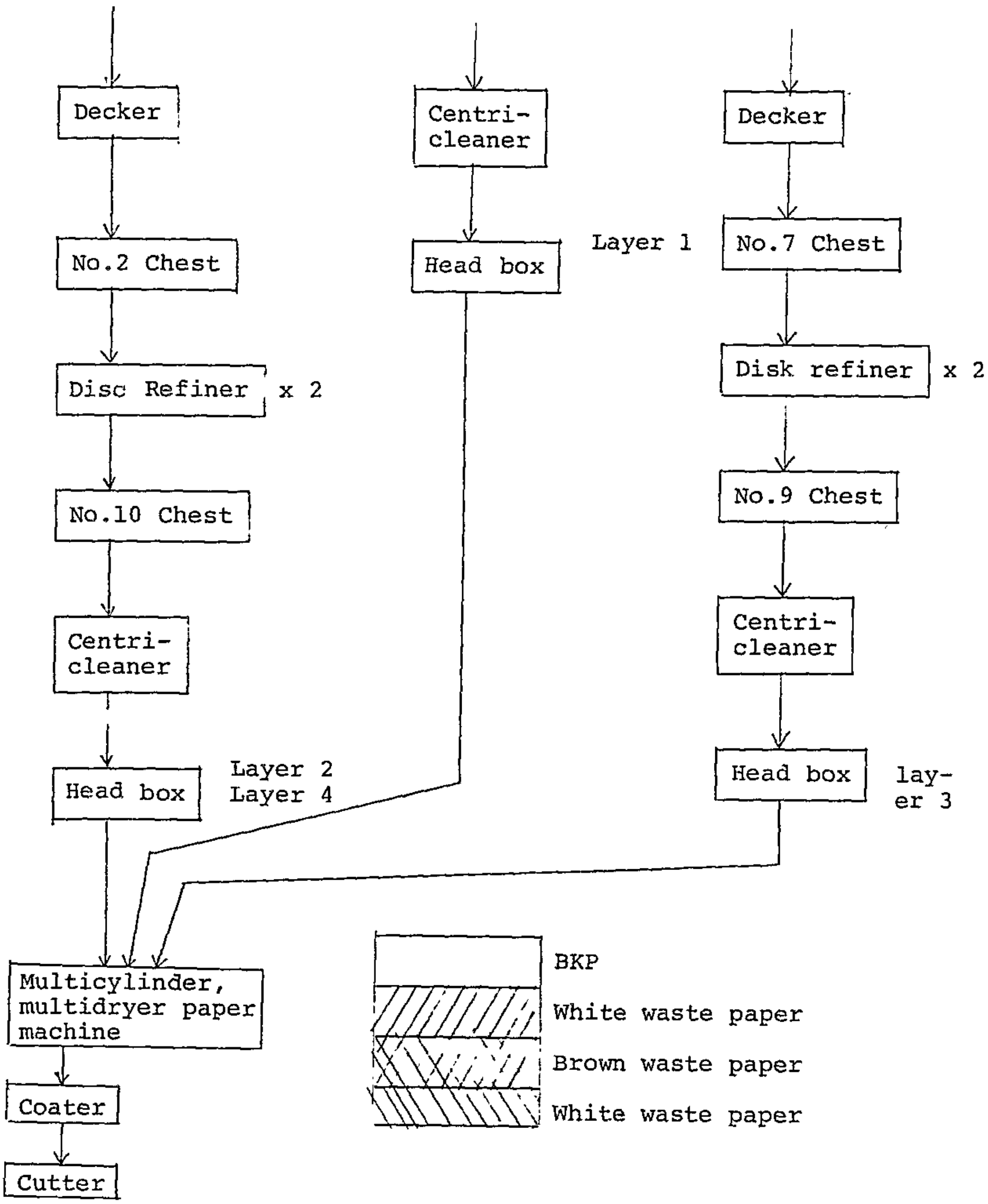
The factory has a workforce of 213. To raise the level of paper making technique, these employees are given practical training by technicians from Taiwan, who are posted at the three paper machines (One technician at one machine).

Expansion of production equipment is now under consideration, but the factory management are playing a careful game due to political instability, a potential increase in tax burdens, and lack of governmental support.

2. Manufacturing Process

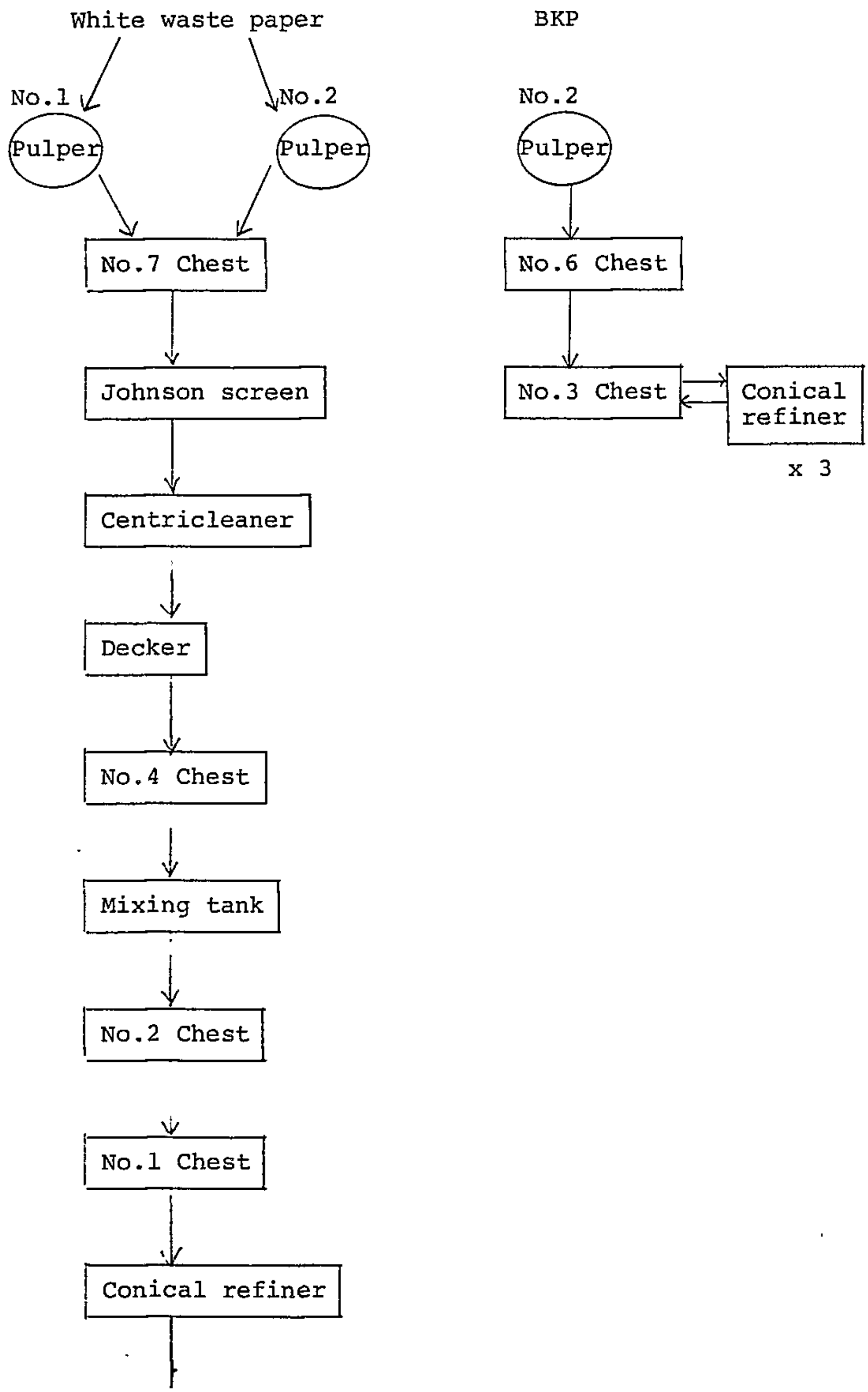
No. 1 Paper Machine

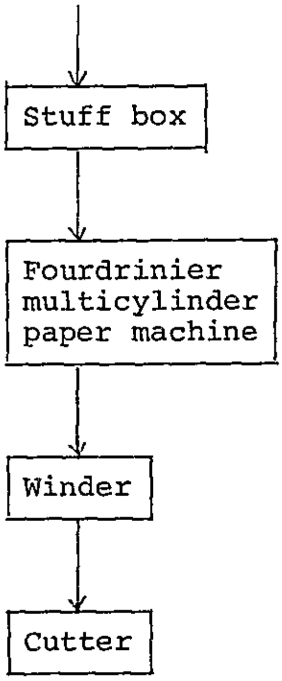




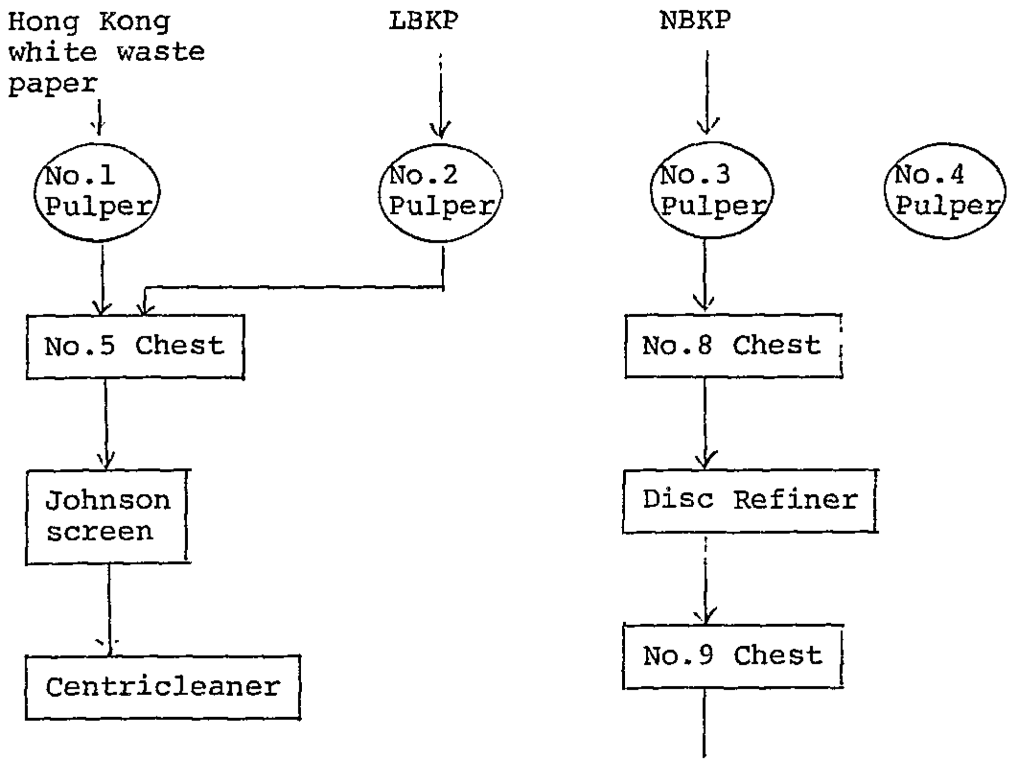
Decker
No.2 Chest
Disc Refiner x 2
No.10 Chest
Centri-cleaner
Head box
Layer 2
Layer 4
Centri-cleaner
Head box
Layer 1
Decker
No.7 Chest
Disk refiner x 2
No.9 Chest
Centri-cleaner
Head box
layer 3
Multicylinder, multidryer paper machine
Coater
Cutter
BKP
White waste paper
Brown waste paper
White waste paper

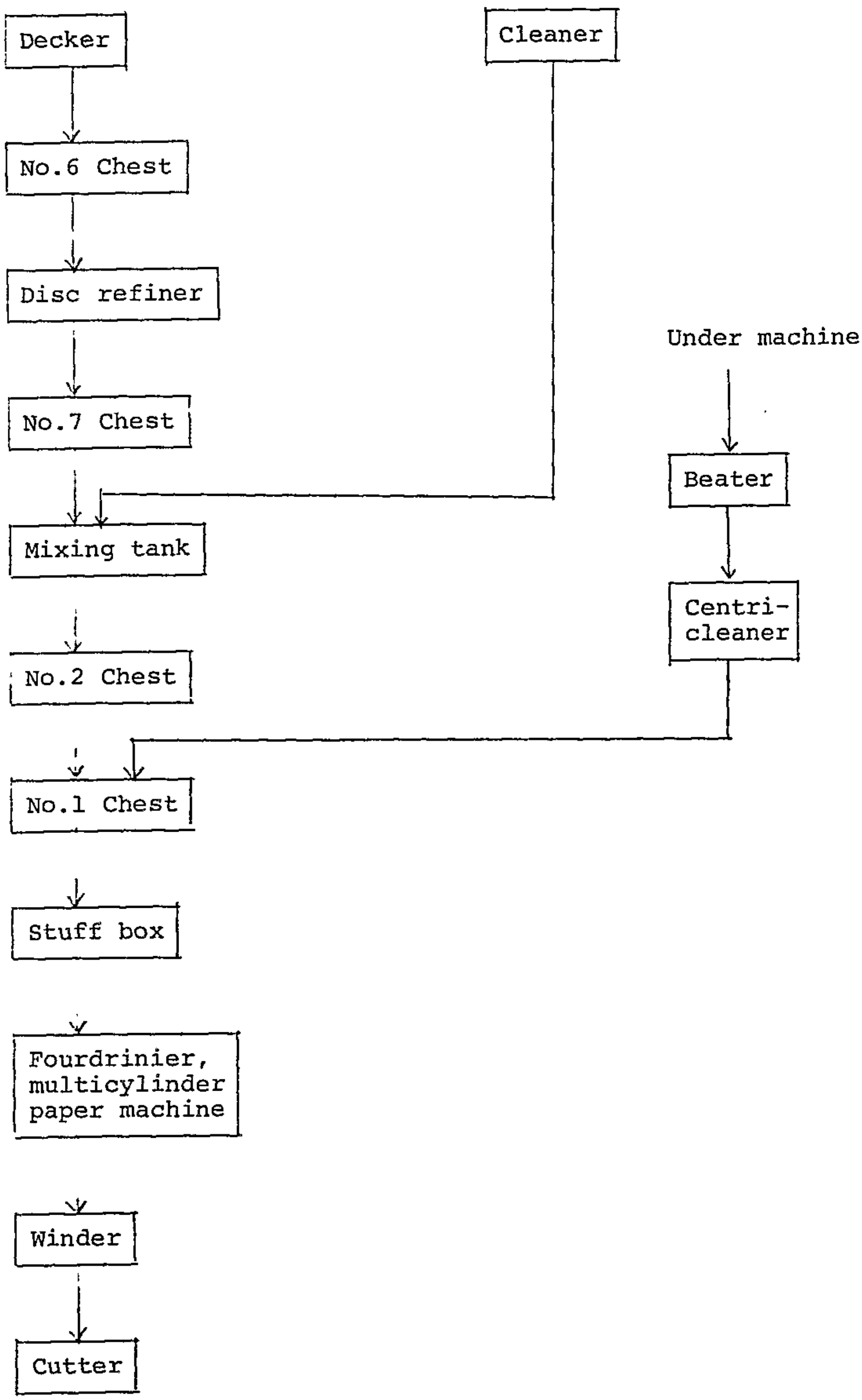
No. 2 Paper Machine





No. 3 Paper Machine




Decker
Cleaner
No.6 Chest
Disc refiner
Under machine
No.7 Chest
Beater
Mixing tank
Centri-
cleaner
No.2 Chest
No.1 Chest
Stuff box
Fourdrinier,
multicylinder
paper machine
Winder
Cutter

3. Major Equipment

(1) Stock preparation

Stock preparation differs from line to line. The three paper machine lines as a whole are provided with the following equipment to prepare stock:

Process	Equipment
Repulping	Pulper (10 units) Beater (3 units)
Screening and separator	Johnson screen (four lines) 1st separator/liquid cyclone (seven lines) 2nd separator/liquid cyclone (two lines)
Thickener	Cylinder filter (four units)
Refining	1st refiner (six lines) 2nd refiner (one line)

(2) Paper machines

Three Taiwanese-made paper machines are installed, of which the No. 1 machine is capable of continuous operation with a coater and cutter.

Major equipment	No. 1 Paper machine	No. 2 Paper machine	No. 3 Paper machine
	76" wide 2 Yankee multicylinder type	76" wide Fourdrinier multicylinder type	76" wide Fourdrinier multicylinder type
Moulder	Cylinder (6)	-	-
Flow box and slice	-	Open nozzle slice	Open nozzle slice

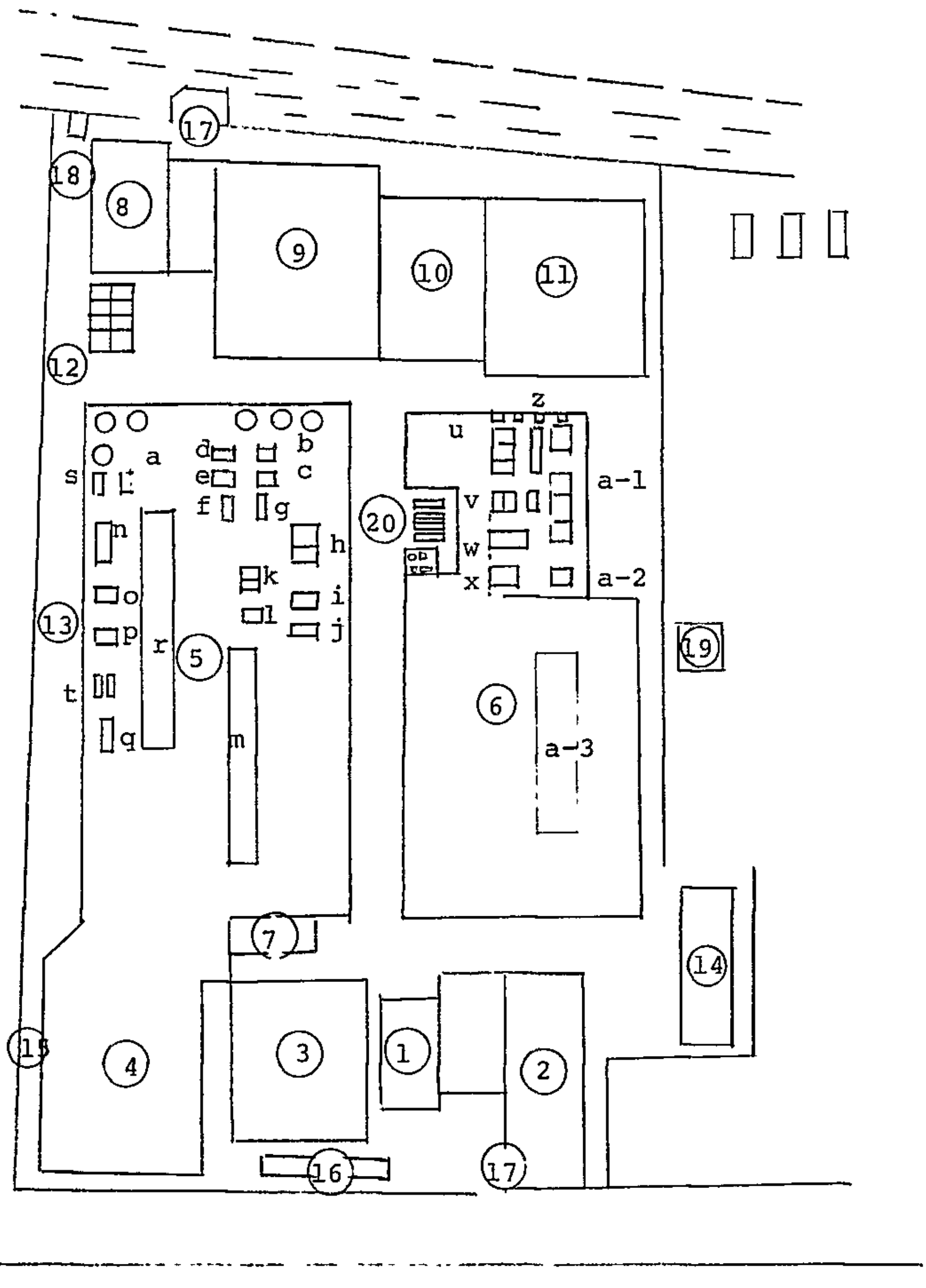
Couch	Open	Suction couch	Suction couch, suction pickup
Press	Baby press (2), press (3)	Fabric press (2)	Suction press (1), press (1)
Dryer	Open hood cylinder (16)	Open hood cylinder (24, including 2 canvas dryers)	Open hood cylinder (24, including 2 canvas dryers)
Calender	Roll (6)	Roll (6)	Roll (6)
Winder	-	2 drum type	2 drum type
Coater	Roll coater, hot air dryer	-	-
Cutter	Single	Single	Single

(3) Boilers

Name	No. of units installed	Type, etc.
Sawdust-burning boiler	1	Capacity - 14 t/h, made in Thailand, with a cylindrical combustion chamber, Lancashire boiler
Oil-burning boiler	2	Capacity - 6 t/h, made in Germany, flue and smoke tube type, one at rest

N.B. The sawdust-burning boiler was formerly fueled by oil.

(4) Layout



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1. Office 1
2. Storage 1
3. " 2
4. " 3
5. Factory building 1
6. " 2
7. Office 2
8. Storage 4
9. " 5
10. " 6
11. Boiler house
12. Deep well
13. Waste water setting tanks
14. Labor housing
15. Maintenance Room
16. Storage
17. Port
18. Fire pump
19. Guard
20. Oil tank
Transformer

a. Conical refiner
b. Johnson
c. Decker
d. Johnson screen
e. Decker
f. Centri-cleaner
g. Coater
h. Disc refiner
i. Beater
j. Centri-cleaner
k. Coater
l. Mixing tank
m. Paper machine 1
n. Mixing tank
o. Conical Refiner
p. Disc refiner
q. Decker
r. Paper machine 2
s. Decker
t. Centri-cleaner
u. Johnson screen
v. Conical refiner
w. Mixing tank
x. Decker
a-1. 3rd Dicker refiner
a-2. White waste water
a-3. Paper machine 3

4. State of Energy Management

Records such as technical and quality data are not kept in good order; there is no established setup to take care of day-to-day records. All in all, the factory is not well-managed regardless of its good facilities and equipment.

It is necessary to set up a solid channel of command, order, and reporting from the factory manager through middle management down to workers. Hourly readings and measured values of gauges and meters should be recorded in a daily report.

Moreover, an attempt will have to be made to set up a laboratory that will be able to furnish basic data for energy, quality and production control as well as to give guidance in routine factory management and technological issues.

Meanwhile, a number of workers are found to have been unconcernedly treading underfoot defective sheets of paper resulting from breakage and those rejected after refining and sorting. This has to be stopped right away because paper, if broken into fragments, is a valuable source of energy bringing bread to workers. On top of that, soiled sheets of paper will most likely suffer breakage once again when they go back to a paper machine.

The frequency of paper breakage in each machine should be recorded and made generally known to employees. It serves as a good indicator of factory management - that is to say, technological level and degree of interest in paper.

5. State of Thermal Energy Consumption

Amount of steam generated:

No. 1 boiler	-	7.5 t/h
No. 2 boiler	-	1.7 t/h

Fuel consumption:

No. 1 boiler	-	5 m^3/h (sawdust)
No. 2 boiler	-	125 liters/h (fuel oil)

Thermal efficiency:

No. 1 boiler	-	60%
No. 2 boiler	-	80%

The No. 1 sawdust-burning boiler was originally installed by a certain company under contract whereby to supply all steam requirements at the fixed rate, but presently it is being operated independently following the cancellation of this contract. Formerly, fuel oil had been consumed in the amount of 14 to 15 kl/d, but it was reduced to 3 kl/d upon installation of this boiler. Though consuming 100 to 120 m^3 of sawdust per day, the No. 1 boiler has contributed to a significant reduction in fuel costs. The No. 1 boiler, though it has a design capacity of 14 t/d, is currently run at the capacity of no more than 7 to 9 t/d; the capacity shortage is supplied by another oil-burning boiler, which automatically starts running whenever necessary. The No. 1 boiler is stopped once a month for inspection and cleaning.

It should be noted in this connection that efforts are made to hold down the amount of water used at a very low level, so that water temperatures are kept at a rather high level, contributing to a saving of steam.

The heat balance in the No. 1 boiler is as shown below.

Heat Balance in the No. 1 Boiler

Input (10^3 kcal/h, %)			Output (10^3 kcal/h, %)		
Heat of fuel combustion	7,350	100	Heat of steam	4,473.7	60.9
			Heat loss in exhaust gas	2,505.7	34.0
			Heat loss in blow water	3.8	0.1
			Heat release from boiler body	367.5	5.0
Total	7,350	100	Total	7,350	100

Notes:

1) Data given for determination of the heat balance -

Type of fuel	-	Sawdust (water content: 40%)
Temperature of fuel	-	30°C
Fuel consumption (F)	-	3,500 kgs/h (specific gravity: 0.7)
Heat contents of fuel (low level, Hl)	-	2,100 kcal/kg (on water content basis)
Oxygen content in exhaust gas (%)	-	11.3%
Air ratio	-	$\frac{21}{21 - 11.3} = 2.16$
Temperature of exhaust gas (Tg)	-	305°C

Steam pressure - 4.3 kgs/cm^2 g

Temperature of feed water - 70°C

Amount of blow - 31 kgs/h

2) Equations for calculating the heat balance -

Input

Heat of fuel combustion

3,500 kgs/h (F) x 2,100 kcal/kg (Hl)

$= 7,350 \times 10^3$ kcal/h

Output

a. Heat loss in exhaust gas

Quantity of wet exhaust gas flow

$= 18,351$ Nm^3/h (measured value)

Water content in exhaust gas = 1,742 Nm^3/h(1,400 kgs/h)

Quantity of dry exhaust gas flow

$= 16,709$ Nm^3/h

Heat loss in water contained in exhaust gas

= 1,400 kgs/h x (736.7 - 30) kcal/kg

$= 989.4 \times 10^3$ kcal/h

Heat loss in dry exhaust gas

$= 16,709$ Nm^3/h $\times 0.33 \times (305 - 30)$

$= 1,516.3 \times 10^3$ kcal/h

Heat loss in wet exhaust gas

$= 989.4 \times 10^3 + 1,516.3 \times 10^3$

$= 2,505.7 \times 10^3$ kcal/h

b. Heat loss in blow water

Amount of blow water : 31 kgs/h

Temperature of blow water : 153°C

Heat loss in blow water

$= 31 \times (153 - 30) = 3.8 \times 10^3$ kcal/h

c. Heat release from boiler body

5 percent of the total amount of input heat is accounted for by heat release from the boiler body.

$7{,}350 \times 10^3$ kcal/h x 0.05 = 367.5×10^3 kcal/h

d. Heat of steam

$7{,}350 \times 10^3$ kcal/h (total amount of input heat)

$- 2{,}505 \times 10^3$ kcal/h (heat loss in exhaust gas)

$- 3.8 \times 10^3$ kcal/h (heat loss in blow water)

$- 367.5 \times 10^3$ kcal/h (heat release from boiler body) = $4{,}473.7 \times 10^3$ kcal/h

e. Quantity of evaporation

Quantity of evaporation =

$$\frac{4{,}473.7 \times 10^3 \text{ kcal/h (heat of steam)}}{656.6 \text{ kcal/kg (enthalpy of steam)} - 30.014 \text{ kcal/kg (enthalpy of feed water)}}$$

= 7,140 kgs/h

Shown below is the heat balance in the No. 2 boiler.

Heat Balance in the No. 2 Boiler

Input (10^3 kcal/h, %)			Output (10^3 kcal/h, %)		
Heat of fuel combustion	1,176.3	99.8	Heat of steam	1,024.5	86.9
Sensible heat of fuel	2.7	0.2	Heat loss in exhaust gas	91.7	7.8
			Heat loss in blow water	3.8	0.3

			Heat release from boiler body	59.0	5.0
Total	1,179.0	100	Total	1,179.0	100

Notes:

1) Data given for determination of the heat balance -

Reference temperature (To) - 30°C

Type of fuel - fuel oil

Temperature of fuel (Tf) - 80°C

Fuel consumption (F) - 122 kgs/h (125 liters/h)

Heat contents of fuel (low level, Hl) - 9,642 kcal/kg

Oxygen content in exhaust gas (%) - 4.4%

Temperature of exhaust gas (Tg) - 200°C

* Other data are the same as for the No. 1 boiler.

2) Equations for calculating the heat balance -

<u>Input</u>

a. Heat of fuel combustion

122 kgs/h (F) x 9,642 kcal/kg (Hl)

$= 1,176.3 \times 10^3$ kcal/h

b. Sensible heat of fuel

122 kgs/h (F) x 0.45 kcal/kg (specific heat of fuel) x [80°C (Tf) - 30°C (To)]

$= 2.7 \times 10^3$ kcal/h

<u>Output</u>

a. Heat loss in exhaust gas

Theoretical amount of air (Ao) =

$$\frac{0.85\ Hl}{1,000} + 2.0 = 10.2\ Nm^3/kg$$

Theoretical amount of exhaust gas (Go) =

$$\frac{1.11\ Hl}{1,000} = 10.7\ Nm^3/kg$$

Air ratio (m) =

$$\frac{21}{21 - O2} = 1.27$$

Actual amount of exhaust gas (G) =

$$Go + (m - 1)\ Ao = 13.4\ Nm^3/kg$$

Heat loss in exhaust gas =

122 kgs/h (F) x 13.4 Nm^3/kg (G) x 0.33

x [200°C(Tg) - 30°C (To)]

= 91.7 x 10^3 kcal/h

b. Heat loss in blow water

Amount of blow water: 31 kgs/h

Temperature of blow water: 155°C

Heat loss in blow water

= 31 x (155 - 30) = 3.8 x 10^3 kcal/h

c. Heat release from boiler body

5 percent of the total amount of input heat is accounted for by heat release from the boiler body.

1,179.0 x 10^3 kcal/h x 0.05 = 59.0 x 10^3 kcal/h

d. Heat of steam

1,179.0 x 10^3 kcal/h (total amount of input heat)

- 91.7 x 10^3 kcal/h (heat loss in exhaust gas)

- 3.8 x 10^3 kcal/h (heat loss in blow water)

$- 59.0 \times 10^3$ kcal/h (heat release from boiler body) $= 1,024.5 \times 10^3$ kcal/h

e. Quantity of evaporation

Quantity of evaporation =

$$\frac{1,024.5 \times 10^3 \text{ kcal/hr (heat of steam)}}{656.64 \text{ kcal/kg (enthalpy of steam)} - 69.975 \text{ kcal/kg (enthalpy of feed water)}}$$

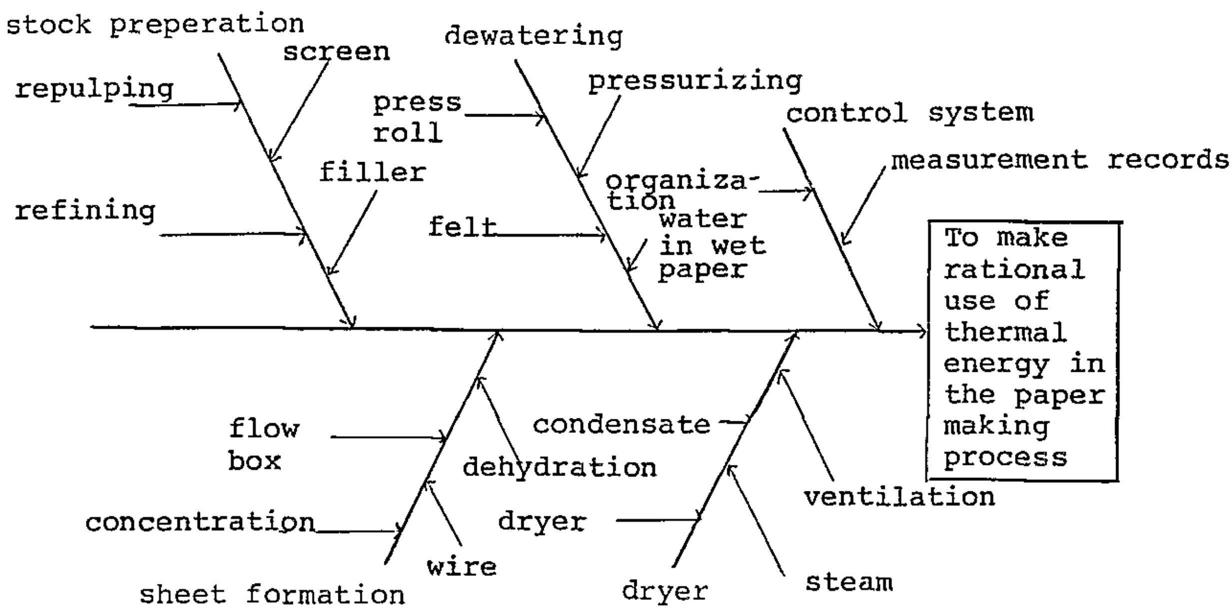
= 1,750 kgs/h

6. Problems in Heat Control and Potential Solutions

The paper industry is one of the most energy-intensive sector, where a large amount of electric energy is used to let a tremendous quantity of water - 500 to 1,000 times as much as the weight of a product - run to make paper and dehydrate and dry it up - water absorbed amounts to about three times as much as the product's weight. Therefore, paper making and energy-saving technologies are not separable at all.

A number of factors affecting the rationalization of energy consumption in the manufacturing process can be illustrated as follows:

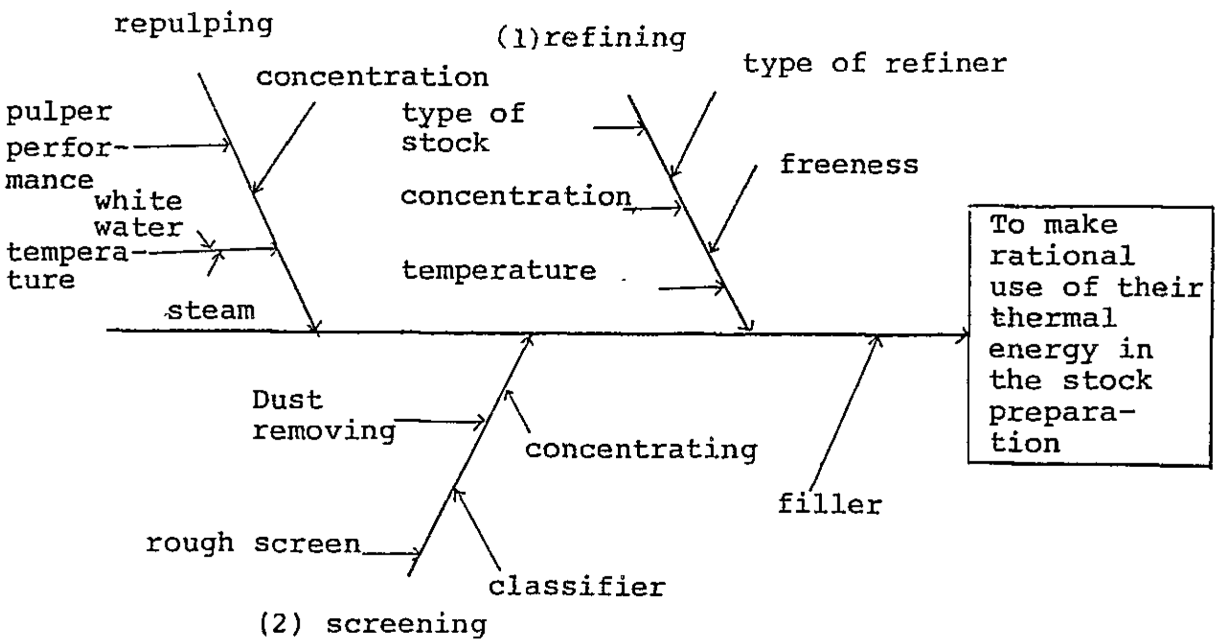
Factors Affecting Rational Use of Energy



Now let's take a look at what factors affect the rationalization of energy consumption in greater detail.

(1) Stock preparation

The chart given below shows what points should be improved to rationalize the use of heat energy.



Based on the above chart, some problems and remedial measures will be pointed out below.

A. Refining

Freeness is one of the most important factors determining the quality of a product. It also affects the dehydration in a wire and press as well as heat transfer and evaporation effects in a dryer. Freeness is a factor that guarantees the quality of stock to be fed into a paper machine and, as such, it is one of the standardized items in factory specifications.

The operator of a refiner is responsible for controlling the application of a refiner bar and the concentration of refining stock so as to make them conform to the standard value of freeness.

The common control practice is to measure freeness once an hour and concentration three times a day in the beginning.

Most of the factories make a review, once a month, of the standard values of freeness and concentration in comparison with the results of quality testing (density, bursting strength, tensile strength, tear strength, sizing, and air (resistance) as well as the amount of steam used in a dryer.

If this review is repeated for six months or so, then quality and freeness standards for a line of products will be established and how much power is needed to run a refiner will be determined, so that the way of operation can be standardized.

B. Screening

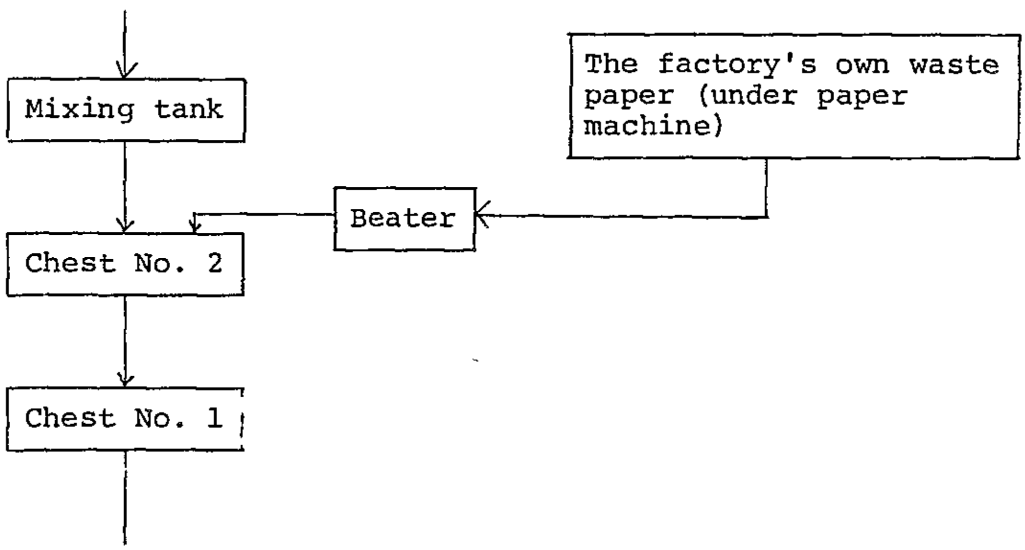
The centricleaner in the No. 3 line was not fitted with a pressure gauge. The dusting efficiency of the centricleaner depends on inlet concentration and pressure, outlet pressure, smoothness of the inner cone, and how a fine reject is passed in the second stage and beyond.

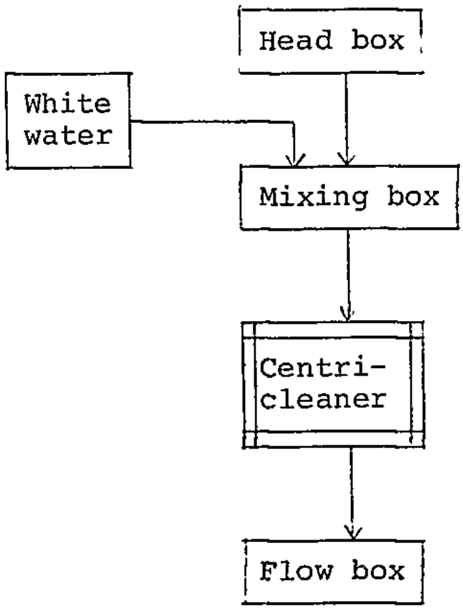
Unless the centricleaner is run as specified, its dusting efficiency will be lowered, resulting in waste of electric power.

The centricleaner should be equipped with a pressure gauge and operated normally.

In a line like this No. 3 where paper of fine quality is made, it is recommended that the centricleaner be arranged as shown in the illustration given below. This proposed arrangement may be of any help to your improvement plan.

<u>Proposed Line Arrangement</u>





Let us explain why we have suggested to adopt the above scheme. In making paper of fine quality, a secondary dust collector is usually installed right before a paper machine when stock preparation has been finished and its concentration is brought down to a low level. To do so, a new cleaner should most preferably be provided. Nevertheless, the above plan has been proposed as a second best measure because, under the current arrangement where the factory's own waste paper is repulped by the beater and then passed through the cleaner, the concentration is so unstable that the cleaner is unable to function properly. No cleaner will be needed if the dust mixture rate for NBKP is under 3 mm^2/m^2. Under these circumstances, care should be taken not to let dust get mixed in during repulping work and, at the same time, to put package paper into the pulper for waste paper.

A number of benefits can be derived from the removal of dust, which include:

a. Fish eyes (dirty spots) caused by a foreign matter will be decreased, and excessive use of steam due to overdrying can be prevented;

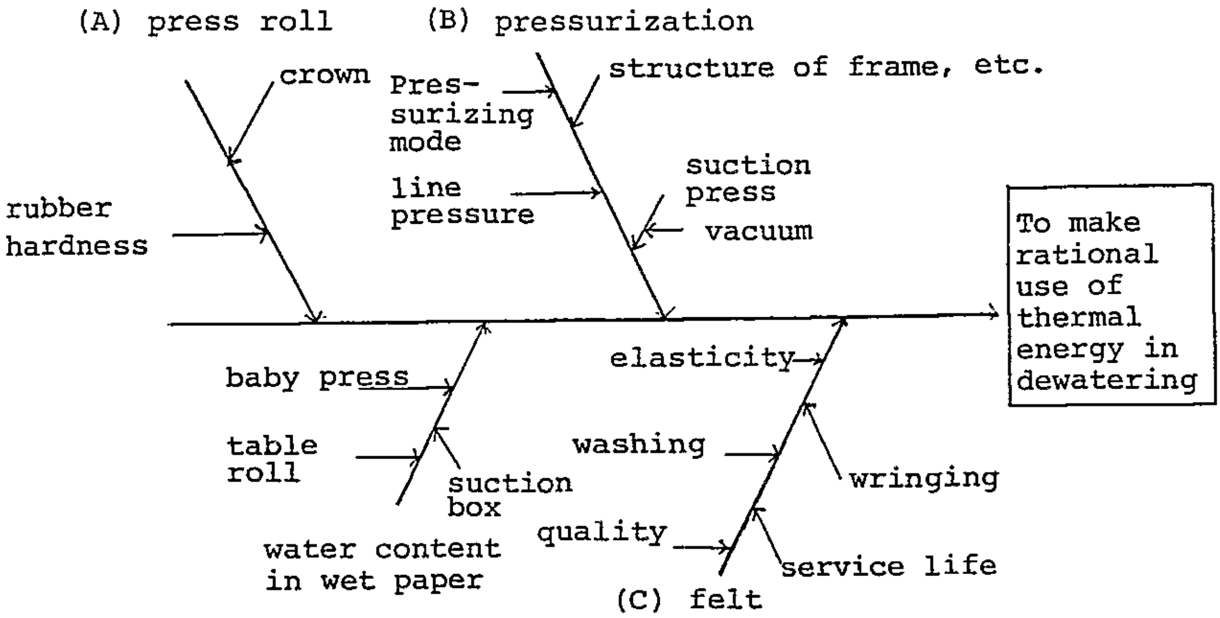
b. Sheets of paper broken in the dryer and those rejected after sorting in the finish process will be decreased in quantity, resulting in an increase in production as well as an overall saving of energy; and

c. The quality of the product will be improved.

The prevention of paper breakage and overdrying is expected to bring about a saving of 10 percent of steam.

(2) Press part

Factors contributing to the betterment of dewatering in the press part can be illustrated as follows:



No attempt, we were told, has so far been made to measure the water content of paper at the wet end. A 1 percent reduction in the water content before the dryer will result in a 3 to 5 percent cutback on steam in the dryer. The water content after the press part should be made clear without fail by sampling, which must be made crosswise at four to five spots to compare data on the water content.

A. Press roll

A crosswise variation in the water content of paper causes overdrying in the dryer. This variation is attributable to the crown of a press roll getting out of shape or to partial stains on a felt. Unless the press roll's crown is kept in proper shape, its overall dehydrating capacity will be lowered. So the press roll should be examined to see if its crown is in good shape when the felt is renewed or the roll is stopped for repair. If the press roll's crown is found to be out of shape, it must be corrected immediately. In addition, the rubber hardness should be checked to see if it is proper.

B. Pressurization

How to pressurize by the press roll is the job which the machine tender should always give the best attention to. Applying too much force may damage equipment. An attempt should be made, therefore, to have some specialists or manufacturers check up on the strength of frames. The pressure level should be raised little by littel to squeeze water out of paper, while the quality is being checked.

C. Felt

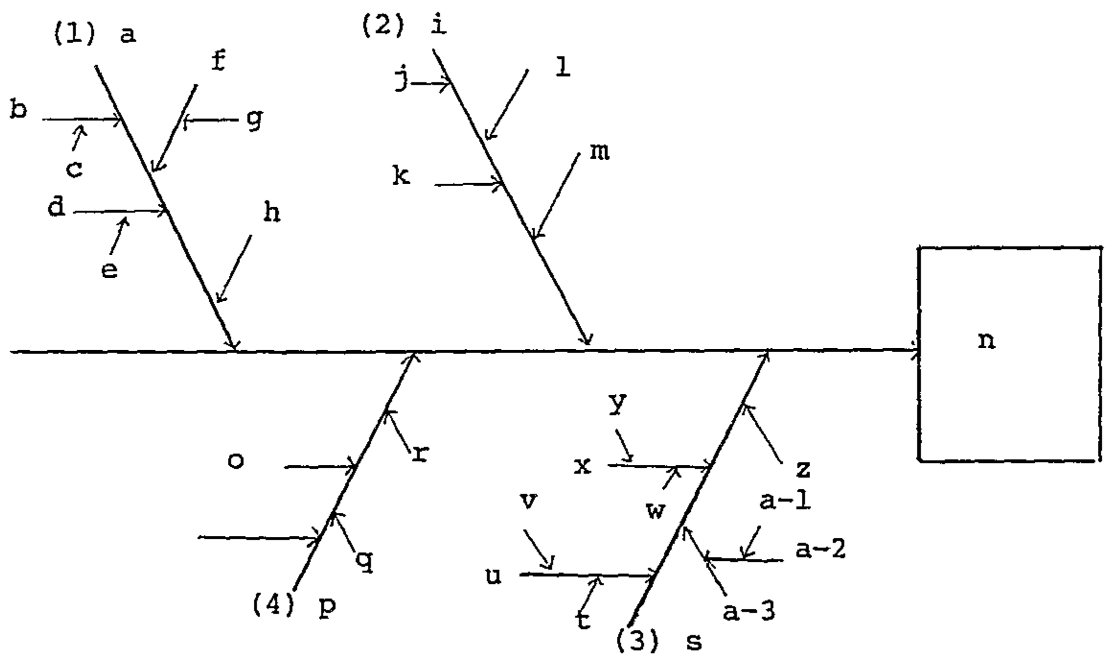
Felt seems to have been poorly maintained. Dehydration occurs this way. The moment felt is relieved from the nip pressure of the press roll, it swells all of a sudden to restore its original form and, in so doing, absorbs water from wet paper. Felt, therefore, should be less resistant to water permeation and elastic enough to absorb water.

With better understanding of its function, efforts should be made to keep felt clean by making full use of showering and squeezing devices for washing, thereby improving the dehydration efficiency, as much as possible, and stepping up energy rationalization. As a result of 1% reduction in water content after pressing process, steam saving rate is expected to get to as much as 4%.

(3) Dryer part

Effects of remedial measures, if depending on what measures are taken, are remarkable in the dryer part where, using steam, paper with the water content of 57 to 60 percent will be evaporatively dried up to become almost bone-dry.

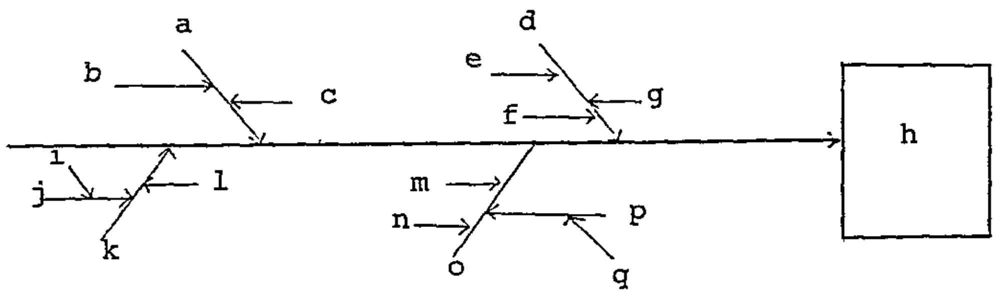
Factors contributing to energy conservation in this dryer part can be illustrated as follows:



a. dryer cylinder; b. surface heat transfer efficiency; c. doctor; d. condensate; e. siphon f. steam; g. blow pressure (temperature); h. no. of units; i. canvas; j. air permeability; k. canvas dryer; l. tension; m. hot air blow roll; n. Making rational use of thermal energy in the dryer; o. use of flash steam; p. condensate system; q. trap; r. heat insulation; s. ventilation; t. closed hood; u. hood; v. open hood; w. forced exhaust; x. exhaust; y. natural exhaust; z. waste heat recovery; a-1. air current; a-2. uneveness in drying; a-3. construction of hood.

A. Dryer cylinder

A cylinder transfers the heat of steam taken in to its surface and raises the temperature of wet paper in contact so that evaporation can be accelerated. An effective use of this heat affords a marked saving of energy. Factors affecting the rationalization of thermal energy consumption can be expressed in a graphical form as follows:



a. Keeping a condensate film over the inner wall of a cylinder thin; b. type of siphon; c. proper use of siphon; d. resistance between layers of paper; e. freeness; f. density; g. sheet formation; h. To increase thermal efficiency in a cylinder; i. doctor; j. dregs removal; k. Decreasing thermal resistance of cylinder surface; l. quality of material; m. canvas; n. tension; o. Making closer contact with cylinder bottom; p. Holding angle; p. to keep air out

The siphon should be periodically inspected and regulated so that a condensate film can be made as thin as possible. Some siphons have their own limits in this regard; if the siphon in use is not good, replace it by a more efficient one to make better use of energy.

Remove paper dust and other foreign substances, if any, from the cylinder surface as they adversely affect the thermal conductivity. The doctor is a dust collecting device that contributes to the smoothness of the cylinder surface and influences contact between paper and the cylinder surface.

B. Canvas

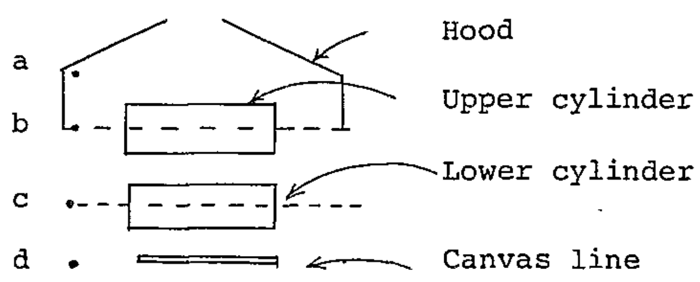
A canvas makes contact between paper and the cylinder surface closer, holds and releases vapor given off by wet sheets of paper in an open space from one cylinder to another. To allow a canvas to perform this function effectively, it is necessary to prevent it from getting dirty and keep the temperature from going down due to the cold outside air when it returns. The temperature can be kept at a high level by hanging a polyethylene-film curtain on the side of the dryer down to the floor.

C. Ventilation

The so-called dryer pocket - a section inside the dryer surrounded by a cylinder, canvas and sheets of paper - is poorly ventilated; the partial pressure of water vapor is so high due to an air eddy staying at the center of the cylinder that the canvas is hindered from dehydration and drying, so it seemed.

When the dryer, or for that matter the dryer pocket, is badly ventilated, it is desirable to convert an open hood into a closed one, but this conversion costs enormously. Yet, as mentioned earlier, if the machine is not so wide, the ventilation can be improved by hanging a polyethylene-film curtain in front of the dryer.

Given below are the results of measurement of temperatures in front of the Nos. 1 and 2 machines.



Points	1 m/c	2 m/c
a.	51°C	-
b.	44	42
c.	37	41
d.	36	38

The points c. and d. showed a lower temperature due to the outside air coming in. The backflow of a hot air from the central area of the dryer was observed during measurement.

Water sprinkling over the floor in the periphery of the dryer should be discontinued as it raises the temperature of the air coming in from outside.

Energy conservation will be worth doing if only it is achieved not by a sweeping, decisive measure but through concerted efforts by workers at large, using their own ingenuity and going slow but steadily. Such a process will also have an inspiring effects on the morale of the factory on the whole.

Taken together, it is expected that a saving of 2 percent of steam will be achieved by the above-mentioned remedies.

(4) Others

A. Resin coming from printing ink, adhesives or adhesive tapes, etc. attached to waste paper as well as wood resin, etc. contained in BKP are condensed with additives of alum and deposited, which causes stains on the felt and broken paper. If resin cannot be removed by a screen or liquid cyclone, it is a good idea to use some proper chemicals capable of separating it into fine particles.

B. Stains on a felt and deposits in paper are sometimes caused by starch, which is mainly attributable to inadequate cooking. Starch must be cooked carefully.

Polyacrylamide is used as a paper strength improver in place of starch. Though its price is a little high, this chemical substance requires no steam for cooking, making work much easier. So it is advised to study polyacrylamide to improve paper strength.

C. It is also advised to examine the possibility of raising the temperature of water by making use of waste heat recovered from the exhaust gas coming out of the hood in the future.

(5) Boilers

Although the water content of sawdust is around 40 percent, it is recommended to use it after drying it up as much as practicable.

Neither the No. 1 boiler nor the No. 2 boiler was fitted with a feed water flowmeter; the No. 2 boiler was not equipped with a fuel flowmeter, either. So these flowmeters should be fitted both boilers. With data obtained by these flowmeters, an attempt will have to be made to check up on the ratio of the amount of steam produced to that of fuel consumed in order to see if boilers are operated properly and improve their operation.

Although the No. 1 boiler was insulated with glass wool, its surface temperature stood at 131°C but its heat release amounted to as much as 1,330 kcal/m^2 h. A thermometer should be provided to measure temperatures of the exhaust gas at the outlet of the boiler.

The quality of feed water and boiler water is as shown below.

	Feed water	Boiler water
pH	8.4	10.14
Conductivity (μs/cm)	650	16,680

The electric conductivity of boiler water should be kept at 6,000 μs/cm or below. To do so, it is necessary to make more blows and control the quality of feed water.

The sawdust-burning boiler was discharging a high-temperature exhaust gas (305°C). Recovery and use of this waste heat to raise the temperature of feed water up to 120°C will result in a saving of 5 percent of fuel:

Economizer's heat transfer area - 200 m^2

Amount of water - 8 t/h

Temperature of water

,

At inlet	-	70°C
At outlet	-	120°C

Also, the air ratio of this sawdust-burning boiler stood at a higher level of 2.16, resulting in a large amount of heat loss in the exhaust gas. It is necessary to regulate the outlet damper and adjust the amount of secondary air to be blow in.

If the air ratio is lowered from the current level of 2.16 to 1.5, then the exhaust gas will be decreased by about 30 percent and fuel can be saved by around 12 percent.

(6) Steam pipes

The pressure of steam pipes hovered somewhere between 4.3 and 5.3 kgs/cm^2. This seems to be because an auxiliary boiler has been in on-and-off operation.

Some of the small pipes for the paper machine should be given better insulation.

It is necessary to check up on gauges and meters as well as the steam trap.

(7) Insulation improvement

Headers and others were covered with strips of hemp cloth, representing a sign of energy-saving efforts. Some of the valves and flanges in the boiler room, and some of the pipes for the paper machine were not insulated and some broken. These should be insulated or repaired, and then a saving of about 2 percent of steam can be achieved. Also condensate pipes and feed water tanks must be completely insulated.

(8) Utilization of flash steam

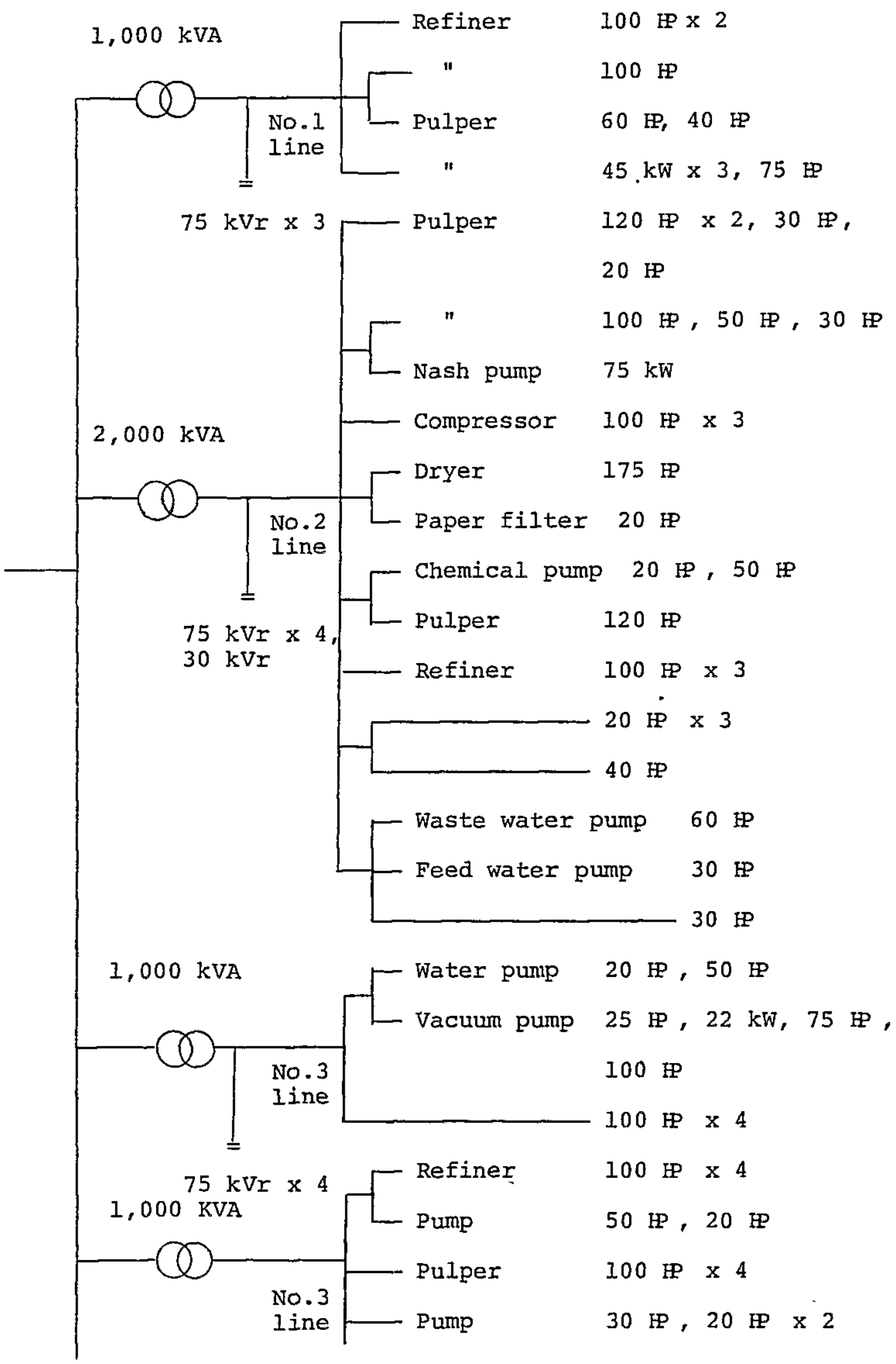
Utilization of flash steam is now under consideration, so we were told. Considerable energy-saving effects can be secured if steam generated is used for the rear stage of the dryer, its condensate guided into a flash tank, and low-pressure steam generated in this tank utilized for the front stage of the dryer, etc. Ordinarily, 35 percent of the energy of a condensate generated from 4kgs/cm^{2}G of steam will turn into flash steam, but currently this flash steam is not utilized. Another way of energy conservation is to recover a drain under pressure and feed it as it is into a boiler; a special pump is required to do so.

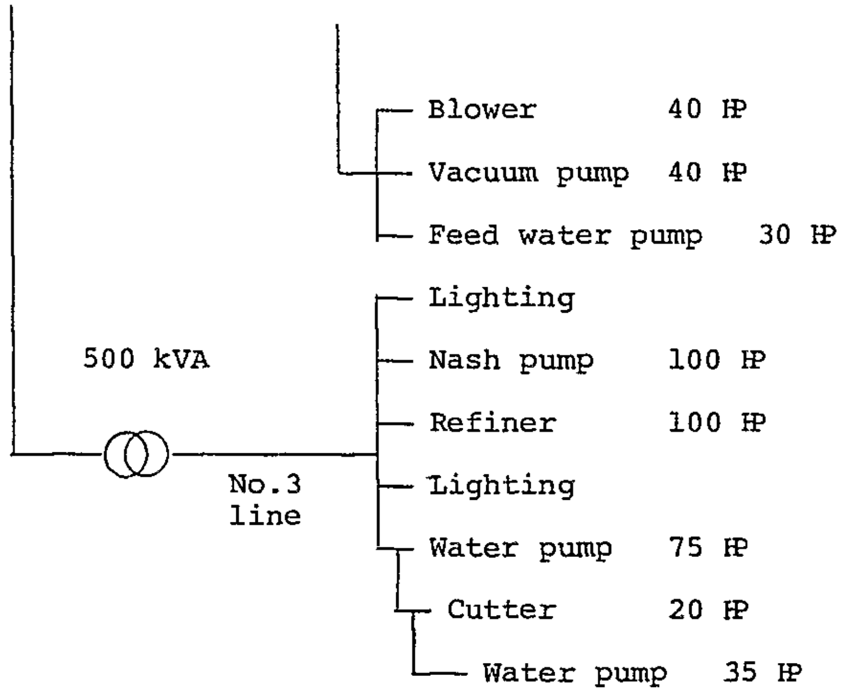
7. State of Electric Power Consumption

(1) The principal data relating to power consumption are as follows:

Power company	-	PEA
Peak demand	-	2,580 kW
Power consumption	-	1,321,000 kWh/m
Load factor	-	73.5%
Penalty	-	-
Power factor	-	91.0%
Transformers	-	5,500 kVA in all
Power consumption rate	-	1,245 kWh/t

(2) One-line diagram





8. Problems in Electric Power Control and Potential Solutions

(1) Transformers

Power and power factor of each transformer are as given below.

Power and Power Factor of Transformer

Line no.	Capacity of trans-former (kVA)	Condenser (kVr)	Power	Apparent power (kVA)	Power factor (%)
No.1	1,000	225 (total)	543+j351.3	647	80 - 87
No.2	2,000	330 (total)	784+j288.8	817	94 - 97
No.3	1,000	300 (total)	416+j121.5	434	90 - 96
No.3	1,000	No conden-ser	330.6+j204.1	388.6	85

No.3	500	No condenser	227.7+j139.9	267.2	85
Total	5,500	855	2,301.3 +j1,045.6	2,553.8	

Of these, the power factor of the 1,000 kVA transformer for the No. 1 line stood at a rather low level of 80 to 87 percent. The capacity of condenser is a little insufficient. It would be wiser to change the capacity of the condenser from the current level to 4 x 75 kVr, and to let it be turned on and off automatically.

The 1,000 kVA and 500 kVA transformers for the No. 3 line were not connected with a condenser, nor they were fitted with a power factor meter and voltmeter. Based on the results of measurement of ampere, voltage, and power levels by each branch, the power factor for each transformer was calculated as follows:

Power levels of the 1,000 kVA transformer are:

$\dot{P}r = 122.9 + j82.2$ - For refiner

$\dot{P}p = 38.9 + j40.6$ - For pulper

$\dot{P}c = 117.3 + j59.3$ - For chest pump

$\dot{P}b = 51.5 + j22.1$ - For boiler

So, the total power of this transformer is: $\dot{P}_1 = 330.6 + j204.2$. Its total apparent power is: $|P_1| = = 388.6$. And its power factor runs at 85.1 percent.

The total power of the 500 kVA transformer is: $\dot{P}_2 = 227.7 + j139.8$; its apparent power: $|P_2| =$

267.2; and its power factor 85.2 percent.

From the foregoing table, it is clear that the transformers have too large a capacity as compared with power requirements.

Now let us find the total of the loads in the Nos. 1 and 2 lines. The maximum load in each line is considered here.

The maximum load in the No. 1 line is 667 + j396.0, and the maximum load in the No. 2 line 849 + j279.2. So the total power combined will be 1,516 + j675.2. The total apparent power will be 1,660 kVA and the power factor 91.3 percent.

Next, let us add up loads on the two 1,000 kVA transformers in the No. 3 line. Then, the power will amount to 746.6 + j325.6 and the combined apparent power 814.5.

It should be apparent from the above that the 1,000 kVA transformer in the No. 1 line and the 2,000 kVA transformer in the No. 2 line can be replaced by one 2,000 kVA unit, and the two 1,000 kVA transformers by one 1,000 kVA unit. Therefore, there will be no more iron and copper losses in the two 1,000 kVA transformers, whereas there will be an increase in copper loss in the remaining transformers. These changes in iron and copper losses can be reckoned as follows:

If a reduction in iron loss in one 1,000 kVA transformer is 4 kW per hour, then the iron loss for two units will be decreased by: 4 x 365 x 24 x 2 = 70,080 kWh/y. When the 1,000 kVA transformer in the No.1 line is run at full load, the copper loss can be assumed to be 13 kW per hour. So the yearly copper loss in this unit will be reduced by: $13 \times (\frac{647}{1,000})^2 \times (365 - 24) \times 24 = 44,537$ kWh/y. And before improvement, the 2,000 kVA transformer in the No.2 line is run at full load, the copper loss in this unit will be reduecd by: $17 \times (\frac{817}{2,000})^2 \times (365 - 24) \times 24 = 23,261$ kWh/y. Supposing that the Nos.1 and 2 lines are operated by a single 2,000 kVA transformer, the resulting copper loss will be: $17 \times (\frac{1,448}{2,000})^2 \times (365 - 24) \times 24 = 72,928$ kWh/y. Accordingly, the copper loss will increase by: 72,928 - 44,537 - 23,216 = 5,175 kWh/y.

Let us see what will happen if the two 1,000 kVA transformer in the No.3 line are replaced by a single unit.

A copper loss in each one of the two 1,000 kVA transformer is:

$$13 \times (\frac{434}{1,000})^2 \times (365 - 24) \times 24 = 20,040 \text{ kWh/y}$$

$$13 \times (\frac{389}{1,000})^2 \times (365 - 24) \times 24 = 16,099 \text{ kWh/y}$$

By contrast, a copper loss in a single 1,000 kVA unit will be:

$$13 \times (\frac{814.5}{1,000})^2 \times (365 - 24) \times 24 = 70,582 \text{ kWh/y}$$

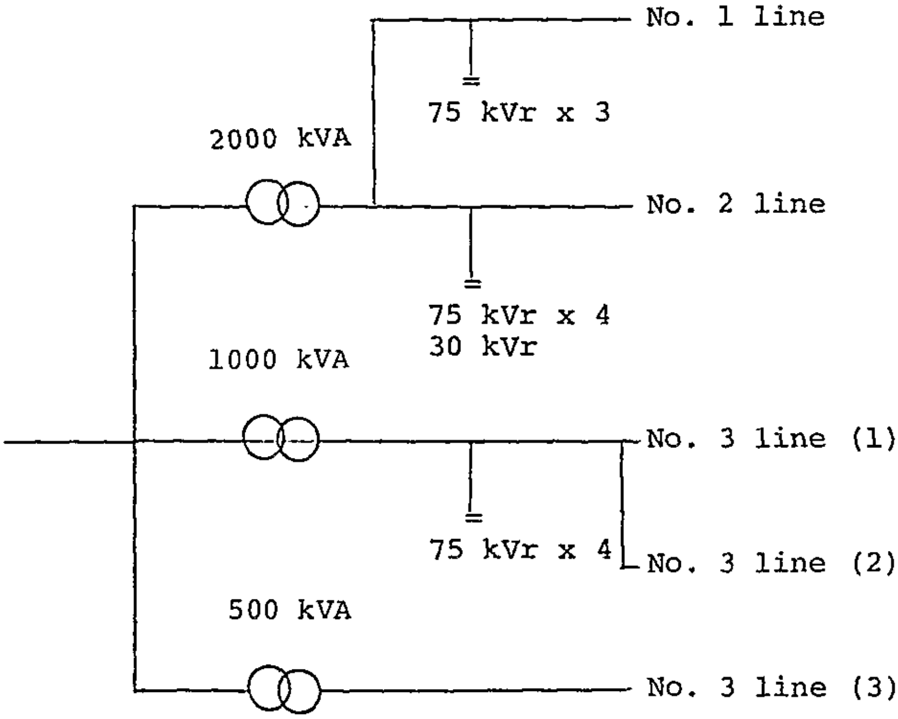
Consequently, the copper loss will increase by:

70,582 - 20,040 - 16,099 = 34,443 kWh/y

Such being the case, the decreased iron loss will amount to 70,080 kWh/y, the increased copper loss (1) 5,175 kWh/y, and another increased copper loss (2) 34,443 kWh/y.

Taken together, an overall saving of 30,462 kWh/y can be achieved.

Proposed Rearrangement of Transformers



(2) Voltage

A proper secondary voltage level of each transformer is around 390 V. The transformers with condensers, however, were found to have shown a rather high secondary voltage level of 404 to 420 V.

A drop in the voltage by a few volts was observed between the transformer terminal and the motor. It is better to hold the secondary voltage at the transformer terminal a little lower than 390 V. So the terminal on the primary side of the transformer should be switched over to a higher one. If a primary line is connected with the 20,900 V terminal, then it should be reconnected with another terminal of around 22,000 V.

Also, an inequality of about 5 volts in the voltage was ovserved on the secondary side. It should be corrected by reconnecting a single-phase load with a line of as high a voltage as possible.

(3) Operation of motors

The table below shows how motors for major equipment are being operated.

No. of line	Used for:	Output HP	Rated current A	Load current B	$\frac{B}{A}$ %
1	Refiner	100	146 A	100 A	68.5
1	"	100	146	100	68.5
1	"	100	146	120	82.2
1	Pulper	60	84	50	59.5
1	"	40	56	60	107
1	Nash pump	22 kW	44	22	50
2	Pulper	120 HP	166	105	63.3
2	"	30	45	39	86.7
2	"	20	29	17	58.6
2	Pulp pump	50	70	48	68.6
2	"	30	45	28	62.2
2	Nash pump	75 kW	145	86	59.3
2	Compressor	100 HP	130	72	55.4
2	"	100	130	64	49.2
2	"	100	141	56	39.7

2	Dryer	175	234	175	74.7
2	Paper filter	20	29	10	34.5
2	Pulper	120	166	105	63.3
2	Refiner	100	133	74	55.6
2	"	100	133	74	55.6
2	Waste water pump	60	84	50	59.5
3	Water pump	20	29	18	62.1
3	"	50	70	39	55.7
3	Nash pump	25	39.5	28	70.9
3	"	22 kW	44	12	27.2
3	"	75 HP	102	80	78.4
3	"	100	158	95	60.1
3	"	100	139	89.3	64.2
3	Refiner	100	134	47.3	35.3
3	"	100	137.5	46.7	34.0
3	"	100	139	29	20.8
3	Water pump	50	70	40	57.1
3	"	20	29	5	17.2
3	Pulper	100	139	30.7	22.1
3	Pump	30	45	23	51.1
3	"	20	25	19	76
3	"	20	29	13	44.8
3	Blower	40	48	29	60.4
3	Nash pump	40	56	31.2	55.7
3	Water pump	35	52	42.5	81.7
3	"	75	104	70	67.3
3	Refiner	100	133	125	94.0
3	Nash pump	100	152	95	62.5

* A double line represents the boundary between branches.

** Those equipment at rest are excluded.

Many of the motors installed in the No. 3 line were given a small load. Since the power factor is lowered, it would be wiser to adjust the number of units in operation or replace them by smaller ones.

(4) Lighting

Most of the lights were daylight fluorescent lamps. If they are replaced by white fluorescent lamps, a saving of about 10 percent in electric power can be achieved. This will amount to: 400 W x 46 x 10 h x 365 d x 0.10 = 6,700 kWh/y

(5) Others

The transformer oil was heavily contaminated. They should be filtered and cleaned up.

The 1,000 kVA and 500 kVA transformers without condenser in the No. 3 line should preferably be fitted with a wattmeter (kW) and power factor meter so that power levels and the power factor can be recorded every hour. It is necessary, however, to examine the rated load for CT and PT.

9. Summary

The abovementioned remedial measures, if actually taken, will bring about energy-saving effects as shown below.

Measures	Potential energy saving		rate (%)
Prevention of paper breakage and over-drying	636 kl/y	(fuel oil)	10
Reduction of moisture (1%) at the wet end	254	(fuel oil)	4
Insulation improvement on pipes and valves	127	(fuel oil)	2
Improved ventilation of the dryer through provision of curtain	127	(fuel oil)	2
Preheating of feed water through use of waste heat from boiler	261	(fuel oil)	4
Regulation of the air ratio in boiler	626	(fuel oil)	10
Subtotal	2,031		32
Rearrangement of transformers	30,500 kWh/y	(electricity)	
Use of more efficient lighting apparatuses	6,700 kWh/y	(electricity)	
Subtotal	37,200 kWh/y		0.2%

Report No. 16: Paper

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

- Arkanae Paper Industry -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Arkanae Paper Industry -

1. Outline of the Factory

Address : 75 Area 13, Tudmai Rd., Tambol Suenlueng
Kratumband District, Samut Sakorn

Type of industry : Paper

Major products : Kraft paper

Output : 4 t/d

Annual energy consumption :

- Electric power : 1,059,000 kWh
- Fuel
  Fuel oil : 600 kl

Interviewee : Phum Upom, president

Date of diagnosis : Aug. 26 - 27, 1982

Diagnosers : A. Koizumi, K. Nakao, and K. Kurita

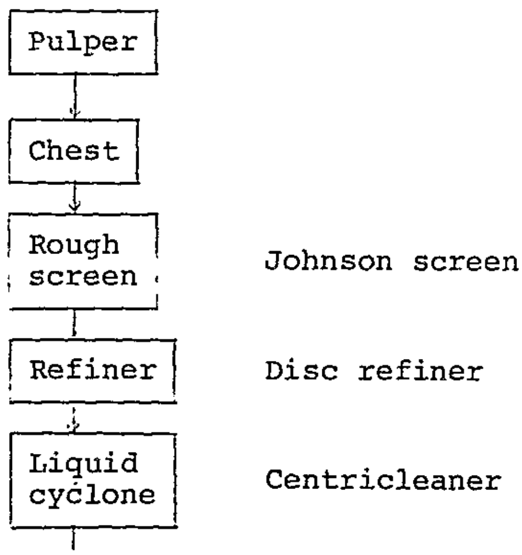
Arkanae Paper Industry now produces four tons of kraft paper a day with a single line of installations using only waste paper as raw materials. The paper mill is planning to install some additional pulpers to increase its capacity to seven tons a day.

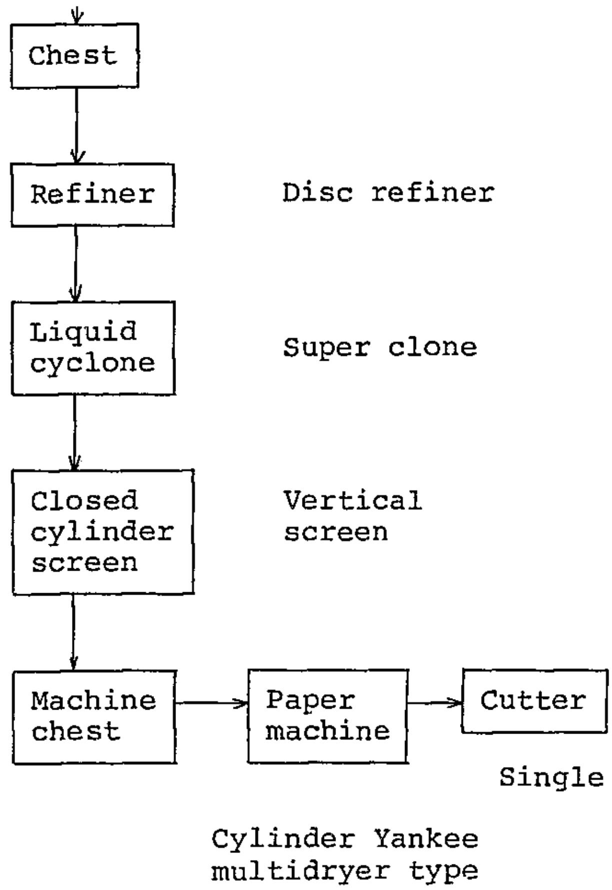
The managing director directly controls management allover the factory, including production, financial affairs, and marketing. His efforts are especially concentrated on production management; when we visited the factory, he took us round in the factory himself and listened to our comments with deep interest.

However, the inside of the factory, particularly around the stock preparing unit, was apparently left uncleaned, and the machines were not kept in good repair. From now on, efforts are needed to provide a proper in-house educational and training program for the employees to improve their know-how and skill, while training some of them as responsible senior staff members for the production, technological, and administrative divisions. Through these improvements, a new system should be set up to introduce management through figures.

On the whole, there is big room for further improvements in the installations and operaitng techniques as the paper mill operation is still based on the idea that products will continue to come out automatically as long as the machines are kept running.

2. Manufacturing Process





3. Major Equipment

(1) Stock preparation part

Process	Equipment
Repulping	Pulper (2 units)
Screening and separating	Johnson screen (2 lines) Liquid cyclone (2 lines) Closed cylinder screen (1 line)
Refining	Refiner (2 lines)

(2) Paper machine

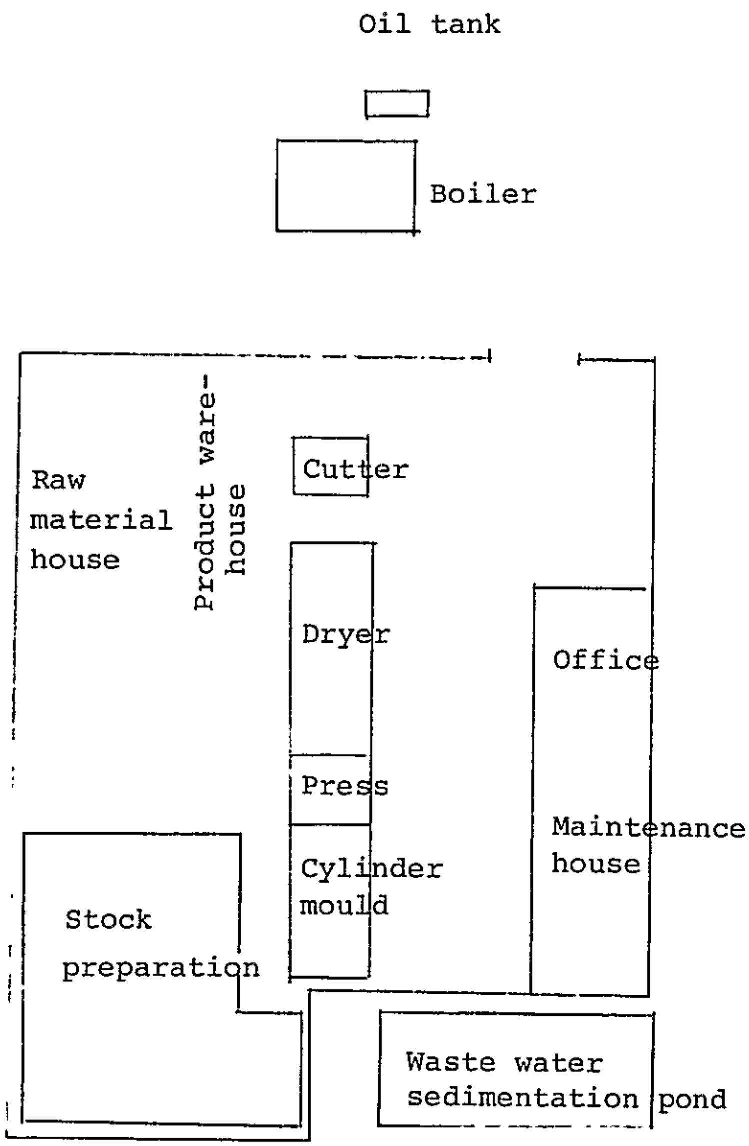
65" wide Yankee multicylinder type combined with cutter (one unit)

Major equipment	Type
Mould	Cylinder 3 units
Press	Baby press 1 set Press 3 sets
Dryer	Yankee 1 Cylinder (without hood) 10
Cutter	Single 1

(3) Boiler

No. of boiler	No. 1	No. 2
Pressure	5.3 kg/cm^2G	5.3 kg/cm^2G
Quantity of evaporation	3,000 kg/h	3,000 kg/h
Fuel	Fuel oil	Fuel oil

(4) Layout



Oil tank
Boiler
Raw
material
house
Product ware-
house
Cutter
Dryer
Press
Cylinder
mould
Office
Maintenance
house
Stock
preparation
Waste water
sedimentation pond

4. State of Energy Management

A proper management system is yet to be built up not only for energy control but also for all other areas including quality control, equipment maintenance, and operational safety. Even necessary data are not kept on record and the mill has no engineer who is conversant with papermaking techniques.

Therefore, a series of steps should be taken as soon as reasonably practicable:

(1) To strengthen the technical staff;

(2) To collect and maintain data on output, operating conditions, and energy consumption;

(3) To install necessary instruments and testing apparatuses such as weighing machines and rupture testers, so that records of measured data be maintained on all the necessary details of paper quality including weight, water content, strength, and impurity content;

(4) To assign a proper manager to check up these data every day and feed them back to the operating conditions of the facilities;

(5) To educate and train the factory workers how to handle raw materials and maintain the machinery;

(6) To make better safety arrangements by providing covers for all rotors and driving belts as well as guardrails for passages; and

(7) To keep the entire facilities clean and in good order.

These improvements would upgrade the existing one-man operation to a modern systematic one which will no doubt bring about greater production efficiency.

5. State of Fuel Consumption

The paper mill operates two boilers alternately for every two weeks, which require some 2,000 liters of fuel oil a day. During our visit, No. 1 Boiler was in operation, burning 78.5 liters (or 73 kg) of fuel oil per hour. All steam generated by the boiler 870 kg/h was supplied to the paper machine. The fuel consumption rate was roughly determined at 400 liters of oil for every ton of paper produced.

Heat Balance in No. 1 Boiler

Input (10^3 kcal/h, %)			Output (10^3 kcal/h, %)		
Heat of fuel combustion	715.5	99.7	Heat of steam	548.1	76.3
Sensible heat of fuel	2.5	0.3	Heat loss in exhaust gas	128.4	17.9
			Heat loss in blow water	5.6	0.8
			Heat release from furnace	35.9	5.0
Total	718.0	100	Total	718.0	100

Notes:

1) Data given for determination of the heat balance -

Type of fuel - Fuel oil

Fuel consumption (F) - 73 kg/h

Heat contents of fuel (Hl) - 9,802 kcal/kg

Specific heat of fuel (C_P) - 0.45 kcal/kg°C

Temperature of fuel (T_F) - 107°C

Reference temperature (T_O) - 30°C

Oxygen content in exhaust gas (O_2) - 8.4%

Temperature of exhaust gas (T_G) - 330°C

Flow rate of blow water (B) - 45 kg/h

Temperature of blow water (T_B) - 154°C

Temperature of feed water (T_W) - 29°C

Steam pressure (P) - 5.3 kg/cm^2 G

2) Equations for calculating the heat balance -

Input

a. Heat of fuel combustion (Q_C)

$Q_C = F \times Hl = 715.5 \times 10^3$ kcal/h

b. Sensible heat of fuel (Q_S)

$Q_S = F \times C_P (T_F - T_O) = 2.5 \times 10^3$ kcal/h

Output

a. Heat loss in exhaust gas (Q_E)

Theoretical amount of air (Ao) $= \frac{0.85 \, Hl}{1,000} + 2.0$

$= 10.33 \, Nm^3/kg$

Theoretical amount of exhaust gas (Go) $= \frac{1.11 \, Hl}{1,000}$

$= 10.88 \, Nm^3/kg$

Air ratio (m) = $\frac{21}{21 - O_2}$ = 1.67

Actual amount of exhaust gas (G) = Go + Ao (m - 1)

= 17.77 Nm^3/kg

$Q_E = F \times G \times 0.33(T_G - To) = 128.4 \times 10^3$ kcal/h

b. Heat loss in blow water (Q_B)

$Q_B = B \times (T_B - T_W) = 5.6 \times 10^3$ kcal/h

c. Heat release from the furnace (Q_R) --- estimated at 5 percent of heat input

$Q_R = (Q_C + Q_S) \times 0.05 = 35.9 \times 10^3$ kcal/h

d. Heat of steam (Q_V)

$Q_V = Q_C + Q_S - Q_E - Q_B - Q_R = 548.1 \times 10^3$ kcal/h

e. Evaporation rate (S)

Enthalpy of steam (E_S) = 658.43 kcal/kg

Enthalpy of feed water (E_F) = 29 kcal/kg

$S = Q_V \div (E_S - E_F) = 870$ kg/h

6. Problems in Heat Control and Potential Solutions

(1) Stock preparation

The first consideration in factory management is to keep it clean and in order, particularly in the stock preparation unit which is likely to become dirty and untidy unless continued efforts are made for this purpose. Major equipment should also be checked up at regular intervals to make sure that the machines are operated with the specified number of belts set at the specified tension level. This will help preclude waste of power.

Apparently some power loss occurs at the pumps of the paper mill because of a labyrinth of pipes which cross each other in different parts. A new piping plan must be worked out to set up a proper piping system step by step to minimize their lengths.

Fluids passing through the refiner, cleaner, and screens must be maintained in a proper concentration range for each of them. In addition, the unit "freeness" is used for finding how much refining is done. Operation of the equipment out of the specified concentration ranges and refining standard would worsen the product quality and allow the dryer to use steam wastefully.

Some arrangements must be made by all means to measure the fluid concentration and freeness at regular intervals, while introducing necessary expertise to establish a proper control setup in the factory.

Major items for necessary heat control are as follows:

a. Finished paper has too much deposits on it. A step should be taken as soon as practicable to replace the existing screens by new ones with finer meshes as well as to increase their number at least for the face-side of paper. This may require an appreciable capital investment, but let us point out that a longer time is needed to dry paper with much deposits on its surface because such substances contain a substantial amount of water. Complete removal to water from these deposits necessarily involves overdrying of paper. Therefore, a decrease in such deposits will lead to a reduction of steam required in the drying process.

b. Fluid concentration for the Johnson screen has to be maintained at a proper level. If no instrument is available, measurement may be performed visually by all the workers assigned to this unit.

c. The inside of the cleaner should be checked up from time to time as necessary because its dust-removing capability would be affected when the inside surface gets rough due to wear and tear. In addition, steps should be taken to properly control the fluid concentration for the cleaner as well as to repair or replace the installation as it is damaged substantially.

(2) Press unit

Dehydration in the press unit depends on the pressure level of the press and the state of the felt. The factory appears to be unaware of the importance of pressing. It is recommended that the press be adjusted properly to produce higher pressure. Since strength of the frame seems insufficient, however, an expert engineer should be called in to examine and strengthen it as necessary before the pressure level of the press is increased. It must be borne in mind that a 1-percent reduction of water in the press will bring about some 3 to 5 percent decrease in the amount of steam required in the dryer.

The felt has to be washed well. Also a step should be taken immediately to repair the squeeze roll now detached from the press and left idle. In combination with a washing shower, the roll must be kept in operation with a clean felt on it.

We noticed that the felt of No. 3 dryer is badly soiled. Whenever any of the felts gets dirty, the machine must be shut down at once, and the felt should be washed well with a suitable detergent. The paper mill now uses dirty felt which leave large pellets of soil on the paper surface, subsequently worsening its quality and increasing steam consumption.

A 1-percent reduction in the water content of paper through the above improvement will save steam by some 4 percent.

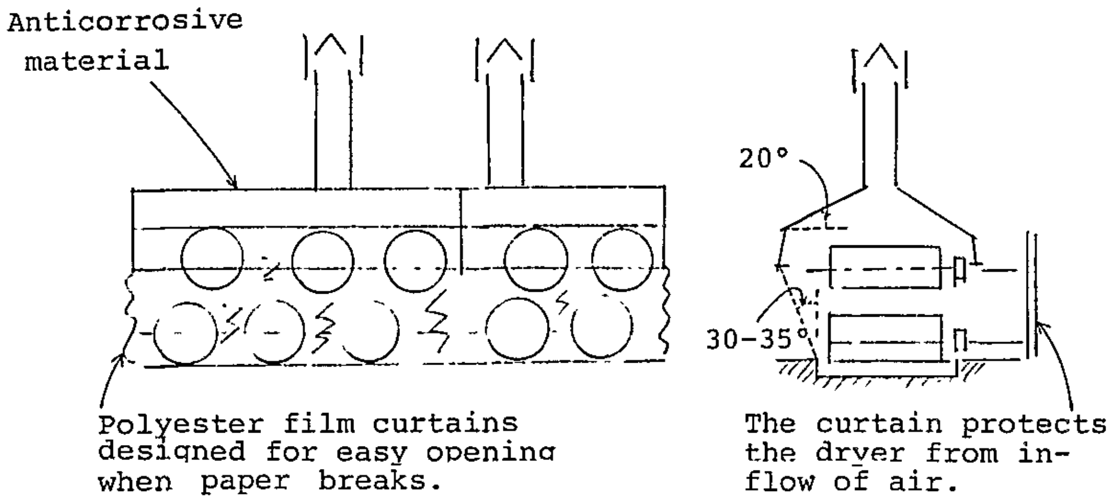
(3) Dryer unit

We found that the steam piping, its valves and flanges, and condensate piping are not adequately insulated. Steam may be saved by at least 10 percent if they are properly insulated.

Apparently the dryer has some excess capacity at the present rate of operation, and the drying process can be performed more quickly if a proper adjustment is carried out. An attempt should be made to lower the steam pressure as far as practicable because right now its level appears to be too high, and paper is overdried. The working environment of the paper mill is also affected by the present way of operation as radiant heat from the dryer increases the room temperature.

To ensure more efficient use of heat in the dryer, it is advisable to install a hood over this installation and attach curtains made of a transparent film to its sides. The hood will not only insulate the dryer but also help remove water vapor from its inside, while the curtains will preclude an excess inflow of air into the dryer unit and keep the hood performance from declining.

The rough sketches below show how to install the hood. It is recommended that the hood be installed at once if it can be prepared in the paper mill.



No record of steam consumption is maintained at the paper mill. At least a pressure gauge should be installed in a conspicuous place for easy reading, and necessary arrangements should be made to control the flow rate of steam according to dryness of paper.

(4) Boilers

In order to control boiler operation properly, adequate installation of measuring instruments for the flow rates of feed water and fuel as well as the temperatures of feed water, fuel, and exhaust gas is required. Also care should be taken to keep the existing instruments in good repair.

No. 1 Boiler shows a high oxygen content in its exhaust gas and also a high air ratio, i.e., 8.4

percent and 1.67, respectively. The air ratio can be reduced to 1.27 if the burner is adjusted to keep the oxygen content of exhaust gas at a 4.5-percent level.

Air ratio	1.67	1.27
Exhaust gas flow rate for 1 kg of fuel	17.77 Nm^3/kg	13.7 Nm^3/kg
Heat loss in exhaust gas (330°C) for 1 kg of fuel	1,935 kcal/kg	1,492 kcal/kg

Heat input from one kilogram of fuel at 107°C is 9,837 kcal/kg. If the air ratio is lowered from 1.67 to 1.27, the fuel consumption can be reduced to:

$$\frac{9,837 - 1,935}{9,837 - 1,492} = 0.947$$

This means that fuel can be saved by 5.3 percent. Exhaust gas seems to be a little too hot as its temperature is at 330°C now. Efforts are needed to operate the boiler more efficiently by cleaning its tubing at regular intervals.

The measured qualities of feed and boiler water are as shown in the table below.

	Feed water	Boiler water
pH		9.49
Conductivity	590 μs/cm	

The boiler water quality was found much worse than the allowable limit; its electric conductivity could not be determined as it was out of the measurable range (over 20,000 μs/cm), and also it was found to have a low pH value of 9.49.

An adjustment must be made immediately to increase the amount of blowoff from the boiler so that its water quality can be properly controlled. Some arrangements are also needed to improve the quality of feed water.

For reference, the normal pH value and electric conductivity of boiler water are given in the table below.

Normal pH value	11.0 - 11.8
Normal electric conductivity (μs/cm)	4,000 or less

We noticed that fuel oil is preheated to 90°C to 107°C. From the viscosity of the fuel used, we believe, it is quite satisfactory to preheat it to 70°C to 80°C.

(5) Steam piping

The steam piping is insufficiently insulated at many places. More specifically,

a. Some 6-meter length of the 3-inch piping from the main steam valve of the boiler to the steam header is left uninsulated;

b. The silica covering used for heat insulation has openings at many places;

c. A total of three of the main steam valves of the boiler and the steam header valves are left uninsulated;

d. The steam header as a whole is inadequately insulated; and

e. The back wall of No. 1 Boiler is not either insulated satisfactorily.

The table below gives an example of decreases in heat loss when the steam piping is satisfactorily insulated.

	Heat loss		Length and area of insulation	Heat loss reduced by:
	Without insulation	With insulation		
3-inch piping	570 kcal/m h	24 kcal/m h	6 m	3,276 kcal/h
Steam header	2,080 $kcal/m^2h$	72 $kcal/m^2h$	2.55 m^2	5,120 kcal/h
Total				8,396 kcal/h

This reduction of heat loss means about 1-percent fuel saving relative to the heat input.

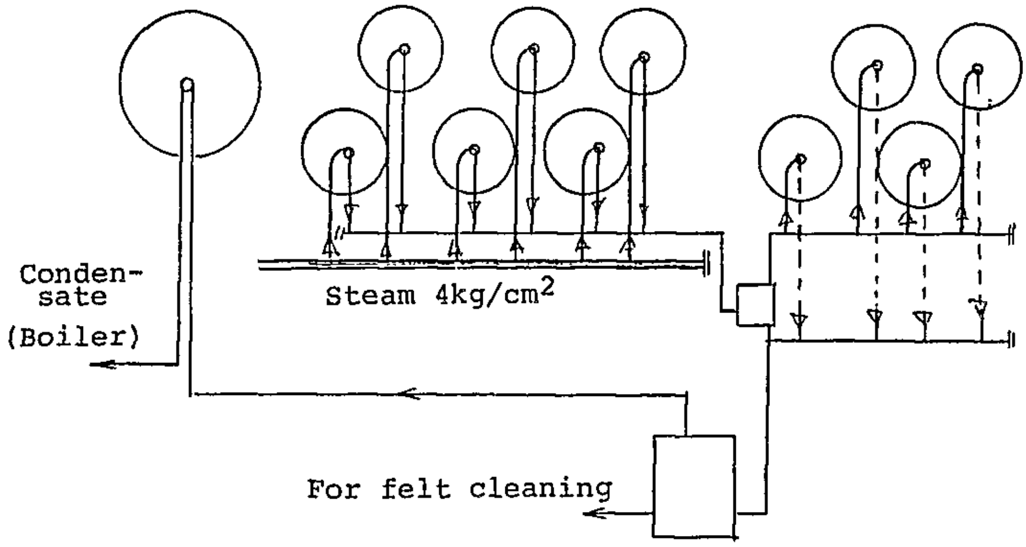
Many steam leaks were found at the inlet, outlet, and valve joints of the paper machine. Assuming that there is an opening of 1 mm in diameter at each of these places and that the steam pressure is 5 kg/cm^2 G, the steam leak would amount to 2.44 kg/h.

A combined total of leak at three places would reach 7.32 kg/h; this means an extra fuel consumption of 0.64 kg/h or 0.9 percent of the current consumption rate.

(6) Recovery of condensate

The paper mill has no system to recover condensate fluid from the dryer. Some favorable results may be obtained by recovering this fluid because it has a heat contents equal to 1/4 of the steam used. Therefore the condensate fluid, if recirculated as boiler feed water, will not only provide a useful heat source but also help improve the feed water quality, subsequently enabling the paper mill to reduce the required amount of blowoff from the boiler.

Two methods are available for recovering such fluids. The system shown in the rough sketch below puts the condensate fluid from the dryer into a flash tank where its pressure level is reduced. The steam generated in the tank may be used for the dryer, while the decompressed condensate fluid can be recirculated as boiler feed water. We recommend the paper mill to adopt this system.



The other method is to send the high-pressure condensate fluid as it is into the boiler, but this requires installation of a special pump.

Some steps should also be taken to satisfactorily insulate condensate piping and feed water tank and to keep the steam trap in good repair.

The foregoing improvements will save fuel by some 10 percent.

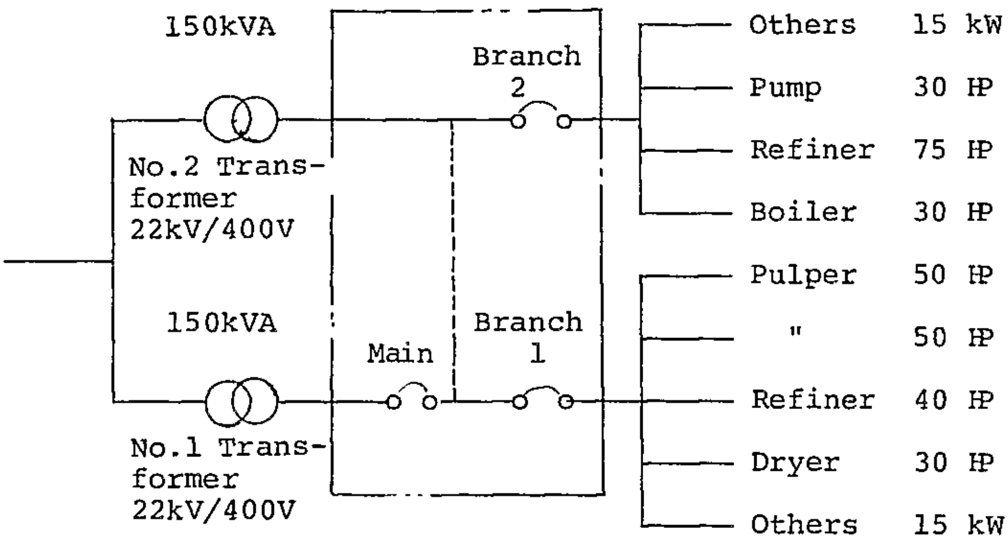
7. State of Electric Power Consumption

(1) The principal data relating to power consumption are as follows:

Power company - PEA

Peak demand	-	180 kW
Electric power used	-	88,250 kWh/m
Load factor	-	72.9%
Penalty	-	None
Power factor	-	63 - 65%
Transformers	-	150 kVA x 2
Power consumption rate	-	498.2 kWh/t

(2) One-line diagram



Note: The perforated line indicates where a new line will be added when No. 1 Transformer is replaced by a new one with 500 kVA capacity and No. 2 Transformer is removed.

8. Problems in Electric Power Control and Potential Solutions

(1) Load factor

The electric equipment of the paper mill, although shut down fortnightly, shows a favorable load factor as reflected in the following calculation because it is mostly operated continuously.

$$\text{Average electric power} = \frac{88,250}{28 \times 24} = 131.3 \text{ kW}$$

$$\text{Load factor} = \frac{131.3}{180} \times 100 = 72.9\%$$

(2) Power factor

A clamp-on wattmeter was used to determine the power factor since neither a wattmeter nor a power-factor indicator was installed in the receiving panel. The measured results are given in the tables below.

Voltage, amperage, electric power, and power. factor of No. 1 Transformer

(as of Aug. 26, 1982)

Time	Voltage (V)			Amperage (A)			kW	kVr	kVA	cos θ
	V_R	V_S	V_T	I_R	I_S	I_T				
15:51	220	222	224	173	154	160	74	80	109	0.679
16:06	223	224	225	169	151	164	76	81	111	0.685
16:21	224	225	227	140	125	134	57	70	90.3	0.631
16:33	226	227	229	143	131	141	60	72	93.7	0.640
16:44	228	229	231	144	132	140	62	73	95.8	0.647

Average: 0.6564

Voltage, amperage, electric power, and power factor of No. 2 Transformer

(As of Aug. 27, 1982)

Time	Voltage (V)			Amperage (A)			kW	kVr	kVA	cos θ
	V_R	V_S	V_T	I_R	I_S	I_T				
11:30	230	232	228	180	185	176	82	96	126.3	0.649
11:45	232	232	228	178	183	177	84	98	129.1	0.651
12:00	236	237	233	190	194	185	87	104	135.6	0.642
12:15	238	238	233	178	185	178	75	105	129	0.581

Average: 0.6308

As the power factors are low, it is desirable to install one 30 kVr condenser to No. 1 Transformer and two 30 kVr condensers to No. 2 Transformer in order to reduce transformer loss.

Calculation for No. 1 Transformer based on the data obtained from measurement at 16:44 is as follows:

Present performance is:

$$\dot{P}_1 = 62 + j73, \quad |P_1| = 95.8, \quad \cos\theta = 0.647$$

When a 30 kVr condenser is added, it follows

$$\dot{P}'_1 = 62 + j43, \quad |P'_1| = 75.5, \quad \cos\theta = 0.821$$

No. 2 Transformer is to be studied based on the data recorded at 11:30. The power factor at present is:

$$\dot{P}_2 = 82 + j96, \quad |P_2| = 126.3, \quad \cos\theta = 0.649$$

If two 30 kVr condensers are added, it follows

$\dot{P}'_2 = 82 + j36, \quad |P'_2| = 89.6, \quad \cos\theta = 0.915$

Assuming that copper loss in a 150 kVA transformer is 2.2 kW at full load, it follows

No. 1 Transformer : $2.2 \times \left\{ \left(\frac{95.8}{150}\right)^2 - \left(\frac{75.5}{150}\right)^2 \right\}$

$\times (365 - 24) \times 24 = 2{,}781.7$ kWh/y

No. 2 Transformer : $2.2 \times \left\{ \left(\frac{126.3}{150}\right)^2 - \left(\frac{89.6}{150}\right)^2 \right\}$

$\times (365 - 24) \times 24 = 6{,}339.5$ kWh/y

This means that loss will be reduced by 9,121.2 kWh per year in total.

(3) Operation of motors

The motors were found to have a ratio of load current to rated current below a 35-percent level. Therefore their power factors are low, and still lower are their ratios of load (kW) to rated power.

The table below shows the load levels of the major motors.

Operation of motors

Rated voltage: 380 V, 50 Hz

Used for:	Output (HP)	Rated Ⓐ current (A)	Load Ⓑ current (A)	Ⓑ/Ⓐ %	Remarks
Dryer	30	44	13.9	31.6	No.1 Transformer
Refiner	40	53.6	17.9	33.4	"
Pulper	50	67	20	29.9	"

Pulper	50	67	20.8	31.0	"
Refiner	75	96.6	24.6	25.5	No.2 Transformer
Pump	30	40.6	14.1	34.7	"

Two pulpers and two refiners are now operated, but if the paper mill can be satisfactorily run with one each, it is desirable to leave the other ones idle.

For the refiner, we think, the one with 75 HP motor should be left out of operation. When one is shut down for three hours a day for each of the pulper and refiner, the power loss can be reduced as follows:

With iron loss in the pulper motor (50 HP) given as 1.3 kWh/h, the reduction of loss would be

1.3 x 3 x (365 - 24) = 1,330 kWh/y

Assuming that iron loss in the refiner motor (75 HP) is 1.6 kWh/h, it follows

1.6 x 3 x (365 - 24) = 1,637 kWh/y

In total, the power saving would amount to 2,967 kWh/y.

(4) Lighting

No lighting is needed in daytime as the factory has no wall, and only a few lights are needed even at night.

9. Summary

The foregoing improvements will achieve the following energy conservation:

Measures	Potential energy saving	Rate (%)
Through better control for the screens and cleaner	12 kl/y (fuel oil)	2
By increasing the pressure level of the press and regularly cleaning the felt.	24 kl/y (fuel oil)	4
Through better insulation for the steam piping of the dryer unit	60 kl/y (fuel oil)	10
With recovery of condensate and installation of hood over the dryer	60 kl/y (fuel oil)	10
By improving the air ratio for the boiler	30 kl/y (fuel oil)	5
With better insulation for the boiler room	6 kl/y (fuel oil)	1
By stopping steam leaks	6 kl/y (fuel oil)	1
Subtotal	198 kl/y (fuel oil)	33%

Through a better power factor	9,121 kWh/y (electricity)	
By shutting down some low-load motors	2,967 kWh/y (electricity)	
Subtotal	12,088 kWh/y	1%

Report No. 17: Paper

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

- New Century Paper Industry Co., Ltd. -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- New Century Paper Industry Co., Ltd. -

1. Outline of the Factory

Address : 224 Area 1, T. Bangprakod Town District
Samut-prakarn

Capital : 10 million bahts

Type of industry : Paper

Major products : Kraft paper

Annual output : 3,800 t

No. of employees : 100

Annual energy consumption :

- Electric power : 4,000,000 kWh
- Fuel
  Lignite : 3,500 t

Interviewee : Mr. Prasit, managing director

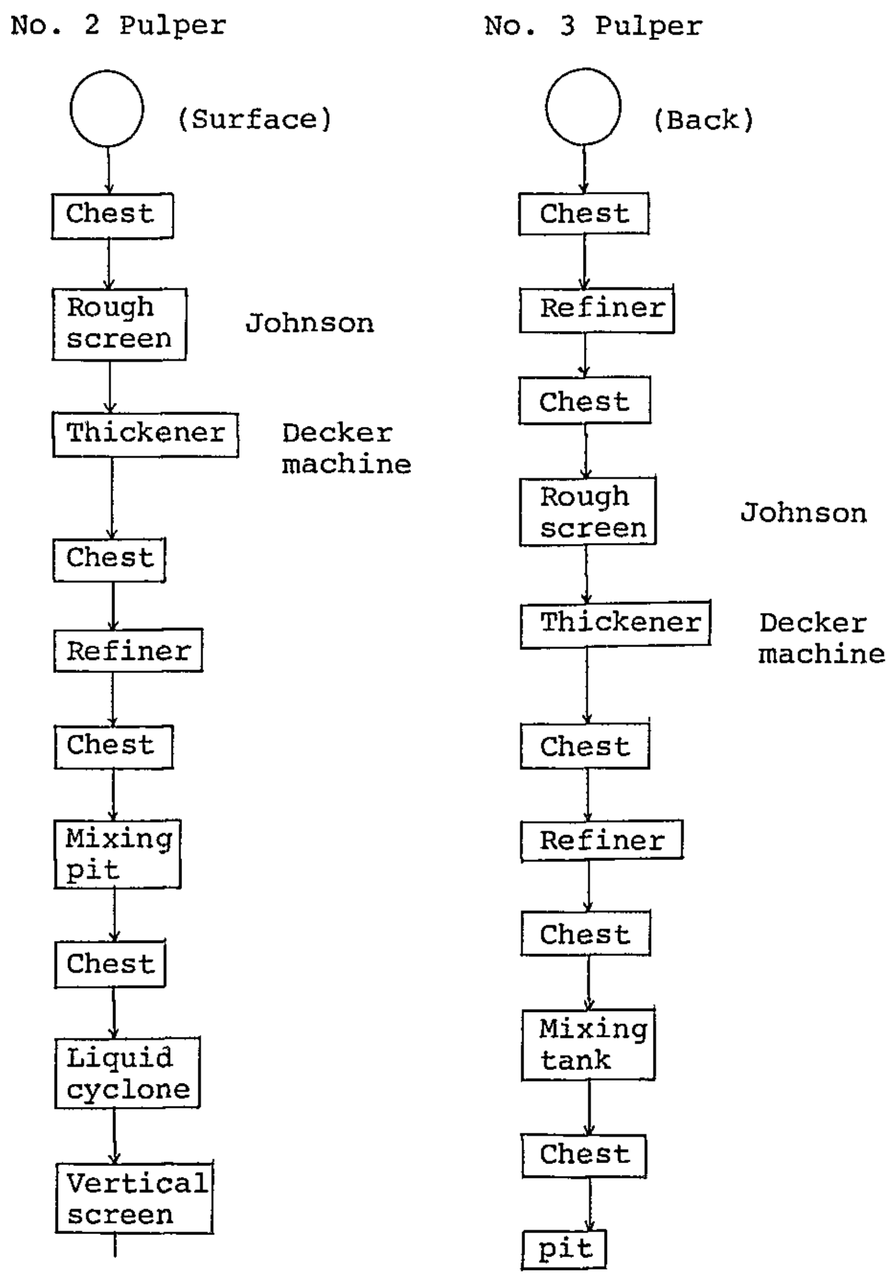
Date of diagnosis : Sep. 9 - 10, 1982

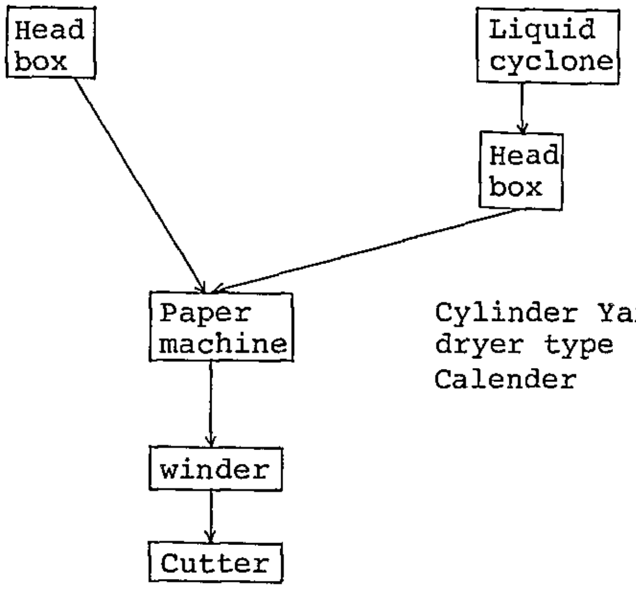
Diagnosers : A. Koizumi, K. Nakao, and K. Kurita

Upon takeover of the present factory four years ago, New Century Paper Industry has implemented a number of reform measures, including the conversion of fuel from oil to lignite, the installation of additional steam traps, the refurbishment of exisitng ones, and the commencement of open-system condensate recovery. These reflect the company's keen interest in energy conservation, or for that matter, energy costs.

Paper machines are provided in two systems, of which one is currently in operation to produce about 12 tons of kraft paper per diem.

2. Manufacturing Process





Cylinder Yankee Multi-dryer type
Calender

3. Major Equipment

The remodeling of the No. 1 paper machine is now under way. The following equipment are provided in the No. 2 paper machine system.

(1) Stock preparation

Process	Type of equipment	No.
Repulping	Pulper	2 units
Screening and separating	Johnson screen Liquid cyclone	1 set 1 set
Beating and refining	Disc refiner	1 set
Thickener	Cylinder filter	2 units

(2) Paper machine

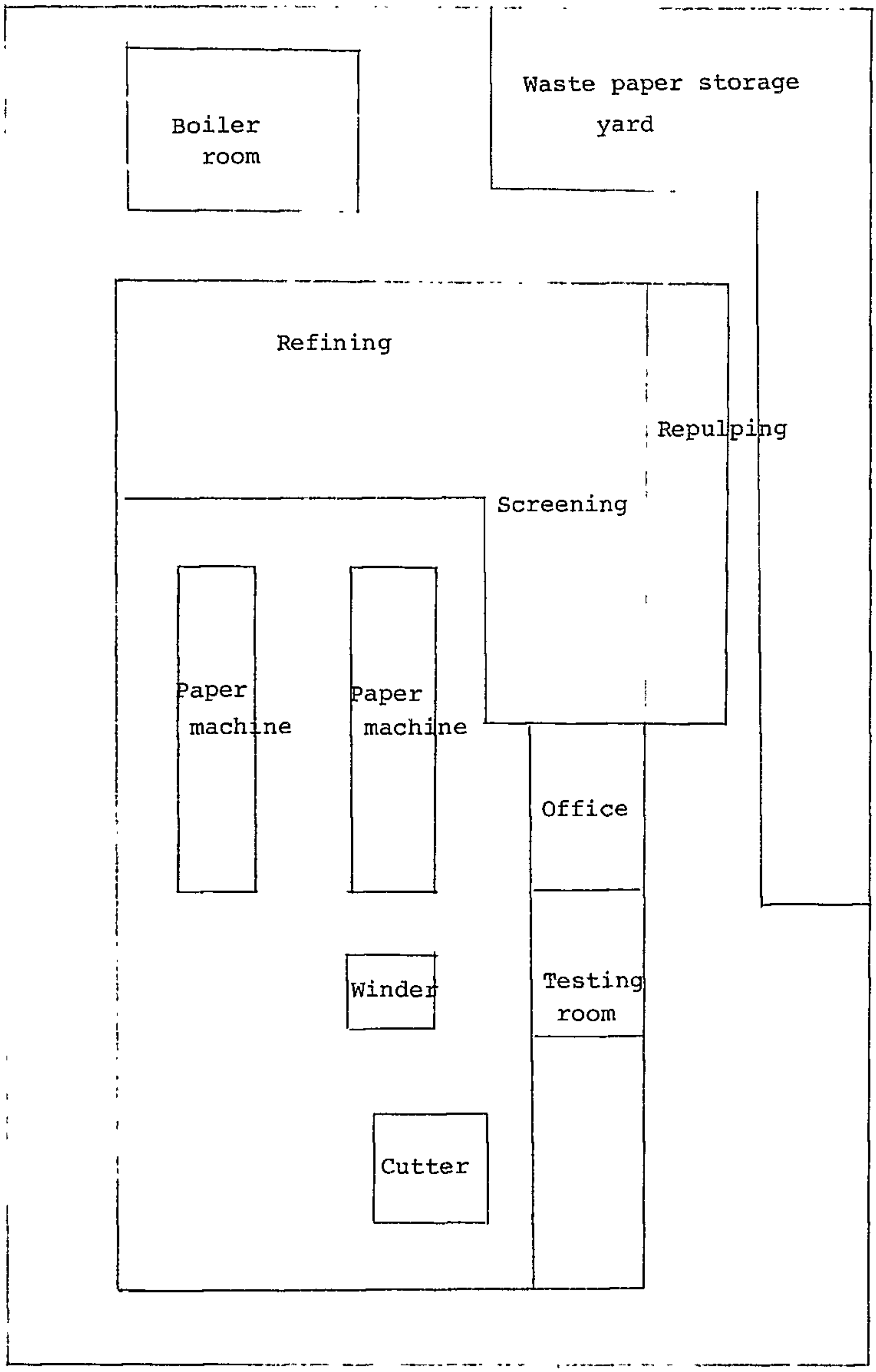
The No. 2 paper machine is of 72" cylinder, Yankee multidryer type provided with the following major equipment:

Major equipment	Type	No.
Moulder	Cylinder	4 units
Press	Baby press Press	1 set 3 sets
Dryer	Yankee (glazed) Cylinder (no hood)	2 units 5 units
Calender	8 rolls	1 set
Winder	Drum type	1 unit
Cutter	Single type	1 unit

(3) Boiler

Two units of boilers installed are of 120 psi flue tube type fueled by lignite.

(4) Layout


Boiler
room
Waste paper storage
yard
Refining
Repulping
Screening
Paper
machine
Paper
machine
Office
Winder
Testing
room
Cutter

4. State of Energy Management

To raise the technical level of the whole factory, an attempt should be made to bring up engineers and train and educate workers at large to have them acquire advanced skills.

Energy management is not based on data relating to the boiler and a number of processes. Data of importance concerning production, quality, and energy consumption in each process should be recorded hourly in a log every day. Data on strength and weight of paper must also be recorded. An analysis of these data will enable you to clarify cause-effect relations and hence what actions to take for improvement.

Steam traps, meters and gauges, heat insulation, etc., were poorly managed. Steam, due to traps being out of order, was found to have leaked through a drain pipe into a feed water tank. A sharper eye should be kept on loss, waste of resources, or whatever happened in each process.

Data gathered at a laboratory make important information to workers. The laboratory should allow them easier access to such data and willingly accept their request for testing. If workers are given an incentive to act on their own according to data obtained, their technical level will go up step by step.

Workers are found to have taken to a bad habit of walking on waste paper with indifference. Such a habit should be stopped right away. Waste paper is used once again as materials for paper and, if soiled, it will require extra energy to remove impurities and result in defective products at that. That waste paper helps save much electric and thermal energy and hence an important money-maker should be made generally known to the workers. It is a good idea to bring shift groups of workers into competition in waste paper reduction. In that case, however, a sheet sample for every reel should be placed aside to prevent products from being lowered in quality as a result of competition.

The factory on the whole should be kept clean. If it is kept in good order, the morale of the workers can be raised so that they will be motivated to take better care of their own factory.

5. State of Thermal Energy Consumption

460 kgs/h of lignite are burnt in two boilers to produce steam, which is totally used in the paper machine. Lignite has virtually cut down fuel costs by about 30 percent as compared with fuel oil. The fuel consumption rate runs at 513 liters/t in oil equivalent.

Shown below is the heat balance in two boilers. Since data on the heat contents of lignite, the quantity of ashes, and the amount of feed water are not available, figures given are based on estimates. According to the heat balance, the quantity of steam consumed is estimated at about 3.4 t/h and the steam consumption rate at 6.8 t/t of paper.

Heat Balance in the Nos. 1 and 2 Boilers

Input (10^3 kcal/h, %)			Output (10^3 kcal/h, %)		
Heat of fuel combustion	2,610.6	100	Heat of steam	1,899.5	72.8
			Heat loss in exhaust gas and ashes	574.3	22.0
			Heat loss in blow water	6.3	0.2
			Heat release from boiler body	130.5	5.0
Total	2,610.6	100	Total	2,610.6	100

Notes:

1) Data given for determination of the heat balance -

Reference temperature	-	30°C
Type of fuel	-	Lignite
Temperature of fuel	-	30°C
Fuel consumption	-	458 kgs/h two units of boilers
Heat contents of fuel (Hl)	-	5,700 kcal/kg (estimated on the basis of figures in other factories as well as data available in Japan)
Oxygen content of exhaust gas (%)	-	- %

Temperature of exhaust gas	-	- °C
Steam pressure	-	5.6 kgs/cm^2 G
Temperature of feed water	-	100°C
Amount of blow	-	100 kgs/h
		two units

2) Equations for calculating the heat balacne -

Input

a. Heat of fuel combustion:

458 kgs/h (fuel consumption) x 5,700 kcal/kg (heat contents of fuel) = 2,610.6 x 10^3 kcal/h

Output

a. Heat loss in exhaust gas and ashes

Calculation here is based on heat loss in exhaust gas and ashes from a coal-burning boiler, which stands at about 22 percent of input heat. Given heat loss in exhaust gas and ashes as 22 percent of input heat, it will amount to:

2,610.6 x 10^3kcal/h x 0.22 = 574.3 x 10^3 kcal/h

b. Heat loss in blow water

Amount of blow water: 100 kgs/h

Temperature of blow water: 163°C

Heat loss in blow water: 100 x (163 - 100) = 6.3 x 10^3 kcal/h

c. Heat release from boiler body

Given heat release from boiler body as 5 percent of input heat, it will amount to:

2,610.6 x 10^3 kcal/h (total input heat) x 0.05 = 130.5 x 10^3 kcal/h

d. Heat of steam

Since the flow rate of feed water is unknown, heat of steam is assumed to be what is left after taking heat loss off the total input heat.

$2,610.6 \times 10^3$ kcal/h (total input heat) - 574.3×10^3 kcal/h (heat loss in exhaust gas and ashes) - 6.3×10^3 kcal/h (heat loss in blow water) - 130.5×10^3 kcal/h (heat release from boiler body) = $1,899.5 \times 10^3$ kcal/h

e. Quantity of evaporation

Quantity of evaporation

$$= \frac{1,899.5 \times 10^3 \text{ kcal/h (heat of steam)}}{658.90 \text{ kcal/kg(enthalpy of steam)} - 100.09 \text{ kcal/kg(enthalpy of water)}}$$

= 3,399 kgs/h

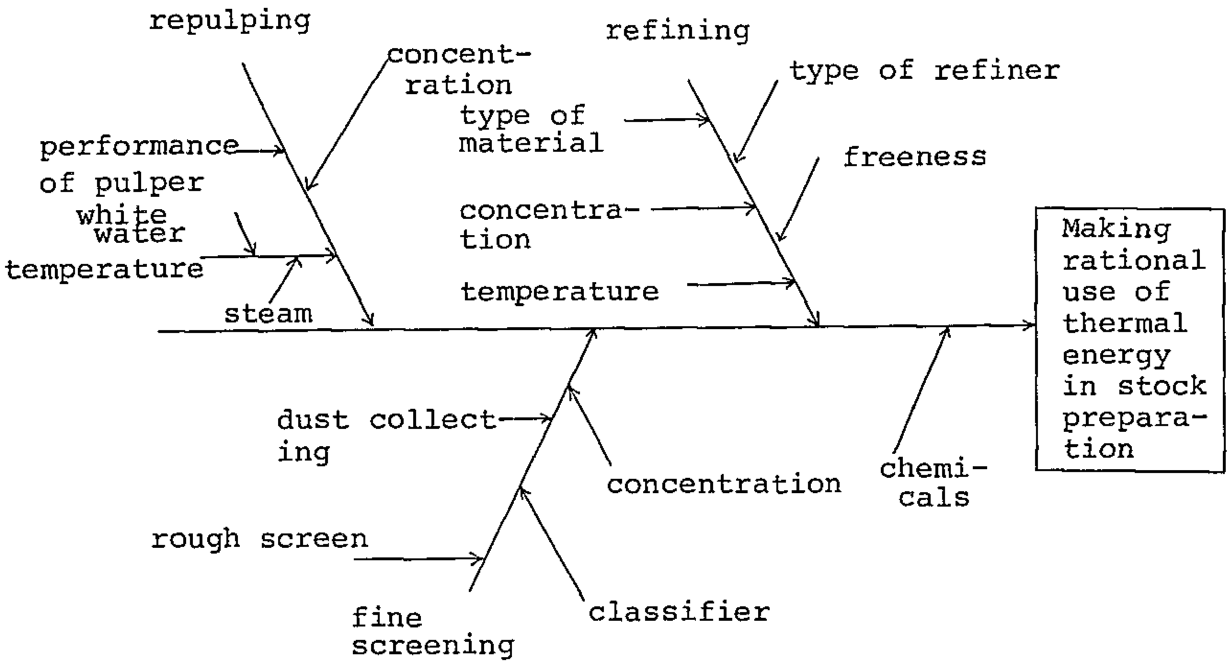
So, the quantity of evaporation is estimated at 1,500 kgs/h for the No. 1 boiler and 1,900 kgs/h for the No. 2 boiler.

6. Problems in Heat Control and Potential Solutions

(1) Stock preparation

The factory's management seem to have taken great pains in arranging old equipment. Apparently, however, they care nothing about product quality. Lack of evenness in quality could result in an increase in waste paper and hence waste of energy. The first consideration to step up energy conservation should therefore be quality improvement.

Factors affecting a saving of thermal energy in stock preparation can graphically be expressed as follows:



A. Screening - measures against deposits

A large amount of foreign matters are found to have gotten mixed in a product. These foreign matters absorb water in large quantities to form fish eyes in and around deposits. To eliminate these fish eyes would result in overdrying in the dryer. Overdrying, in turn, would not only deteriorate the quality of the product but also cause waste of heat energy.

One of the main reasons for a large quantity of deposits seems to be that a disc refiner is provided before a Johnson screen in the No. 3 pulper line. In other words, large foreign matters are broken in the disc refiner into such fine particles that they will not be removed in the Johnson screen and get mixed in fine stock.

To cope with this problem, the following three measures are available:

a. To feed stock into the disc refiner after large foreign matters have been removed in the Johnson screen;

b. To reduce the pressure of the disc refiner to a very low level and make the meshes of the Johnson screen smaller than 3 mm; and

c. To replace the disc refiner by equipment like a classifier.

The measure a) would result in an increase in rejects. As for the measure b), the size of meshes should primarily be determined after many trials; what is clear is that the smaller meshes will result in the Johnson screen's capacity shortage and necessitate more stages of the screen. Although equipment investment has to be made, the measure c) is worth consideration in view of quality improvement and energy cost reduction.

B. Refining

A small capacity of a pit installed after a decker in the No. 2 pulper line is actually counterbalancing the advantage of concentrating stock in the decker and refining it in high concentration.

The freeness of stock should be measured by all means to make clear how much it is refined; it is one of the important factors affecting the quality of the product as well as dehydrating and thermal efficiency at the press and dryer parts respectively. Moreover, a system whereby to refine stock always in fixed concentration should be established. Effects that can be achieved by mixing NUKP, in particular, will be lowered unless concentration and freeness requirements are satisfied.

If the remedial measure c) is carried out in the No. 3 pulper line as mentioned above, then a single chest can be done without and instead it can be used for stabilizing the refining process.

C. Centricleaner

A pressure gauge is not provided, nor concentration control is made. A liquid cyclone like the centricleaner should be operated after setting pressure levels at its inlet and outlet as well as concentration at its inlet as specified; otherwise, its dust collecting efficiency will not only be lowered but its power will be wasted as well.

The abovementioned measures are expected to bring about a total saving of 4 percent of steam, which is broken down into:

2% at the screen system;

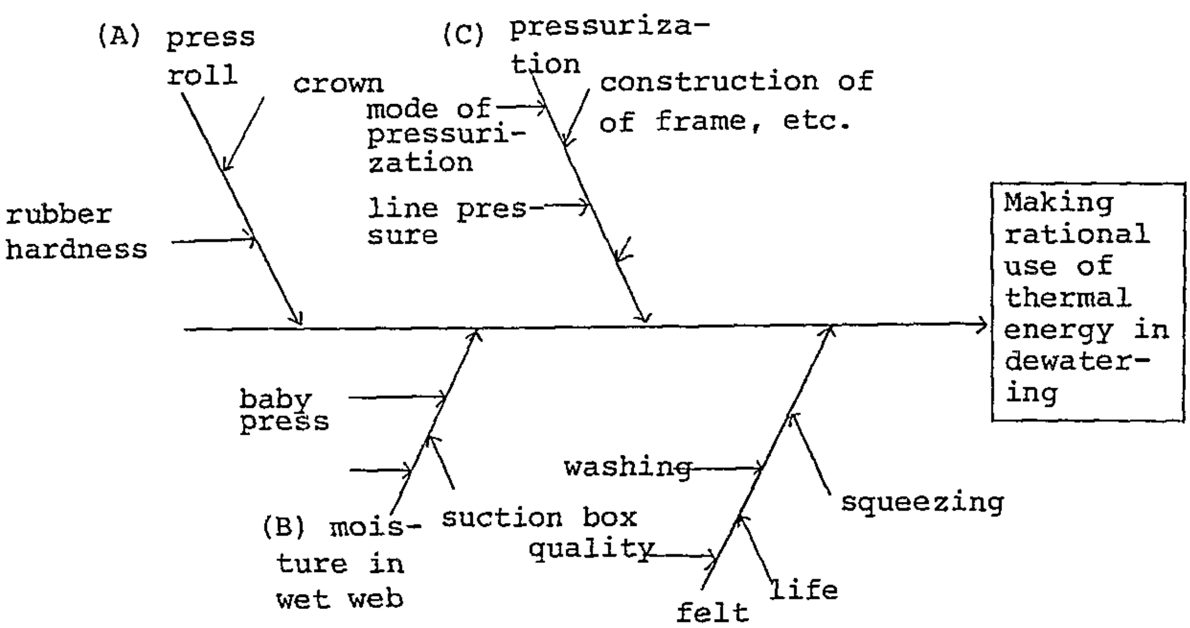
1% at the refining system; and

1% at the cleaner system.

(2) Press part

A 1 percent reduction in moisutre at the press part will result in a 3 to 5 percent saving of steam in the dryer.

The following section will discuss some points to be taken up for better dehydration at the press part according to the diagram given below.



A. Press roll

The press roll should be checked to see if its crown is kept in good shape and its rubber has a proper hardness. If the crown is out of shape, there will be a crowsswise variation in the water content of wet sheet, resulting in overdrying in the dryer.

B. Moisture in wet sheet

Reduce the water content of wet sheet, if slightly, before going into the press, and a burden on the press will be alleviated. The suction box and baby press should be utilized to the full.

C. Pressurization

To increase dehydrating efficiency through pressurization with the press roll is a task of a machine tender, whereas that of an equipment engineer is to make clear the critical strength of press equipment. Both should work together to reduce moisture in wet sheet to the minimum.

The No. 2 press roll was standing idle. Idling away of such a fine equipment could only result in an increase in consumption of steam energy as well as in the lowering of bursting strength.

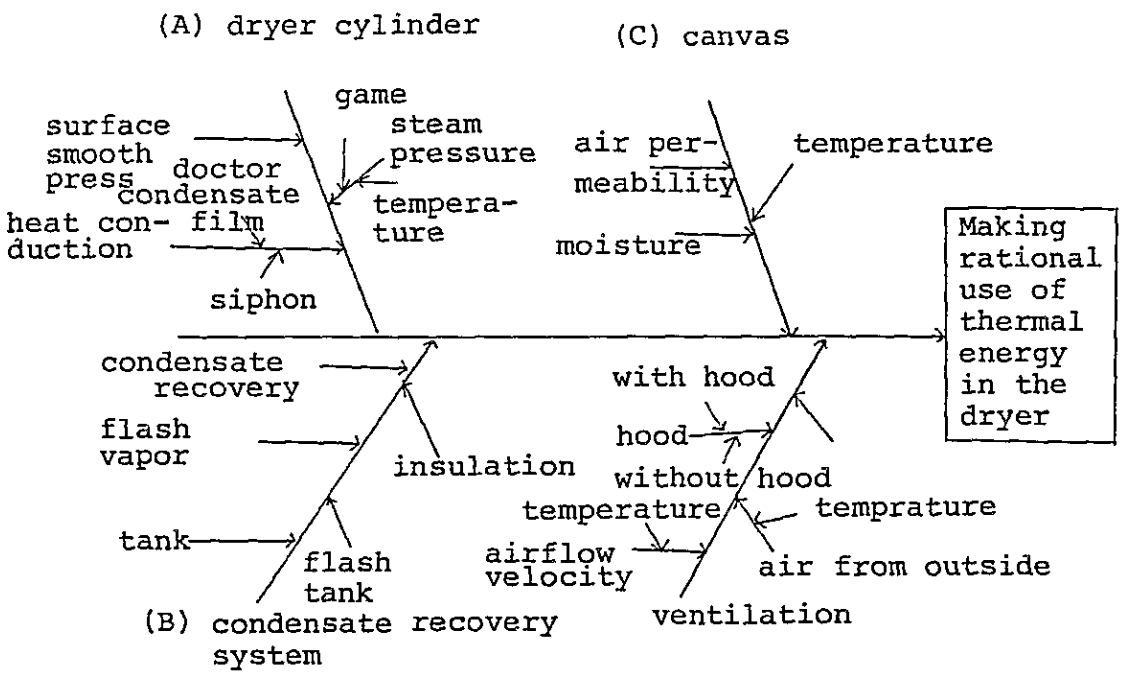
D. Felt

A felt brings wet sheet together into the press and is placed under the nip's pressure. And the moment it is relieved from this pressure, it absorbs water from wet sheet. Functioning this way, the felt should therefore be highly water-absorptive and adequately elastic. You will see how important it is to keep the felt clean. A machine tender should take good care of the felt by making the most of showering and squeezing devices so that dehyrating efficiency can be improved. The No. 2 felt was not privided with a shower and squeeze roll; it is advisable to examine the possibility of installing such devices.

These measures will reduce moisture in wet sheet by 1 percent and thereby bring about a saving of 4 percent of steam.

(3) Dryer part

There exist a number of factors contributing greatly to energy conservation at the dryer part where wet sheet containing 57 to 60 percent moisture will be evaporatively dried up by steam to become a.most bone-dry. These factors can be graphically shown as follows:



A. Dryer cylinder

a. The dryer's surface should be made always smooth. In the Yankee dryer, as its surface is kept in closer contact with paper, thermal conductivity will increase and hence better heat efficiency. The dryer's surface should be kept clean and free of dregs by making use of a doctor in good repair.

b. A condensate, if it stays in the cylinder, will lower heat efficiency. The cylinder should be drained well, and a condensate film over the inner wall of the cylinder should be made as thin as possible. To this end, the condensate outlet of a siphon should be positioned correctly. The cylinder has to be inspected at regular intervales to secure efficient operation.

c. Maintenance of a pressure gauge
A reliable and accurate pressure gauge must be provided; steam should be utilized at as low pressure as practicable. Moreover, a valve should be installed to allow easy control of steam blown in, and the pressure gauge must be laid out to enable workers to have a good look from where the valve is installed.

B. Condensate recovery system

The present system is supposed to be a remodeled one, but it is still unsatisfactory in some respects. Guide a condensate of steam used on the high temperature side of the system into a flash tank, and use flash vapor produced there on the low temperature side. Or, recover a condensate as it is under high pressure directly into a boiler. Flash vapor has a heat contents 7 to 8 percent of the original steam. So a saving of about 5 percent in heat energy is expected to come from the use of flash vapor.

C. Canvas

A canvas repeats the process of holding vapor given off by a sheet of paper and letting it loose in an open space from one cylinder to another. To allow it to follow this process efficiently, the canvas should be neither clogged nor wet, and it should be kept at high temperatures. Currently, however, there is a drop in temperatures of the canvas by the time it returns and comes into contact with the dryer once again. The common remedy is to install a canvas dryer. But it is more advisable to provide a protector at the front part of the machine so that the canvas will be kept away from the outside air and instead it will be warmed by radiant heat from above. This measure is expected to bring about a saving of 5 percent of steam.

(5) Boiler

To control the operation of boilers more efficiently, it is necessary to provide required gauges and meters and record and check their readings in a daily report every day.

In addition, it is advisable to take the following measures:

a. Fit a feed water flowmeter into each boiler to have a clear understanding of the amout of feed water;

b. Provide different lignite storage yards for the Nos. 1 and 2 boilers to place the consumption of lignite under good control. Make an analysis of lignite from time to time to make clear its heat contents. Based on the amount of feed water and that of fuel combusted, determine the evaporative power (amount of steam/amount of fuel combusted) to control the operation of boilers more effectively;

c. Install a blow meter to control the amount of blow;

d. Install a thermometer to obtain data on the temperature of exhaust gases. A rise in exhaust gas temperatures means that the boiler's heat transfer surface may have been heavily stained. Inspect the boiler and clean it up right away lest it should develop any trouble;

e. Fit a thermometer into a feed water pipe at the inlet of the boiler to control the temperature of feed water;

f. Fit a flowmeter into a pipe leading from a water softening plant to a feed water tank to control the flow rate of soft water as well as the amount of condensate recovered. A better understanding of the amount of condensate recovered will allow more efficient control;

g. Keep a boiler room in good order and inspect and maintain fittings; and

h. Make better control of the quality of boiler water.

Shown below are data on the quality of feed water and boiler water.

	Feed water	Boiler water
pH	8.0	9.87
Conductivity	1,740 μs/cm	19,760 μs/cm

Apparently, boiler water has a low pH and a large electric conductivity. It is advisable to bring the pH of boiler water up to 11.0 - 11.8 and its electric conductivity down to 6,000 μs/cm.

A sand filter and a softener should be overhauled. A chemical tank should be covered to keep rubbish away, and chemical should be put into the suction pipe of a feed water pump.

(6) Steam piping

A. Insulation

There are many sections which are not insulated or poorly insulated. Insulation is not given, for example, to valves (4" x 3 and 3" x 2), a steam header (220 mm in diameter, and 1.2 m in length), and two 3" and 4" pipelines (6.5 m in length each).

If these parts are perfectly insulated, fuel can be saved as follows:

	Heat loss		Reduction in heat loss (kcal/h)	Area or length
	(kcal/m h)	(kcal/m h)		
Valves (4" x 3 and 3" x 2)	1,980	70	5,196	2.72 m^2
Header	1,890	70	1,648	0.91 m^2
Pipeline 4"	732	24	4,602	6.5 m
Pipeline 3"	570	24	3,549	6.5 m
Total			14,995	

This reduction in heat loss is equivalent to a saving of 22.7 kgs/h in steam.

In this connection, the feed water tank should also be insulated.

B. Steam leakage

Steam was found to have leaked from:

a. A flange of a main steam valve (4 inches) for the No. 2 boiler;

b. A water gauge for the No. 2 boiler;

c. A float level regulater for the No. 1 boiler;

d. A joint of a feed water pipe for the No. 1 boiler; and

e. Joints at the steam inlet and outlet of the dryer and the middle of a condensate return pipe.

Given steam pressure as 4 kgs/cm^2G, the amount of steam leaked is estimated at about 8 kgs/h.

If insulation is given and steam leakage stopped, a saving of 18.5 t/m or about 1 percent in steam can be achieved.

C. Maintenance of steam traps

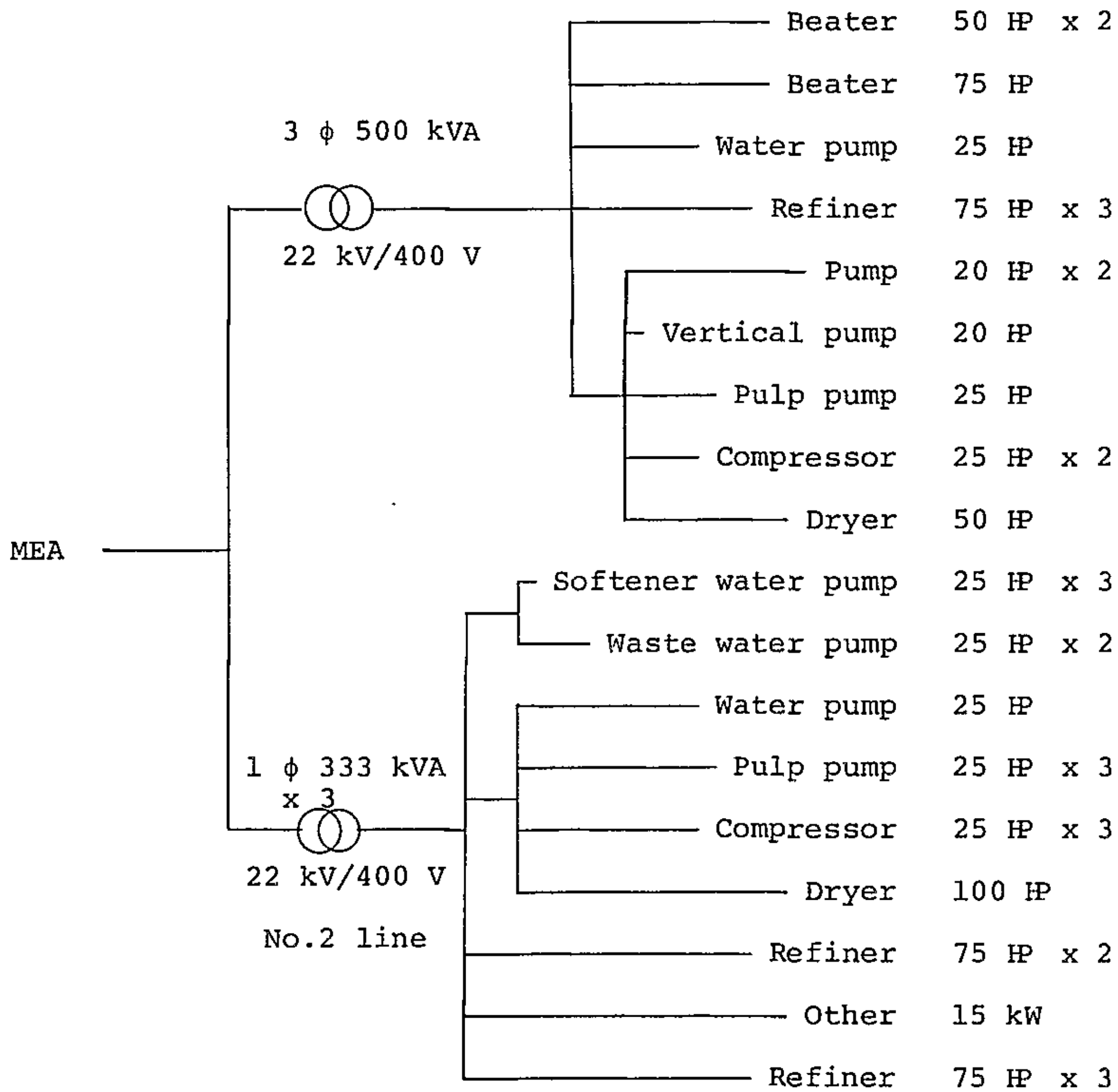
Steam was found to have flown into the feed water tank due to traps out of order. It is advisable to number steam traps and inspect and keep them in good repair at regular intervales.

7. State of Electric Power Consumption

(1) The principal data relating to power consumption are as follows:

Power company	-	MEA
Peak demand	-	870 kW
Power consumption	-	334,000 kWh/m
Load factor	-	59.2%
Penalty	-	382 kVr
Power factor	-	58.2% (measured)
Main transformers	-	1) 3 ϕ 500 kVA, 22 kV/ 380 V
		2) 1 ϕ 333 kVA x 3, 22 kV/380 V

(2) One-line diagram



8. Problems in Electric Power Control and Potential Solutions

(1) Transformers

The transformer's capacity stands at 1,500 kVA, far exceeding the load level. If six 100 kVr condensers are provided for power-factor improvement, then the whole equipment can be operated with a set of three 333 kVA transformers. Another 500 kVA transformer can be done without.

Now let us assume that the power demand and reactive power reach their peak, with the following given data:

$$\dot{P}1 = 870 + j930$$

$$|P1| = 1{,}273 \text{ kVA}$$

$$\cos\theta = 0.683$$

Supposing that the power factor has been improved with the condensers of 600 kVr, then the apparent power will be:

$$\dot{P}'1 = 870 + j330$$

$$|P'1| = 930 \text{ kVA}$$

$$\cos\theta = 0.935$$

Therefore, the peak demand will not exceed the transformer's rated capacity (333 kVA x 3 units).

More specifically, the removal of a single 500 kVA transformer and the provision of six condensers for power-factor improvement will produce the following effects:

- Supposing that the average power runs at 515 k kW and the average power factor at 72 percent, the present situation is:

  Combined power - $\dot{P}$ - 515 + j496

  Apparent power - $|P|$ = 715 kVA

  $|P|$ = 240 kVA for 500 kVA transformer

  $|P|$ = 475 kVA for three 333 kVA transformer

- If four of the six 100 kVr condensers are provided and instead the 500 kVA transformer is removed, then:

  Three 333 kVA transformers -

  $\dot{P}$ = 515 + j96

  $|P|$ = 524 kVA

- No-load loss (iron loss) in 500 kVA transformer:

  2.5 kW x 365 x 24 = 21,900 kWh/y ...... (i)

  Copper loss:

  $$8 \text{ kW} \times \left(\frac{240}{500}\right)^2 \times (365 - 24) \text{ d/y} \times 24 \text{ h/d}$$

  = 15,084 kWh/y .... (ii)

- An increase in copper loss in three 333 kVA transformers:

  $$4.5 \text{ kW} \times \left\{\left(\frac{524}{999}\right)^2 - \left(\frac{475}{999}\right)^2\right\} \times (365 - 24) \times 24 \times 3$$

  = 5,414 kWh/y .... (iii)

- If the load is concentrated on three 333 kVA transformers, therefore, power loss will be reduced by:

  (i) + (ii) + (iii) = 31,570 kWh/y

  Viewed in terms of value, this reduction will amount to 53,750 bahts/y and, if a penalty, which should no longer be paid, is added, then a total profit can be calculated at 113,750 bahts/y.

  And the cost of this remedy will be:

Condensers and panel	-	200,000 bahts
Voltmeter (1) and power factor meter (1)	-	6,000 bahts (inclusive of installation charges)

  All told, the abovementioned measure will cost 206,000 bahts, the sum that can be recovered within one year and ten months.

(2) Operation of motors

The table below shows how the major equipment are being operated.

Equipment	Capacity (HP)	Current			Power factor (%)
		Rated Ⓐ	Load Ⓑ	Ⓑ/Ⓐ	
No. 2 line dryer	100	380 V/ 139 A	37.8 A	27.2	41
No. 2 line	75	104 A	134 A	128.8	90

refiner					
No. 2 line refiner	75	105 A	94 A	89.5	86
No. 2 line beater	75	103 A	65.5 A	63.6	77

Attention should be paid to the fact that the No. 2 line dryer has a small load and the No. 2 line refiner has shown, if momentarily, an overload.

(3) Secondary voltage of transformer

The secondary voltage stands at a rather high level of 400 V both in the three-phase 500 kVA transformer and the three single-phase 333 kVA transformers. Taps should be changed to bring the secondary voltage down to 385 to 390 V. Inequality in voltage poses no problem as it runs at about 1.2 percent.

(4) Power factor

The power factor was measured due to absence of a power factor meter.

No. 1 line (three-phase 500 kVA transformer) – $\dot{P}a1 = 56 + j124$

No. 2 line (three single-phase 333 kVA transformers) – $\dot{P}a2 = 324 + j406$

So, the combined power is:

$$\dot{P}a1 + \dot{P}a2 = 380 + j530$$

$$|\dot{P}a1 + \dot{P}a2| = 652$$

$$\cos\theta = 0.582$$

The power factor runs at a very low level of 58.2 percent. This seems to be because, when measurement was made, one of the lines was placed at rest, resulting in a small load.

(5) Meters in an incoming panel

The receiving panel is currently provided with a voltmeter and an ammeter alone. It is advisable to install also a watt-meter and a power factor meter and record their readings hourly so that changes in the load can be made clear to help control equipment more efficiently.

The ammeter in each receiving panel is found to have shown a large error and hence inaccurate readings. It should be fixed right away and kept in good repair.

9. Summary

The abovementioned measures, if actually taken, are expected to bring about energy-saving effects as shown below:

Measures	Potential energy saving	Rate(%)
Improvement on screening in stock preparation	39 kl/y (fuel oil)	2
Better control of refining in stock preparation	19 kl/y (fuel oil)	1

Better control of centri-cleaner in stock preparation	19 kl/y (fuel oil)	1
Improved dehydration at the press part	78 kl/y (fuel oil)	4
Better control at the dryer part	97 kl/y (fuel oil)	5
Insulation improvement on steam pipes	19 kl/y (fuel oil)	1
Use of flash vapor	97 kl/y (fuel oil)	5
Subtotal	368 kl/y (fuel oil)	19
Rearrangement of trans-formers	31,570 kWh/y	1

Report No. 18: Paper

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

- Central Paper Industry Co., Ltd. -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Central Paper Industry Co., Ltd. -

1. Outline of the Factory

Address : 40 Poochaosamingpry Rd., T. Banghuasuar
Samutprakarn

Type of industry : Paper

Major products : White paper

Annual output : 2,460 t

No. of employees : 130

Annual energy consumption :

- Electric power : 4,152,000 kWh
- Fuel
  Sawdust : 23,720 m^3

Interviewees : Mr. Sompona and Mr. Ree

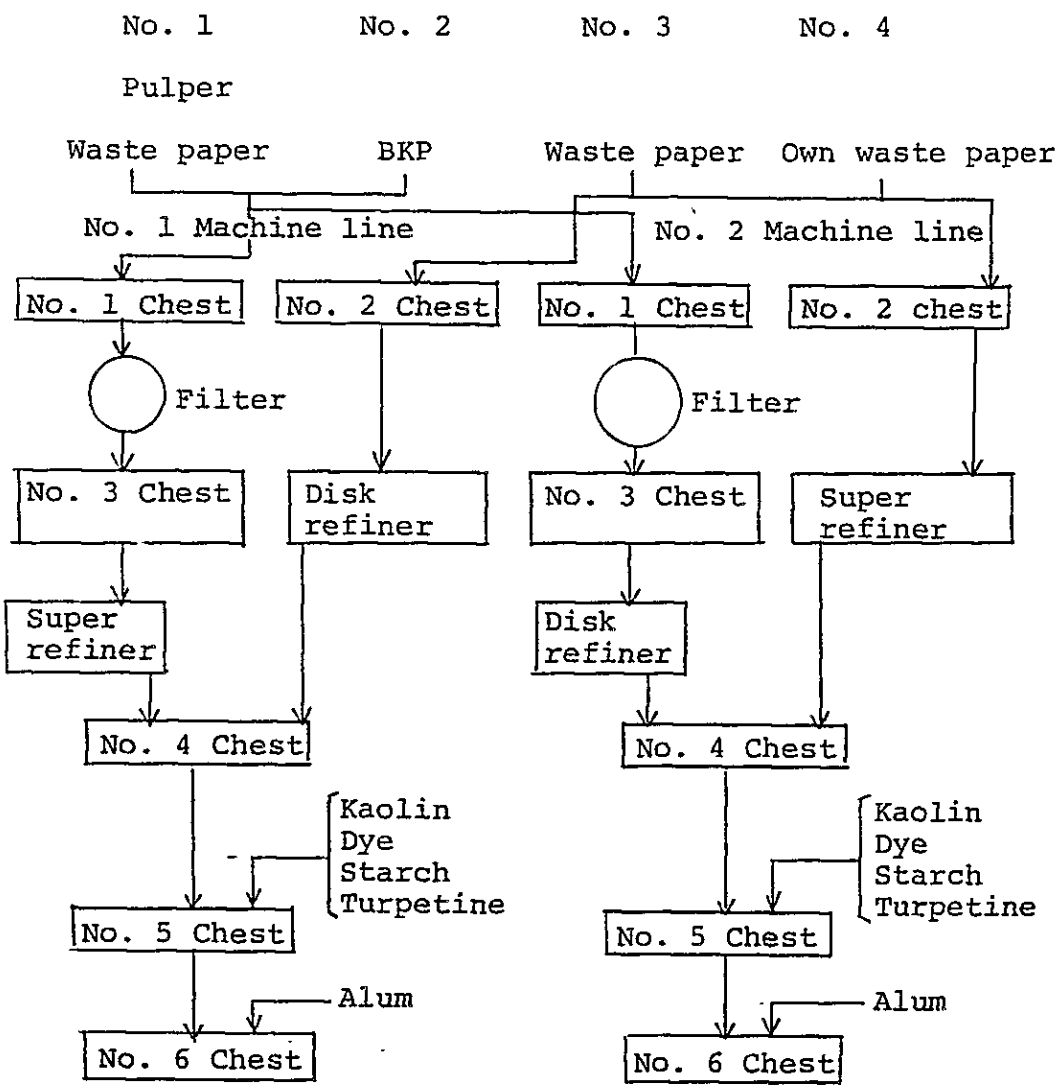
Date of diagnosis : Aug. 20 - 21, 1982

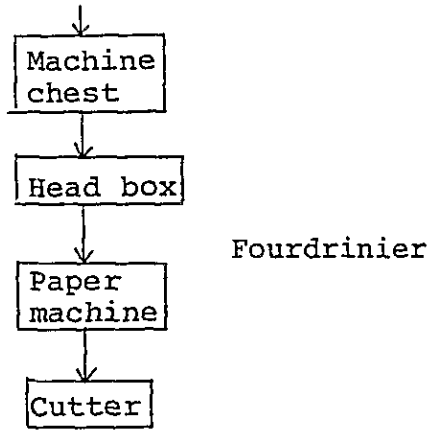
Diagnosers : A. Koizumi, K. Nakao, and K. Kurita

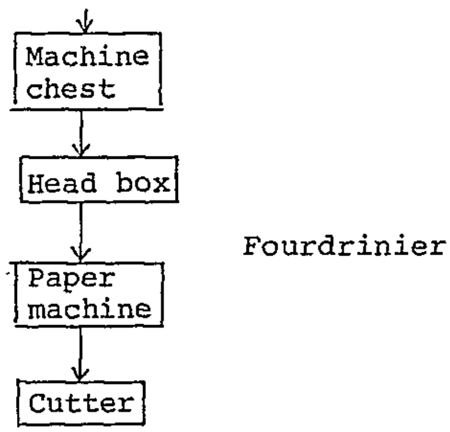
Central Paper Industry makes eight tons of white paper daily with two paper machines using waste paper and BKP as raw materials. The paper mill has two boilers, of which one was converted, to burn sawdust instead of fuel oil, a few months ago.

The most serious problem Central Paper faces now is that as much as over 20 percent of its products is discarded as unacceptable because they are affected by sheet breaks or their quality fails to come up to the specified standard. The paper mill makes light white paper, weighing some 45 to 60 grams per square meter, which is very likely to rip or tear during processing and it is technically difficult to produce satisfactorily. We are afraid there is still a difficulty to minimize the percentage of such unacceptable products.

2. Manufacturing Process







3. Major Equipment

(1) Stock preparation

Paper machines No. 1 and 2 have the pulpers and all subsequent units installed in exactly the same manner.

Process	Equipment
Repulping	Pulper 4 units
Screening and separation	Filters 2 lines
Refining	Disk refiners 2 x 2 lines Super refiners 2 x 2 lines

(2) Paper machines

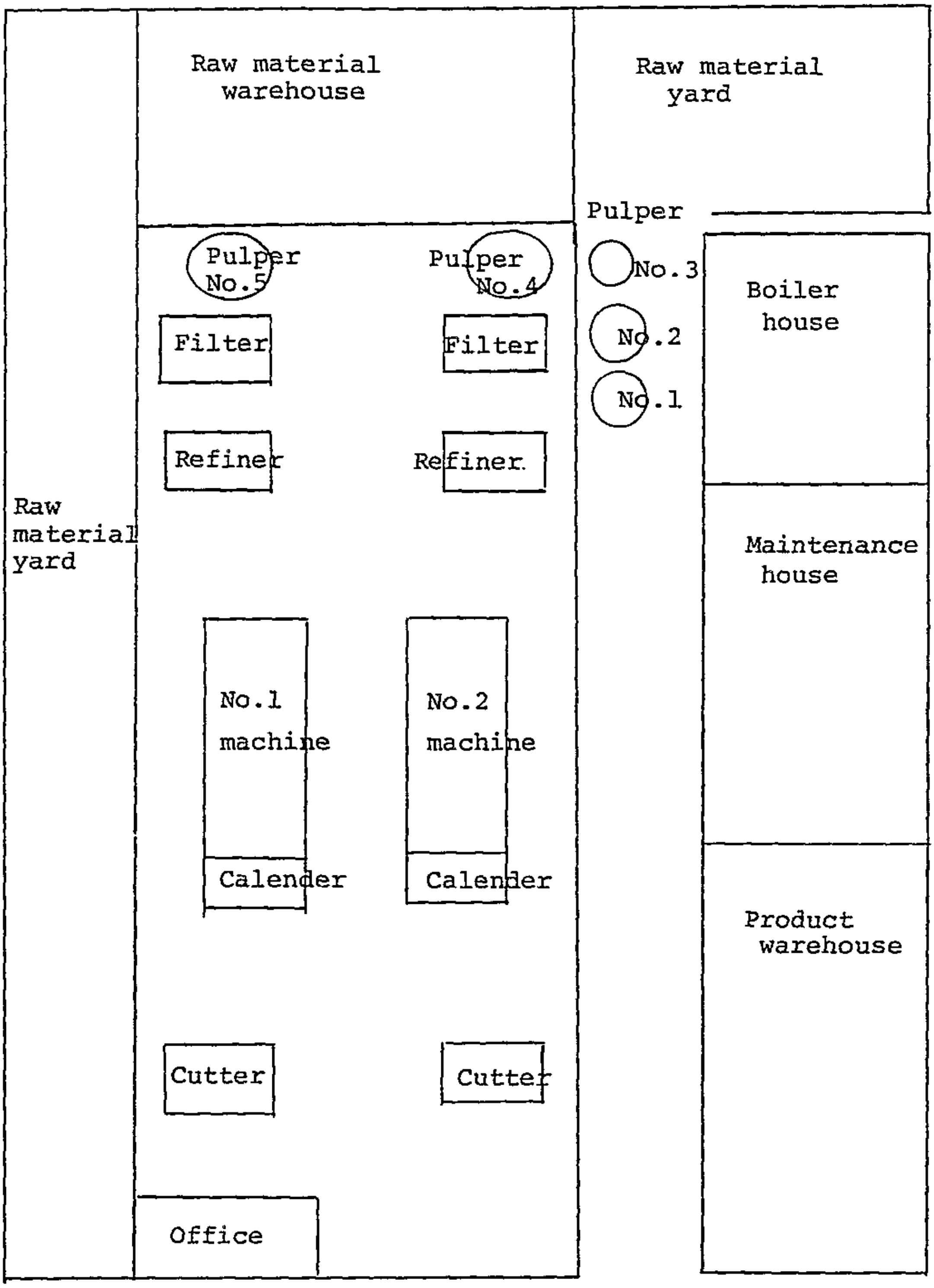
	No. 1 unit	No. 2 unit
Flow box and slice	Open, plate, slice	}
Press	Press 1 set	

Dryer	Yankee	2	Same as the left.
Calender	Roll	1 set of 8 rolls	
Cutter	Single	1 unit	

(3) Boilers

	No. 1 unit	No. 2 unit
Pressure	7 kg/cm^2 G	Out of operation
Evaporation rate	4,000 kg/h	
Fuel	Sawdust	

(4) Layout


Raw material warehouse
Raw material yard
Pulper
Pulper No.5
Pulper No.4
No.3
No.2
No.1
Boiler house
Filter
Filter
Refiner
Refiner
Raw material yard
Maintenance house
No.1 machine
No.2 machine
Calender
Calender
Product warehouse
Cutter
Cutter
Office

4. State of Energy Management

Virtually no step has been taken at Central Paper to control energy. To reduce energy consumption, an attempt should first be made to find exactly how energy is consumed in the paper mill. Comparison of daily energy consumption and paper production will help identify when and where energy consumption increases unusually. The average rate of consumption may be lowered gradually through persevering efforts to find why such an unusual increases occurs in energy consumption and how to preclude it. This alone will achieve substantial energy conservation even if the plant equipment is left as it is.

A similar step may apply to the high percentage of unacceptable products which affects the paper mill seriously. A set of suitable testers must be installed in different parts of the factory to determine the product quality and pulp concentration in each process, while recording the conditions under which the appropriate products are prepared. An attempt should then be made to examine how the product quality is related to the pulp concentration etc., or manufacturing conditions. For this purpose, we suggest that a test laboratory be installed in the factory by all means. The paper mill suffers a high percentage of unacceptable products partly because its workers carelessly walk on and soil waste paper that is stored as raw materials. Some in-house educational program is needed to help the workers fully understand that a high percentage of unsatisfactory products means so much waste of energy. Also they have to realize that waste paper to be used as raw materials should be carefully handled and that their cooperation is essential to stabilize the factory's manufacturing conditions.

5. State of Heat Energy Consumption

As noted earlier, the paper mill has two boilers, but now operates only one of them which has recently been converted to burn sawdust instead of fuel oil. This boiler is estimated to generate 3,300 kg of steam per hour, burning 77 m^3 of sawdust a day; the steam is used to operate the paper machines. The fuel consumption rate is very high, i.e., about 14 million kcal for every ton of paper produced.

The table below shows the heat balance in boiler No. 1.

Heat Balance in Boiler No. 1

Input (10^3 kcal/h, %)			Output (10^3 kcal/h, %)		
Heat of fuel combustion	4,716.6	100	Heat of steam	2,111.3	44.8
			Heat loss in exhaust gas	2,355.6	49.9
			Heat loss in blow water	13.9	0.3
			Heat release from boiler body	235.8	5.0
Total	4,716.6	100	Total	4,716.6	100

Notes:

1) Data given for determination of the heat balance -

Type of fuel	-	Sawdust (with 40-percent water content)
Fuel consumption (F)	-	2,246 kg/h (specific gravity: 0.7)
Heat contents of fuel (Hl)	-	2,100 kcal/kg (based on the water content noted above)
Water vapor enthalpy in exhaust gas (E_{SE})	-	739.1 kcal/kg (310°C)
Amount of wet exhaust gas	-	19,719 Nm^3/h (measured)
Specific volume of water vapor (V_P)	-	1,244 Nm^3/kg
Temperature of fuel (T_F)	-	30°C
Reference temperature (To)	-	30°C
Oxygen content in exhaust gas (O_2)	-	10%
Temperature of exhaust gas (T_G)	-	310°C
Flow rate of blowoff water (B)	-	100 kg/h
Temperature of blowoff water (T_B)	-	169°C
Temperature of feed water (T_W)	-	30°C
Steam pressure (P)	-	7 kg/cm^2G

2) Equations for calculating the heat balance -

Input

Heat of fuel combustion (Q_C)

$Q_C = F \times Hl = 4,716.6 \times 10^3$ kcal/h

Output

a. Loss of heat in exhaust gas (Q_E)

o Loss of heat in the water content of exhaust gas (Q_{EW})

$Q_{EW} = F \times 0.4 \times (E_{SE} - T_F) = 636.8 \times 10^3$ kcal/h

o Loss of heat in the dry component of exhaust gas (Q_{ED})

$Q_{ED} = \{G_W - F \times 0.4 \times V_P\} \times 0.33\ (T_G - T_o)$

$= 1,718.8 \times 10^3$ kcal/h

Hence

$Q_E = Q_{EF} + Q_{ED} = 2,355.6 \times 10^3$ kcal/h

b. Loss of heat in blowoff water (Q_B)

$Q_B = B\ (T_B - T_W) = 13.9 \times 10^3$ kcal/h

c. Heat release from the boiler (Q_R) - estimated at 5 percent of the input

$Q_R = Q_C \times 0.05 = 235.8 \times 10^3$ kcal/h

d. Heat of steam (Q_V)

$Q_V = Q_C - Q_E - Q_B - Q_R = 2,111.3 \times 10^3$ kcal/h

e. Evaporation quantity (S)

Enthalpy of feed water (E_F) = 30 kcal/kg

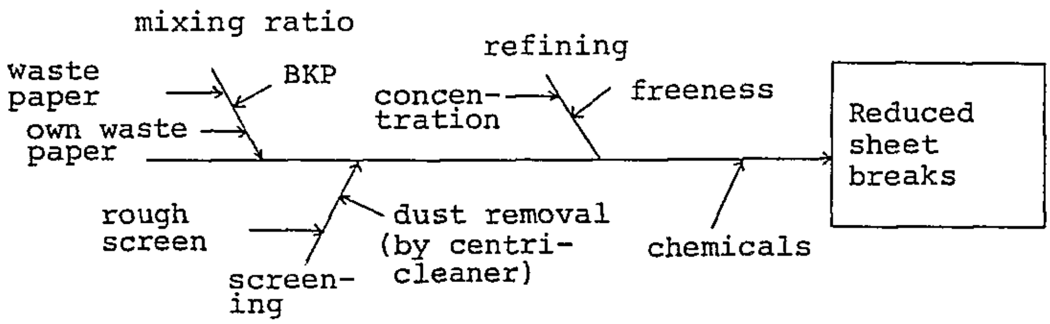
Enthalpy of steam (E_S) = 660.8 kcal/kg

$S = Q_V \div (E_S - E_F) = 3,347$ kg/h

6. Problems in Heat Control and Potential Solutions

(1) Stock preparation

The diagram below shows how to reduce sheet breaks during processing.



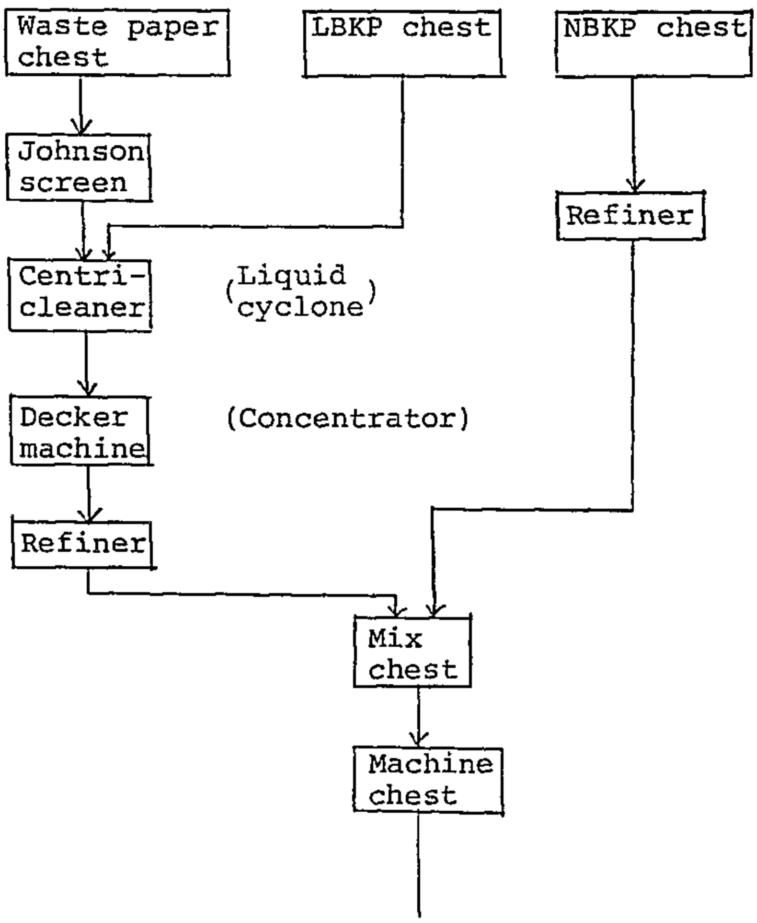
A. Screening

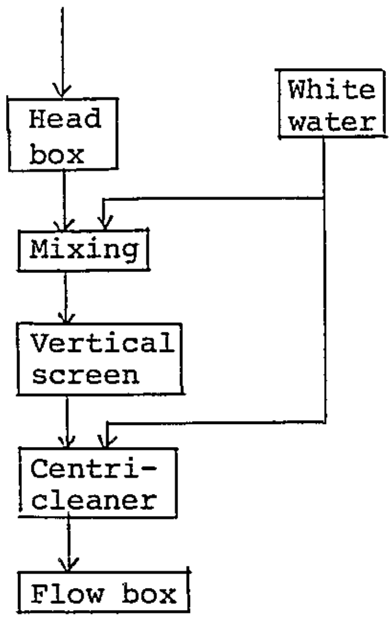
A close examination of the factory's products found that they are affected by a very large amount of dust and fish eyes resulting from impurities in waste paper purchased from external sources or coming from its own production line. Dust and fish eyes may be taken away by the dust remover and through dispersion of deposits. Unfortunately, the paper mill's stock preparation unit is found to have inadequate dust-removing capability. The filters, the specifications of which are unavailable, apparently fail to provide a suitable dust-removing system.

Factories producing high-grade paper ususally have dust removers at two staqes, one installed right before the refiner and the other before the flow box of the paper machine. A flow chart showing a production line now in general use is given below for reference.

Liquid cyclones are often used for dust removal in the paper industry. The performance of this device is affected by pressure levels at the inlet and outlet, liquid concentration at the inlet, and smoothness on the inner surface of the cone. If the device is used for dust removal, therefore, pressure gauges and other instruments will have to be installed to record pressure levels and liquid concentration to ensure that the equipment is operated under the specified conditions.

Flow chart of a widely accepted system





We are afraid that Central Paper Industry has gone a little too far in simplifying its production facilities. It must be pointed out here that energy conservation does not mean a niggardly policy to dispense with even necessary installations, but it means constant efforts to efficiently use energy, while minimizing its wasteful use. A higher yield rate will lead to a lower energy consumption rate and reduced production cost.

Now let us discuss some steps to be taken immediately to preclude sheet breaks during processing.

B. Tests on different mixing ratios of pulp

The very first step toward this goal is to carry out a test on either one of machines No. 1 or 2. To increase the strength of paper, an attempt should be made to raise the mixing ratio of BKP by 20 percent at No. 4 chest, while leaving that of waste paper from the factory's own production line at the present level. For a week before the mixing ratio is changed, necessary data must be collected in accordance with the table and test methods shown below.

Date	Paper weight (g/m^2)	Grade changing time	Frequency of sheet breaks (t/h)	No. of dust particles	Causes of sheet breaks	Causes of shut-down
	55		22/12°30'	33 26 28	1. 15 times by dust 2. 3 times by inproper tension 3. 4 times by unknown causes	
	60	20:30	18/11°30'	27 27 32		
	60	10:00	4/4°	26		10:00-12:00 due to felt wash-ing
	55	12:20		45		

o The frequency of sheet breaks should be recorded daily for each range of weight per square meter.

o Since a sheet of paper begins to tear from either edge, efforts should be made to carefully examine the edges of broken papser to find why it occurred.

o How to determine the number of dust particles

Sampling: One square meter of paper has to be collected from the reel at 4-hour inter-vals: care should be taken to avoid soiling the paper. Two samples measuring exactly 10 cm x 10 cm should be prepared from each square-meter sheet.

Measurement: All dust particles on the side of each sample facing the felt should be marked with pencil under a specified light source in a room completely isolated from the sunlight. The average number of dust particles on the two samples is to be recorded on the data sheet.

Tables of these data must be prepared on products of the same kind with same weight per square meter a week before and a week after the mixing ratio of materials is changed. The data thus obtained should be compared to find the effects of such mixing ratio changes.

The test described above is merely a draft proposal designed to provide a general idea of this improvement work. Based on this suggestion, a more specific plan should be worked out with adequate consideration given to the conditions under which the paper mill operates.

Subsequent remedies based on the results of the first step will gradually reduce the incidence of sheet breaks.

C. Refiners

When pulp is in low concentration, the disc refiner and super refiners accelerate the cutting of fibers, reducing the strength of paper. If the pulp concentration is high, on the other hand, they help facilitate fibrillation and increase the strength of paper.

A decrease in sheet break incidence through increased paper strength will enable the factory to lower the mixing ratio of BKP, consequently reducing the production cost as a whole. Also in determining freeness, therefore, it is advisable to record the concentration of pulp for each sample twice a day so that the standard refining concentration will be set for proper operation of the paper mill.

D. Other considerations

a. During work in the waste paper storage, care should be taken to preclude dust from getting into the building. Particular attention should be given to sawdust because it cannot be removed by a liquid cyclone as its specific gravity is equal to that of paper.

We were informed that the paper mill had removed the vertical screen from the production line, but this device can efficiently take away sawdust from raw materials.

b. Dispersion of dust by chemicals

Waste paper contains some types of resin coming from printing ink, adhesive tape, and other adhesive agents. When alum is added, these substances get condensed into deposits which soil the felt and result in sheet breaks.

If such resins cannot be removed by a screen or liquid cyclone, some chemicals will have to be used to disperse them into fine particles. A suitable dispersant widely used for this purpose is readily available on the market.

c. Reexamination of starch

Soils and paper deposits on the felt of the press unit are often caused by starch. Its cooking must be performed carefully because these unfavorable phenomena are likely to occur particularly when starch paste is not satisfactorily prepared.

These days, polyacrylamide is widely used as a reinforcing agent for paper. This chemcial, although rather expensive, has an advantage in that it requires no steam and helps simplify jobs in the process.

Reduction of unacceptable products to around 5 percent through the foregoing improvements will decrease the steam consumption by more than 20 percent.

(2) Press part

A 1-percent decrease in water content of paper will reduce the required amount of steam in the dryers by some 3 to 5 percent. It was found taht the water content of paper differs with various parts of the sheet coming through dryer No. 1. Such uneven water content results in overdrying of the parts with lower moisture levels, consequently making them weaker and more liable to tear.

Steps needed to ensure uniform dehydration of paper include:

a. Keeping the crown of the press roll in the proper shape;

b. Use of rubber with proper hardness for the roll; and

c. Maintenance of the felt-washing shower and squeeze roll in good working order, and good care for the felt to keep it always clean.

For steps a and b, routine checkups should be done to make sure that these press components are in conformity with vendor's specifications. The assigned machine operators are responsible for increasing the pressure of the press. Before such a step is taken, however, detailed information must be obtained from the corporate maintenance staff as well as from the machine vendor on the strength of the press frame. Note should also be taken of the fact that higher pressure will help increase the density and tensile strength of paper, but it reduces the tear strength. In any event, a 1-percent decrease in the water content of paper just coming out of the press unit will probably lower the steam consumption by some 4 percent.

(3) Dryer part

Major problem areas in this unit include:

a. Deposits of residual substances on the surface of dryer No. 1;

b. Deposits of such substances on the touch felt of dryer No. 1; and

c. Lack of a system to recover condensate from the dryers.

Dryer No. 1 has a well-designed structure that can ensure the highest thermal efficiency as its touch roll directly presses wet paper on the cylinder surface for drying. However, something must be done to solve problem a) above because the heat conductivity and drying performance of this installation are substantially affected by deposits of residual substances on its surface. For this reason, dryer surface is always kept clean in most paper mills. An attempt should be made to find the conditions under which the dryer works most efficiently; this may be achieved through installation of a doctor and careful studies on the pressure level of the touch roll and the way steam is distributed.

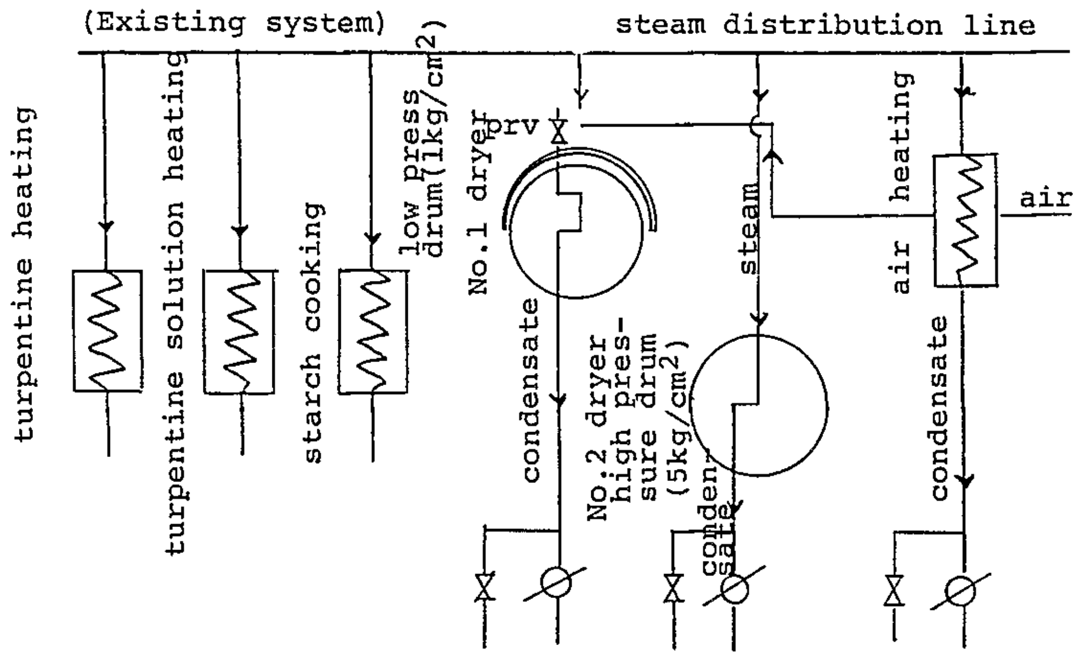
Secondly, the top felt of dryer No. 1 is soiled with deposits of residues which easily come off and fall on paper, contributing to a high incidence of sheet breaks. The paper mill said that the production line is shut down from time to time as necessary to clean the felt by batch washing. To completely solve this problem, we suggest, batch washing should be used in combination with continuous washing.

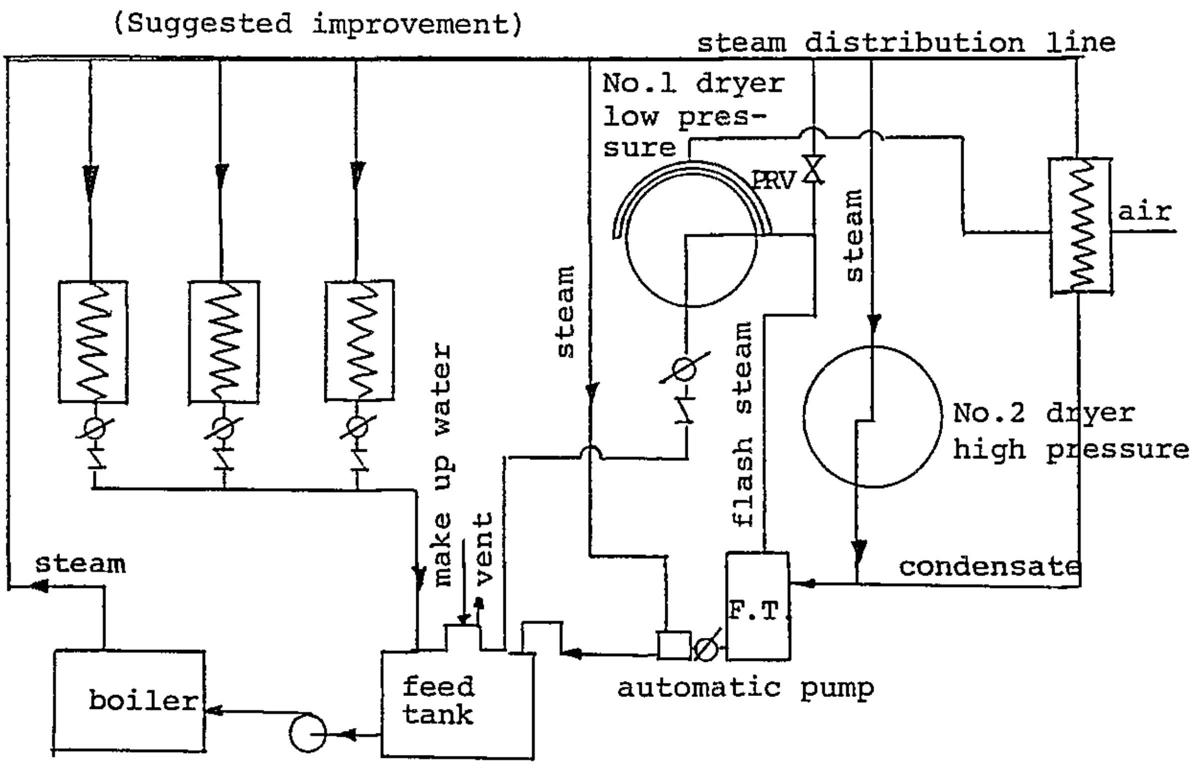
This would involve some new installations including a washing shower, squeeze roll, and suction box, while the steam consumption would increase due to a higher moisutre level of felt resulting from the new washing method. However, its introduction is worth considering because a greater loss from sheet breaks may be minimized.

Finally, a proper step should be taken to recover all condensate from the dryer cylinders. A suggested improvement of the system is shown in the following diagrams.

Another technique for efficiently using flash steam is to directly send this high-pressure condensate as it is into the boiler by a drain pump.

Whichever method may be adopted, recovery of condensate from the dryer cylinders would reduce the steam consumption by some 20 percent.


(Existing system)
steam distribution line
turpentine heating
turpentine solution heating
starch cooking
low press drum(1kg/cm2)
No.1 dryer
prv
condensate
steam
No.2 dryer high pressure drum (5kg/cm2)
condensate
air heating
air
condensate


(Suggested improvement)
steam distribution line
No.1 dryer low pressure
PRV
steam
steam
air
flash steam
No.2 dryer high pressure
make up water
vent
steam
condensate
F.T
boiler
feed tank
automatic pump

(4) Boiler

The boiler has been converted to burn sawdust instead of fuel oil to save the fuel cost, and this is a very good idea.

The flow meter for feed water needs repairs immediately as it was left out of order during our visit. Proper arrangements should also be made to measure a daily consumption of sawdust and keep a log on boiler operation for heat control purposes.

Examination of the boiler found that the exhaust gas temperature and air ratio are 310°C and 1.91, respectively. The air intake must be reduced to a proper level as the present air ratio is too high. The exhaust gas temperature is also a little too high; efforts are needed to operate the boiler more efficiently by cleaning its heat-transmitting surfaces. Reduction of the air ratio to 1.5 and the exhaust gas temperature to 250°C would decrease the fuel consumption by 26 percent. In addition, better insulation must be provided for the boiler because some parts of its walls are as hot as 280°C to 290°C.

A blowoff from the boiler is released six times a day. The discharged water is now recirculated to the feed water tank, but this must be discontinued at once because blowoffs are made to preclude accumulation of salt in boiler water. The system should be changed immediately to discharge all blowoff water into the drain pit. We could not take a sample of boiler water during our visit due to the reason noted above. The table below shows the qualities of feed water.

	Feed water
pH	7.02
Conductivity	3,600 μs/cm

The high electric conductivity of feed water may be attributed to the recirculation of blowoff water. The iron content of feed water is also apparently higher than the normal level.

The feed tank is supplied with untreated ground water, which unfavorably affects the performance and service life of the boiler. A filter or water softener should be installed to improve the feed water qualities.

Studies are also needed to find a suitable grade and amount of boiler compounds. Another important consideration in energy conservation is to install pressure gauges at all places where steam is used; care should be taken to avoid using steam at a higher pressure level than is necessary.

(5) Steam piping

We found that the factory's equipment is inadequately insulated in many places. The table below gives a few instances where heat losses may be reduced through satisfactory insulation.

	Heat loss		Area or length	Heat loss reduced by:
	Without insulation	With insulation		
Two 4-inch valves	2,266 Kcal/m^2h	567 kcal/m^2h	0.8 m^2	1,359 kcal/h
Three 3-inch valves	"	"	0.9 m^2	1,529 kcal/h
4-inch piping	813 kcal/m h	203 kcal/m h	10 m	6,100 kcal/h
3-inch piping	634 kcal/m h	159 kcal/m h	26 m	12,350 kcal/h
Total				21,338 kcal/h

The heat loss reduction shown in the table is equivalent to 1 percent of steam generated by the boiler.

Many other places of the steam system, particularly the piping around the steam header and paper machines as well as the boiler itself, were found to be inadequately insulated.

The steam trap is out of order, and there is a leak in the steam piping; these must be fixed up immediately. We noticed that steam escapes through a hole some 6 mm across at a rate of 90 kilograms per hour which amounts about 3 percent of steam generated by the boiler.

Apparently little maintenance service is provided for the pressure gauges and thermometers, most of which are out of order and left unattended. Satisfactory heat control can never be achieved unless some arrangements are made to keep them in good repair.

7. State of Electric Power Consumption

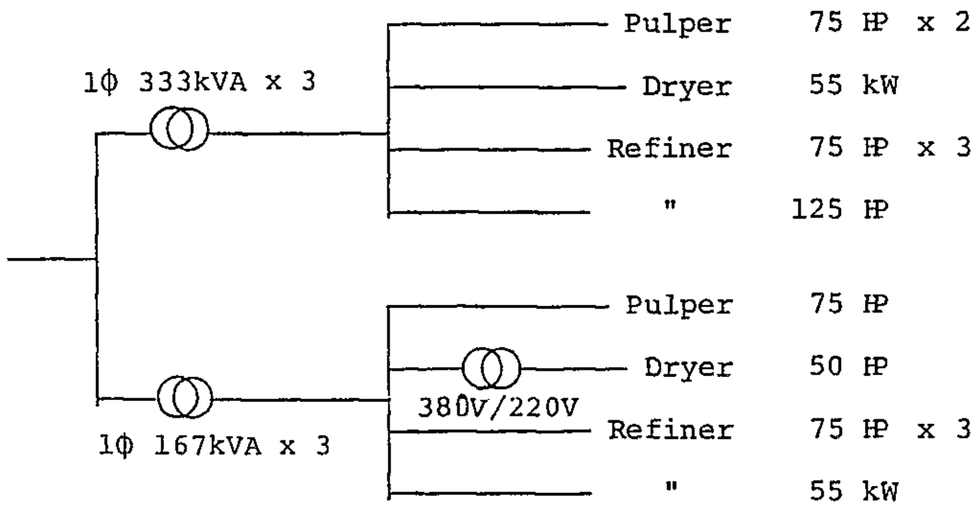
Two banks of transformers are installed on a raised framework some 5 meters high in the mill site. One of them, 1 ϕ 333 kVA x 3, is for line No. 1, and the other, 1 ϕ 167 kVA x 3, is for line No. 2.

We could not find even the transformer capacity until the second day of our visit as the paper mill has neither an electrician nor a one-line diagram. The imcoming panel is equipped with a voltmeter and amperemeter, but no wattmeter or power-factor indicator is provided.

(1) The principal data relating to power consumption are as follows:

Power company	-	PEA
Peak demand	-	800 kW
Electric power used	-	346,000 kWh/m
Load factor	-	72.8%
Penalty	-	None
Power factor	-	71.1%
Transformers	-	1,500 kVA in combined total
Power consumption rate	-	1,688 kWh/t

(2) One-line diagram



8. Problems in Electric Power Control and Potential Solutions

(1) Power factor

Mean wattage was determined by the integrating wattmeter we had brought with us because use of a clamp-on wattmeter was thought dangerous from the incoming panel bus, size of cables used, and distances between them. The power factor was calculated based on measured voltage and amperage as well as an hour's reading of the integrating wattmeter. The mean power factor was found rather low at 71.1 percent.

Since the apparent current can be lowered by increasing the power factor through insertion of a 3 kVr condenser, it is advisable to transfer the load on transformer No. 1 to transformer No. 2 and integrate these installations into one bank. This will reduce power losses in the transformers.

The combined apparent current of transformers No. 1 and 2 in the existing configuration is

$$|\dot{P}| = 794 \text{ kVA} \qquad \cos\theta = 0.711$$

Hence

$$\dot{P} = 794 \times 0.711 + j794\sqrt{1 - 0.711^2} = 564 + j588$$

If a 300 kVr condenser is added, it follows

$$\dot{P}' = 564 + j(558 - 300) = 564 + j258$$

$$|P'| = 620 \text{ kVA} \qquad \cos\theta = 0.91$$

Given the peak demand as 840 kW and the reactive current as 63 percent of this value, it follows

$$840 \times 0.63 = 529.2 \text{ kVr}$$

Hence, the apparent power when no condenser is added stands at

$$\dot{P}'' = 840 + j529.2 \qquad |P''| = 992.8 \text{ kVA}$$

If a 300 kVr condenser is added, the apparent power will be

$$\dot{P}''' = 840 + j(529.2 - 300) \qquad |P'''| = 808.1 \text{ kVA}$$

Through the integration of transformers, copper and iron losses in the three transformers with a 167 kVA capacity each could be reduced as follows:

Decrease in iron loss: $167 \times 3 \times 0.005 \times 24 \times 365$

$= 21{,}944$ kWh/y

Decrease in copper loss: $167 \times 3 \times 0.02 \times 24 \times (365 - 24) \times \left(\frac{287}{501}\right)^2$

$= 26{,}910$ kWh/y

Meanwhile, the copper loss in the other set of three transformers with a capacity of 333 kVA each will increase as follows:

$$333 \times 3 \times 0.012 \times \left\{ \left(\frac{620}{999}\right)^2 - \left(\frac{507}{999}\right)^2 \right\} \times (365 - 24) \times 24 = 12,519 \text{ kWh/y}$$

The net reduction of power loss that may be achieved through the integration of transformer banks will be

21,944 + 26,910 - 12,519 = 36,335 kWh/y

This is equivalent to 0.9 percent of the toal electric power used by the paper mill.

(2) Voltage

The three 333 kVA transformers have secondary voltage of 400 V, 390 V, and 380 V, while the other three transformers with a capacity of 167 kVA each have secondary voltage of 400 V, 395 V, and 390 V.

The rate of unbalance in the three 333 kVA transformers is

$$\frac{400 - 380}{380} \times 100 = 5.3\%$$

And that of the other three transformers is

$$\frac{400 - 390}{390} \times 100 = 2.6\%$$

When single-phase loads on the two lines are unbalanced, the line receiving more single-phase loads than the other is subject to a greater voltage drop.

It is advisable therefore to transfer some of the single-phase loads on the line with lower voltage to the other with higher voltage.

Most of the plant wiring consists of single-core cables laid with insulators. These cables, unlike three-core ones, cannot be laid symmetrically, and unbalance in the reactor and voltage occurs partly because of this. The unbalance may be corrected through transposition of all the cables.

The voltage is also too high, standing at 400 V now. Since the rated voltage of the motors is 380 V, the voltage at the secondary terminal of the transformers should be set at 385 V to 390 V covering an estimated drop of some 5 V to 10 V in the cables.

(3) Operation of motors

Most of the motors are operated at a low load level as shown in the table below.

No. of line	Used for:	Output of motor	Rated current A	Load current B	$\frac{B}{A}$ %	Power factor %
1	Pulper	75 HP	380 V 103.8 A	80 A	77.1	81
	"	75 HP	" 103.8	stop		stop
	Dryer	55 kW	" 105	120	114.3	87
	Refiner	75 HP	" 102.5	20	19.5	10
	"	125 HP	" 180	60	33.3	36
	"	75 HP	" 102.5	stop	stop	stop
	Pulper	75 HP	" 103.8	stop	stop	stop

	Dryer	50 HP	200 V 128	80	62.5	78
2	Refiner	75 HP	380 V 100.5	32	31.8	10
	"	75 HP	" 103	26	25.2	10
	"	75 HP	" 103	stop	stop	stop
	"	55 kW	" 107	stop	stop	stop

(4) Lighting

During our visit, the paper mill mainly relied on the sunlight, leaving most of the electric lights turned off. The factory has a total of 164 lights, 60 percent of which is comprised of daylight fluorescent lamps. Replacing them with white-light fluorescent lamps will increase the luminous efficiency by 10 percent, and therefore, the total number of lights required may be reduced by 10 percent.

This will save electric power as shown below:

40 W x 164 lights x 0.6 x 0.1 x 12 h x 365 d

= 1,724 kWh/y

9. Summary

The foregoing improvements are expected to reduce the factory's energy consumption as follows (after adjustment of the overlapping portions of energy saving coming under more than one item):

Measures	Potential energy saving		Rate (%)
Through reduction of unacceptable products with improved stock preparation	719 kl/y	(fuel oil)	20
With better dehydration in the press	144	(fuel oil)	4
By recovering condensate	503	(fuel oil)	14
Through more efficient combustion in the boiler	683	(fuel oil)	19
With better heat insulation and repairs to stop steam leakage	144	(fuel oil)	4
Subtotal	2,193 kl/y		61
Through integration of transformers into 1 bank and improvement of power factor	36,335 kWh/y		1
With better luminous efficiency for lighting	1,724 kWh/y		
Subtotal	38,059 kWh/y		1

Report No. 19: Paper

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

- Sang-Ngam Industry Co., Ltd. -

(Kwane Hua Industry Ltd.)

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Sang-Ngam Industry Co., Ltd. -

1. Outline of the Factory

Address : 50 Suksawadi Rd., Samut Prakarn

Type of industry : Paper container

Major products : Corrugated card box

Annual output : 1,200 t

No. of employees : 70

Annual energy consumption :

- Electric power : 156,000 kWh

Interviewee : Mr. Suchint, director

Date of diagnosis : Aug. 23 - 24, 1982

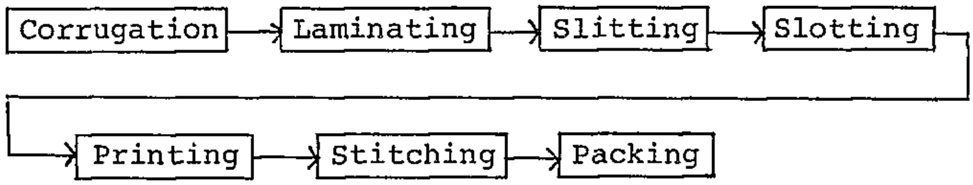
Diagnosers : A. Koizumi, K. Nakao, and K. Kurita

This factory operates in daytime only, producing 4 t of corrugated cardboard boxes through the equipment installed in 1965 when the factory started operation. Corrugators and all other machines arranged separately are operated, in most cases, manually.

There are 70 employees and among them are no engineers, since the president does all their work.

Separated processes make it possible to turn out varieties of products. Good care for their adaptability and the quality of what they produce assure stable production.

2. Manufacturing Process

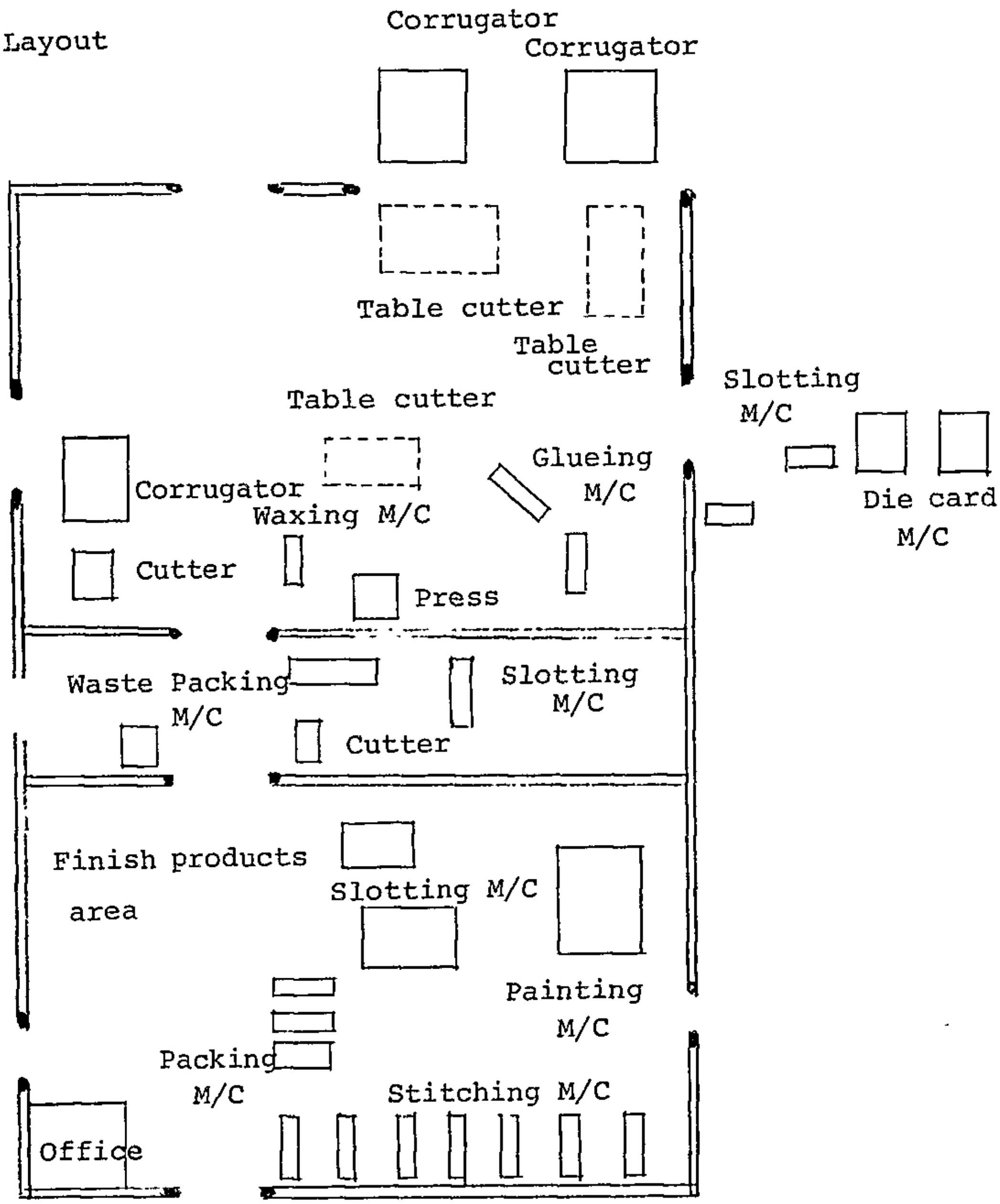


3. Major Equipment

(1) Major equipment

Name	No. of units installed	Type
Corrugator	3	Electric heating
Cutter	2	3.7 kW
Printer	1	3.7 kW
Paper Press	1	7.5 kW
Die card machine	2	3.7 kW

(2) Layout



Corrugator
Corrugator
Table cutter
Table cutter
Slotting M/C
Table cutter
Glueing M/C
Die card M/C
Corrugator
Waxing M/C
Cutter
Press
Waste Packing M/C
Slotting M/C
Cutter
Finish products area
Slotting M/C
Painting M/C
Packing M/C
Stitching M/C
Office

4. State of Energy Management

Power consumption is so small that electricity is being received, without a transformer, on 3 ϕ 220 V for use in everything including habitation. They have no use for oil or steam. Electricity is all that is needed for this factory. The receiving panel is fitted with a voltmeter and ammeter, but not with a wattmeter or power-factor meter. They are deeply concerned for quality with testers prepared for the inspection of raw stock and products. But the testers are not in full use as yet.

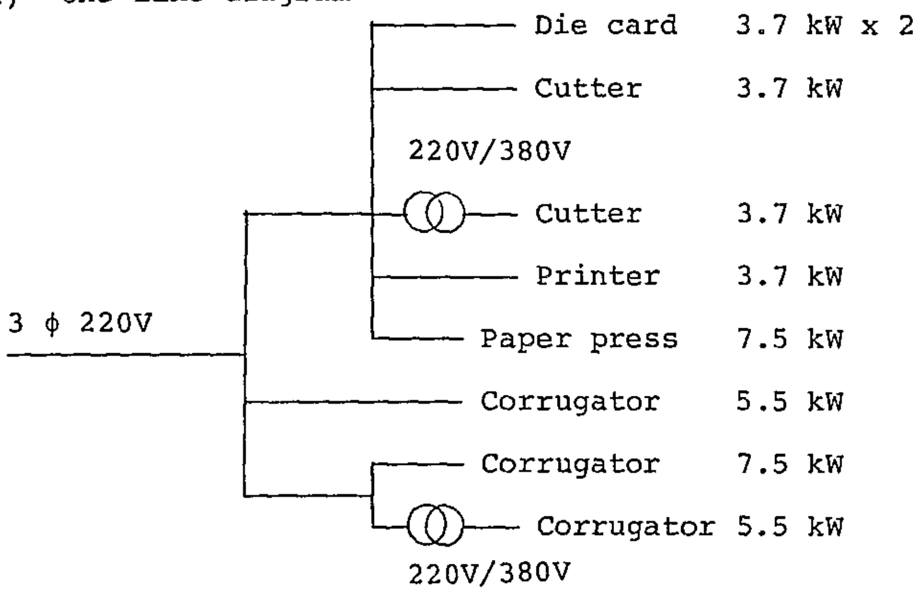
5. State of Energy Consumption

Electricity, the only energy source in use, is being used to power corrugator heaters and machine driving motors.

(1) The principal data relating to power consumption are as follows:

Power company	-	PEA
Peak demand	-	59 kW
Electric power used	-	12,720 kWh/m
Load factor	-	-
Penalty	-	No peanlty
Power factor	-	85.5%
Transformers	-	None
Power consumption rate	-	130 kWh/t

(2) One-line diagram



6. Problems of Energy Control and Solutions

(1) Heat Loss Prevention for Corrugator

Of a total of 60 kW of electricity in use, 16 kW is for corrugator consumption. Heat wires are incorporated in the corrugate roller. Since the conductor inlet on the roll is left open, asbestos plate or mica should be taken to close the opening. This could prevent heat loss and raise the roll temperature, thus bringing about a production speed-up.

(2) Rationalization of Production Procedure

Company executives suggest that production procedure with corrugators should move in order from narrow to wide sheets of raw stock, but factory operators insist on the reverse order. Questions were asked as to why. The reason may be that the surface temperature of the roll in operation ought to be comparatively higher in sections on both sides where it does not contact raw stock than in sections where it does. That is why expansion causes roll to stand less apart on both sides. If raw stock were sent changing in order of width from narrow to broad, while the machine was in motion, the thick paper could bite into the narrow open space between rolls and make them cause damage.

This would lead to the trouble of changing paper each time raw stock fails, possibly involving a waste of paper and a heat loss. It might be advisable to see that production procedure begins with corrugation work on the broader raw stock.

(3) Study on Adhesive Density

Adhesives are an important raw material for the corrugated paper mill. Contracts with adhesives supplers should be made to ensure that they follow a definite quality specification and present a quality test table each time they make delivery.

Since adhesive density is related with adhesive power and the amount of drying heat energy consumption, it should be given first place on the list of data for specification. Operators are advised, once in while, to make an acceptance test of adhesives when they receive them. They are also advised to make sure that they are supplied with material of a constant density before they can try to change for a higher density specification.

Reduced energy for adhesive drying will permit a speed-up in the corrugation process and make a better power consumption rate.

7. Summary

Electricity is the only energy source in this factory, and it consumes a small amount of it. It shows a good power factor. There is not much room for a large saving.

ATTACHMENT

ATTACHMENT I	添付資料 I

Energy Conservation Survey
省エネルギー調査表

1 Name of Factory
工 場 名 ____________________

2 Location
所 在 地 ____________________ Tel. __________

3 Name of Company Officials
会社役員名 __________

President
社 長 __________

Factory Manager
工 場 長 __________

Energy Manager
エネルギー担当者 __________

4 Segment of Industry
業 種 __________

5 Capital
資 本 金 __________ bahts

6 Annual Turnover
年間売上高 __________ bahts

7 Number of Employees
従業員数 __________

8 Number of Engineers
技術者数 __________

Electricity
電 気 __________

Heat
熱 __________

9 Major Products
主要生産物 ____________________

____

10 Production Capacity of Major Products
主要生産物の生産能力 __________

Nominal
公 称 ____________________

Present Condition
現 状 ____________________

11 Fuel Consumption
燃料消費高

☐ Fuel oil 重 油	kl/y	bahts/y
☐ Diesel oil 軽 油	kl/y	bahts/y
☐ Kerosene 灯 油	kl/y	bahts/y
☐ Gasoline ガソリン	kl/y	bahts/y
☐ LPG 液化石油ガス	t/y	bahts/y
☐ Natural gas 天然ガス	m³/y	bahts/y
☐ Lignite or Brown Coal 亜炭又は褐炭	t/y	bahts/y
☐ Bagasse バガス	t(m³)/y	bahts/y
☐ Charcoal 木 炭	t/y	bahts/y
☐ Firewood 薪	t(m³)/y	bahts/y
☐ Others その他 ( )	/y	bahts/y

12 Electric Power, 電力

Electricity Consumption 電力消費高	KWh/y		bahts/y
Contract Demand 契約電力	KW.	Receiving Voltage 受電電圧	V
Power Factor 力 率	%		
Power Plant 発電設備	Have or Not.	Capacity 能 力	KW or KVA.

13 Water Consumption, 水消費量

Sea Water 海 水	m³ or t/y	River Water 河 水	m³ or t/y
Underground Water 地下水	m³ or t/y	City Water 水道水	m³ or t/y

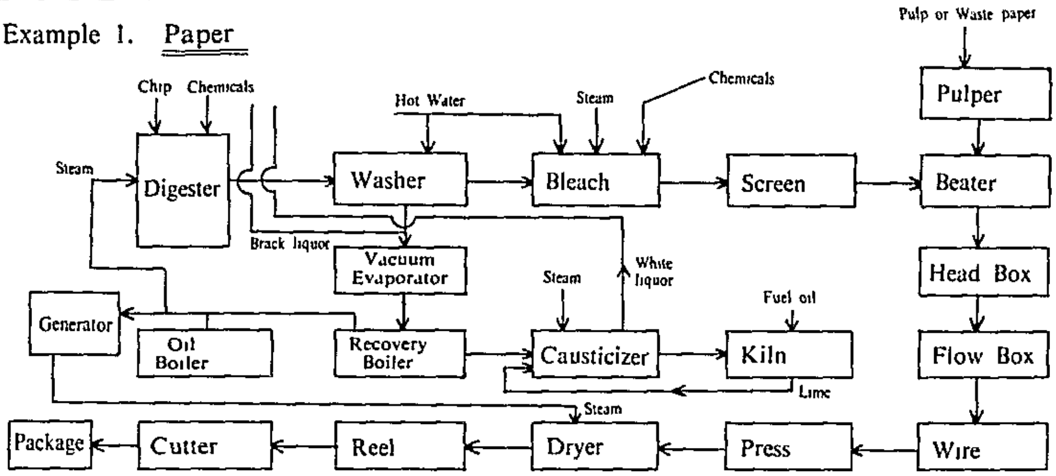
14 Boiler, ボイラ

Built(A.D.) 設置(西暦)	Type 型　式	Nominal Capacity 公称能力		Kind of Fuel 燃料の種類	Operating period 運転時間	
		Steam Press. kg/cm²G	Evaporating Volume t/h		hrs/day	days/y

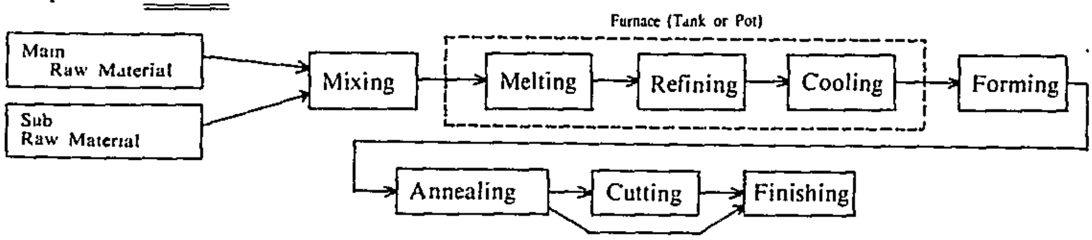
15 Major Facilities Using Energy, エネルギー使用の主要設備

Built(A.D.) 設置(西暦)	Name of Facility 設備名	Products 生産物	Output 生産高		Kind of Energy used 使用エネルギーの種類	Operating period 運転時間	
			Nominal 公称	Present Condition 現状		hrs/day	days/y

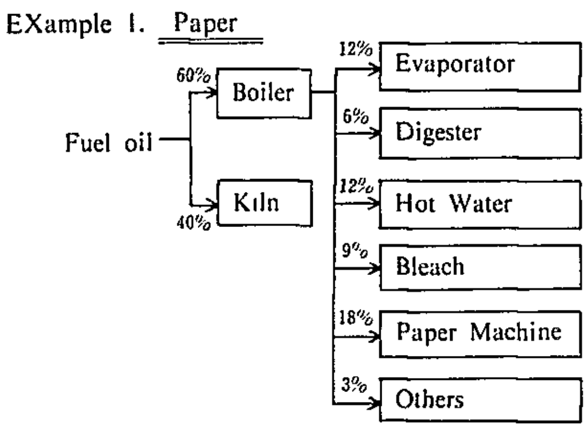
Example 1. Paper

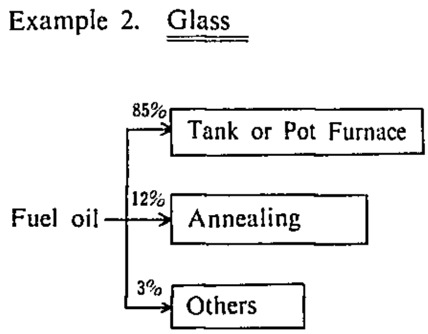


Example 2. Glass



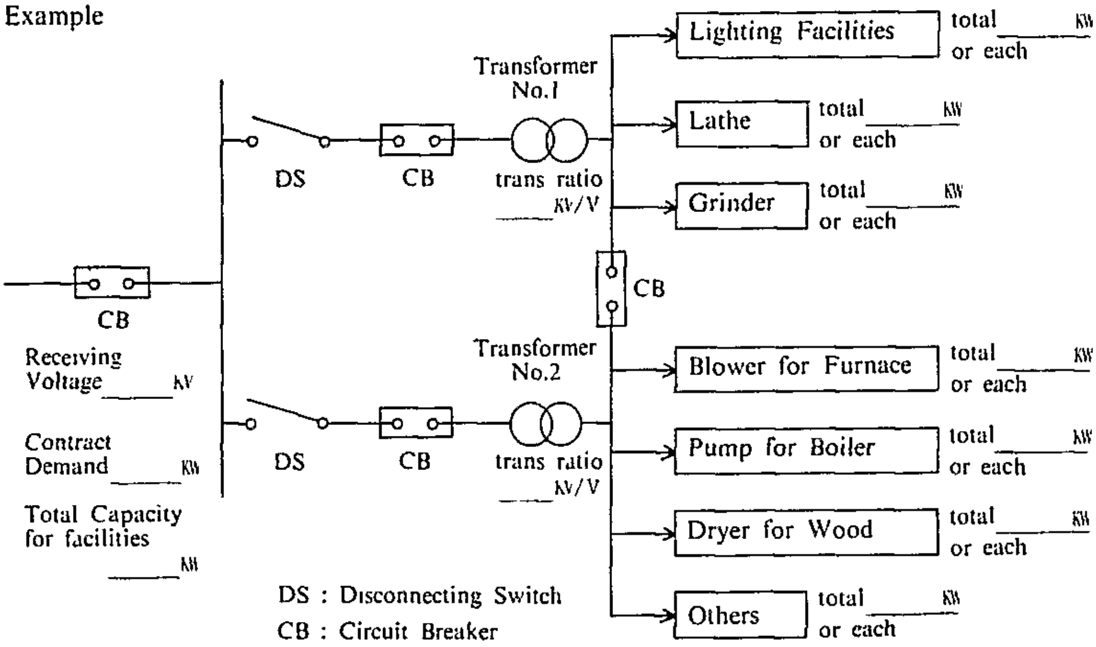
17 Energy Flow-chart, エネルギー流れ図





18 Skeleton Diagram, 単線結線図

Example



19 Plant Layout, 工場配置図

20 In case you have any problem(s) in your course of promotion of energy conservation, please circle the no(s). of applicable item(s) among the following: (Maximum 5 items)

省エネルギー推進上の問題点があれば，下記の該当する項目に丸印を付して下さい。(但し，最高5項目まで)

(1) Prospect of energy price is not clear.
エネルギー価格の見通しが不明。

(2) The proportion of energy cost in the whole cost of enterprise is small.
企業におけるエネルギー費用の割合が小さい。

(3) Increase of energy cost can be covered by raising the prices of products.
エネルギー費用の上昇は製品値上げでカバーできる。

(4) Instability of energy supply. (power stoppage, etc.)
エネルギー供給が不安定（停電など)。

(5) Shortage of engineers.
技術者が不足。

(6) Difficulty in obtaining good energy conservation equipments.
省エネルギー機器のよいものが手に入り難い。

(7) Information such as active cases is not easy to obtain.
実施例のような情報が入りにくい。

(8) System of research and development is not sufficient.
研究開発体制が不十分。

(9) Shortage of fund for facility improvement.
設備改善の資金が不足。

(10) The facilities are superannuated.
設備が老朽化している。

(11) Employees' consciousness is low.
従業員の意識が低い。

(12) No personnel is available who can educate the employees.
従業員教育をできる人がいない。

(13) Shortage of measuring equipments.
計量設備が不足している。

(14) No time to analyze energy consumption rate.
原単位解析を行う時間がない。

(15) Shortage of information on government's measures.
政府施策の情報が不足。

(16) Shortage of government's subsidiary measures.
政府の助成策が不足。

(17) Others
その他。

CHECK LIST

Contents

1-1 Energy Management エネルギー管理

1	Name of Factory	工場名				
2	Date of Survey	調査日				
3	Company's Energy Conservation Policy	企業の省エネルギー方針				
	Setting up Target	目標設定	Set up		not set up	
	Numerical Value of Target	目標値	____% improve to ____ base			
	Completion Deadline	達成期限	by ____			
	Investment for Energy Conservation	省エネルギー投資				
	Investment Scale	投資額	1980 ____ Bhts			
			1981 ____ Bhts			
			1982 Plan ____ Bhts			
	Judgement for Investment	投資基準	Pay Back Time, within ____ Yrs			
	Check on Energy Consumption	エネルギー消費量管理				
	Measurement of Consumption	消費量計測	Electric Power		Fuel	
			Times/		Times/	
	Factory Total	工場計	done	not done	done	not done
	By Major Process	主要工程別	done	not done	done	not done
	By Major Facility	主要設備別	done	not done	done	not done
	Data Analysis	データ解析				
	Grasp of Energy Consumpt's. rate	原単位把握	done		not done	
	Preparation of Control Chart	管理図作成	done		not done	
	Analysis of Variance	変動要因分析	done		not done	
	Cost Control	原価管理				
	Energy Cost Accounting	エネルギー原価計算	Monthly,	Times/y,	not done	
	Energy Cost Distribution by Process	工程別配分	done		not done	

	Name of Factory	工場名			
4	Accounting of Heat Balance	熱勘定	done		not done
	Organization	組　織			
	Planning and Promotion	企画・推進	Section		Person in Charge
	Committee	委員会	held		not held
	Frequency of Holding	開催頻度	______	Times/y	
	Committee Chairman	委員長	______		
	Project Team	プロジェクトチーム	made		not made
	Consultant Contract	コンサルタント契約	made		not made
	System	制　度			
	Improvement Proposition System	改善提案制度	is		isn't
	Achievement Commendation System	実績表彰制度	is		isn't
	Inspection, Audit	視察, 診断	done		not done
5	Education of Employees	従業員教育			
	Seminar	研修会	held	Times/y	not held
	Observation Meeting	見学会	held	Times/y	not held
6	Campaign to Employees	従業員への呼びかけ			
	Appeal from Factory Manager	工場長の呼びかけ	done		not done
	Poster, etc.	ポスター　等	done		not done
7	Activities in the Business Circles	業界の活動	Practised		not practised

1-1-2

1-2 Furnace, Kiln, Dryer

Use separate sheet for each different use.

1	Name of Factory 工場名	Part 工 程	Name of Equipment 設 備 名	Use 用 途	Charge 被加熱物		Date of Survey 調 査 日
~ 6							

7	No. of Furnace	番 号				
8	Type	型 式				
9	Maker	メーカー				
10	Time built	設置時期				
11	Outer Dimension Length or Dia. Width Height	外法寸法 長さ・径 巾 高				
12	Design Capacity	設備能力				
13	Usage Continuous Batch h/Day h/month	使用状況 連 続 非連続				
14	Induced Draft Fan Forced Draft Fan	吸込み送風機 押込み送風機	____ m^3/h ___ m/mAq ___ kW ____ ___ ___			
15	Improvement done	改造実績				

Name of Surveyor ____________

16	Fuel	燃料						
	Name	名前						
	Lower Heating Value	発熱量（低位）		Kcal/kg. ℓ.m^3N				
	Specific Gravity	比重						
	Moisture	水分						
17	Average Consumption	燃料使用量（平均）		/h				
18	Oil Storage	油貯蔵						
	Tank Contents	タンク	油種					
	Volume		容量	m^3				
	Temp.		温度	°C				
	Insulation		保温	m/m				
19	Fuel Receiving	受入れ						
	Measuring Volume		計量	done	not done			
	Temp.		温度測定	done	not done			
	Sp.grav.		比重 〃	done	not done			
	Analysis		分析	done	not done			
20	Oil leak	油洩れ		good	not good			
21	Steam	スチーム						
	Pressure		圧力	kg/cm^2g				
	Temp.		温度	°C				
22	Electricity	電力						
	Elect. Heater		電熱	______ kW	______ V			
	Infra Red Lamp		赤外ランプ	______ kW	______ V			

1-2-2

	No. of Equipment	設備名							
23	Combustion								
	Burner	バーナー	Pressure jet, 油圧	Low pr.air atomizing, 低圧噴霧	Steam or air atomizing, 高圧噴霧	Rotary, 回転式	Intermixing, 内部混合	Interior atomizing, 外部混合	Semi mixing, 半混合
	Burner Tile	バーナータイル	Good	not good					
	Cleaning	バーナー手入	______ times/y						
	Burner tip								
	Flame Color	火焔色	good	not good					
	Length	長さ	good	not good					
	Sparks	花火	good	not good					
	Blow off	吹きとび	good	not good					
	Color of Smoke	煙の色	good	not good					
	Air/fuel ratio	空気比	Factory Data ______		Measured ______		$m = \frac{0.21}{0.21 - (O_2)}$		
	Automatic Controller	制御装置	exist	not exist					
	Fuel Consumption	燃料量	______ kg.ℓ.m^3/h						
	Fuel Temp.	油温	______ °C						

	No. of Equipment	設備番号	
24	Furnace Pressure	炉圧	________m/mAq (Measuring Point 測定位置 ________m/mH)
	Pressure Control	炉圧制御	done not done
	Movement of Damper	ダンパー作動	good not good
	Air Sucking	空気吸込	
	from Wall	炉壁	good not good
	Burner Side	バーナーまわり	good not good
	Door	出入口	good not good Single Door, Double Door
	Truck	台車シール	good not good
	State of Stack, Gas duct	煙突，煙道の状態	good not good
	Cooling Air	冷却空気	________m^3/min.
25	Heating	加熱	Firing Zone Preheating Zone Cooling Zone
	Furnace Temp.	炉温	________°C ________°C ________°C ________°C
	Charging Temp.	装入温度	________°C
	Extracting Temp.	抽出温度	________°C
	Temp. measurement	温度測定	Thermocouple( ), Resistance Thermometer, Optical Pyrometer, Radiation thermometer, Seger cone
	Temp. Controller	温度制御装置	exist not exist
	Burner Setting	バーナー配置	good not good
	Arrangement of Charge (Furnace Load Factor)	被加熱物の積み方	good not good, Truck Speed________
	Heat Utilization of previous process	ホットチャーヂ	done not done

	No. of Equipment	設備番号	
26	Drying	乾燥	
	Air Temp.	風温	________°C
	Air Flow	風量	________m^3/h
	Moisture of Charge	装入物水分	
	Inlet	入口	________%
	Outlet	出口	________%
27	Insulation	断熱	
	Structure of Wall	壁面構成	
	Refractory Brick	耐火材	________m/m Brick, Castable, Ceramic Fibre
	Insulating Zone	断熱材	________m/m Brick, Castable, Ceramic Fibre, Asbestos, Rock Wool, Glass Wool, Calcium Silicate
	Outer Wall	外壁	________m/m Brick, Steel Plate
	Color of Wall Surface	壁の色	
	Temp. of Wall Surface	壁面温度	Heat Flux
	Side Wall	側面	________°C ________°C ________°C ________°C ________$Kcal/m^3h$
	Roof, Crown	上面	________°C ________°C ________°C ________°C ________$Kcal/m^3h$
	Insulation of Skid	スキッド断熱	good not good
	Weight Reduction of truck, conveyor, etc.	台車・コンベア等の軽量化	done not done

	No. of Equipment	設備番号				
28	Waste Heat Recovery	廃熱回収				
	Name of Recovery Equipment	回収設備名				
	Type	型式				
	High Temp. Fluid	高温流体				
	Low Temp. Fluid	低温流体				
	Heat Recovered	回収熱量				
	Flow	流量				
	Temp. Rising (Falling)	温度上昇(低下)				
	Specific Heat	比熱				
	Temp. of Waste gas	排ガス温度				
	Furnace Outlet	炉出口	________ °C			
	After Heat Recovery	廃熱回収後	________ °C			
	Cleaning of Heating Surface	伝熱面掃除	________ Times/y			
	Preheating Zone in Furnace	炉の予熱帯	exist not exist			
	Air Leak in Heat Recovery Equip.	廃熱回収設備への空気洩れ	found not found			

1-2-6

	No. of Equipment	設備番号	
29	Operational Management	操業管理	
	Operation Standard	作業標準	made　　not made
	Heating Curve	昇温曲線	exist　　not exist
	Recording	記録	good　　not good
	Maintenance	保全整備	good　　not good
	Period	周期	______ly
	Record	記録	good　　not good
30	Current Performance	実績	
	Output (or Input)	処理量	______t/h
	Fuel Consumption	燃料量	______ ℓ.kg.m^3/h
	Heat Efficiency	熱効率	______
	Loss with Waste Gas	排ガス損失	______Kcal/h　______%
	Loss with Coolant	冷却水損失	______Kcal/h　______%
	Loss through Wall	放熱損失	______Kcal/h　______%

1-3 Steam Consumed Equipment（蒸気使用設備）

1 2	Name of Factory 工場名	Part 工程	Object to Use 用途	Name of Equipment 設備名		Date of Survey 調査日
5						

6	No. of Equip.	番号	
7	Type	型式	
8	Maker	メーカー	
9	Time built	設置時期	
10	Dimension	寸法	ℓ ___ mm x w ___ mm x h ___ mm, d ___ mm x h ___ mm
11	Heating surface area	伝熱面積	m^2
12	Volume	容量	
13	Capacity	能力	
14	Subject of heating	被加熱体	
15	Heat source	熱源	Steam: kg/cm^2G, °C t/hr, Hot water °C, t/h
16	Quantity of Treatment	処理量	
17	Operating condition Temp. Press.	操業条件 温度 圧力	 °C kg/cm^2G
18	Insulation Surface Temp.	断熱 表面温度	mm good, not good °C heat flux $Kcal/m^2h$

1-3-1

19	Cleaning for heating surface	伝熱面の掃除	done　　not done
20	Instruments	計装	Temp.　Press.　Flow.　Other:
21	Auxiliary Equip.	附属設備	
	Heat Recovery	熱回収	exist　　not exist　　type
	High Temp. Fluid	高温流体	specific heat
	Low Temp. Fluid	低温流体	specific heat
	Temp. rising (falling)	温度上昇(降下)	
	Flow	流量	m^3/h
	Condensate recovery	ドレン回収	done　　not done,　　open system,　　closed system
	Rate of Recovery	回収率	%

1-4 Boiler (ボイラ)

1 〜 4	Name of Factory 工場名	Part 工程	Object to Use 用途		Date of Survey 調査日
5	No. of Boiler	番号			
6	Type	型式	Water tube boiler (水管) Flue tube boiler (炉筒) Once-through boiler (貫流) Hot-water boiler (温水) Other (その他)		
7	Rated evaporation	定格蒸気量	ton/h		
8	Manufacture date	製造年月日			
9	Steam pressure	圧力	Rated (定格) kg/cm^2G, Normal (常用) kg/cm^2G		
10	Heating surface area	伝熱面積	m^2		
11	Auxiliary Equip.	附属設備	Superheater (過熱器) m^2, Reheater (再熱器) m^2 Economizer (節炭器) m^2, Air heater (空気予熱器) m^2		
12	Fuel Name Lower Calorific Value Specific gravity	燃料 名前 発熱量(低位) 比重	 Kcal/kg, ℓ, m^3N		
13	Usage Continuous Batch	使用状況 連続 非連続	 h/d, d/m, h/y,		

	Item	項目	Unit 単位	Nominal 定格	Actual 実績	Remarks 備考
14	Oil Tank	油タンク	———			
	Volume	容量	m^3			
	Temp.	油温	°C			
	Insulation	保温	mm			
	Leak	洩れ	———			good, not good
15	Boiler	ボイラ	———			
	Steam Pressure	蒸気圧力	kg/cm^2G			
	Steam Temp.	蒸気温度	°C			
	Feed water flow rate	給水 給水量	m^3/h			
	" Temp.	温度	°C			
	" Meter	流量計	m^3/h			Type
	Blow off flow rate	ブロー量	m^3/d			Continuous, Intermittance, Heat recovery
	Boiler water	缶水	———			
	pH	ピィエッチ				
	Conductivity	電気伝導率	μs/cm			
16	Feed Water	給水	———			
	pH	ピィエッチ				
	Conductivity	電気伝導率	μs/cm			
	Preparation method	処理法	———			
	Testing time	検査頻度	———			
	Cl' content	クロール濃度	ppm			

	Item	項目	Unit 単位	Nominal 定格	Actual 実績	Remarks 備考
17	Combustion	燃焼	———			
	Fuel	燃料	ℓ.Kg m^3/h			
	Consumption	使用量				
	Temp.	温度	°C			
	Meter	計器	———			exist, not exist
	Burner	バーナー				Oil burner
	Type	型式	———			Low press. air atomizing (低圧噴霧式) Steam or air atomizing (高圧噴霧式) Press. jet type (油圧式) Rotary (回転式) Gas burner Intermixing type (内部混合式) Injector atomizer (外部混合式) Semi-mixing (半混合式)
	Capacity	容量	ℓ.Kg m^3/h			
	Burner tile	バーナータイル	———			good, not good
	Clinker	クリンカー	———			found, not found
	Air/fuel ratio	空気比	———			Measuring point (場処)
	Insulation	断熱	mm			good, not good surface temp. heat flux.
	Sucking air	侵入空気	———			good, not good
18	Color of smoke	煙の色	———			good, not good
19	Air heater	空気予熱器	———			exist, not exist
	Air temp.	空気温度	———			
	Inlet	入口	°C			
	Outlet	出口	°C			

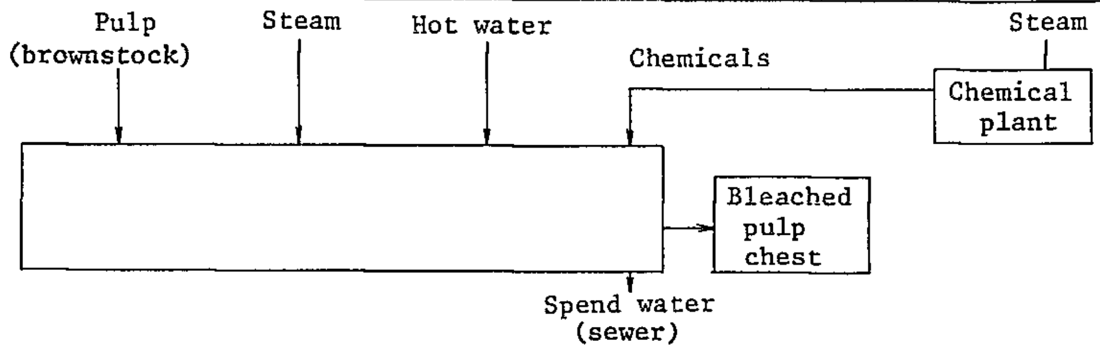
1-4-3

	Item	項目	Unit 単位	Nominal 定格	Actual 実績	Remarks 備考
	O_2 % Inlet	O_2 % 入口	%			
	Outlet	出口	%			
	Waste gas temp.	排ガス温度	———			
	Inlet	入口	°C			
	Outlet	出口	°C			
20	Economizer	エコノマイザー	———			exist, not exist
	Waste gas temp.	排ガス温度	———			
	Inlet	入口	°C			
	Outlet	出口	°C			
	Feed water Temp.	給水温度	———			
	Inlet	入口	°C			
	Outlet	出口	°C			
21	Automatic Controller	自動制御	———			exist, not exist
	Subject	対象	———			Steam press. air/fuel ratio
	System	方式	———			
	Operation	作動	———			good, not good
22	Steam accumulator	スチームアキュムレーター	———			exist, not exist
	Capacity	容量	m^3			
	Pressure	圧力	kg/cm^2G			
23	Condensate recovery	ドレン回収	———			exist, not exist
	Rate of recovery	回収率	%			
	System	回収方式	———			Open system, close system

	Item	項目	Unit 単位	Nominal 定格	Actual 実績	Remarks 備考
24	Evaporation ratio	蒸発倍数	Kg/kg,ℓ			
	Boiler efficiency	ボイラ効率	%			Hh base, Hl base
	Loss with waste gas	排ガス損失	Kcal/h			
25	Soot blow	スートブロー	/d			
	Service a burner	バーサー手入	/m			
	Removal of scale	スケール除去	———			
	Air heater	空気予熱器	/y			
	Economizer	エコノマイザー	"			
	Gas duct	煙道	"			
	Stack	煙突	"			
	Cleaning burner tip	バーナチップ手入	/m			

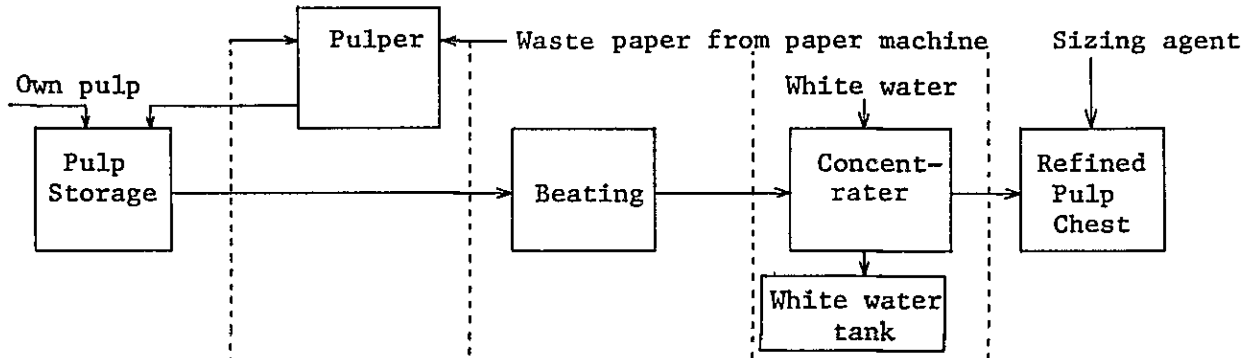
1-4-5

1-5 Paper (紙)

	項　　目	Item			Date of survey	調査日
1	Name of factory	工 場 名				
2	Stuffs (Pulp)	原 料(パルプ)	Kind (種類)	Moisture (水分)	Making (製造)	Charge weight (使用量)
				%	purchase, own (購入) (自製)	$ton, m^3/d$
				%	waste paper (廃ペーパー)	$ton, m^3/d$
				%		$ton, m^3/d$
				%		$ton, m^3/d$
3	Bleaching	漂　　白				
	Equipment	設　　備		Continuous		Batch
			Sequence (シーケンス)			
			No. of unit (系列数)			
			No. of stage (段数)			
			Time built (設置時期)			
			Capacity (能力)			

	Operation	操　　業	Stage temp. （各段温度）		
			Stage Conc. （各段濃度）		
			Steam consumption （蒸気消費量）	Temp. °C Press. Kg/cm^2G t/d	Temp. °C Press. Kg/cm^2G t/d
			Hot water consumption （温水消費量）	Temp. °C m^3/d	Temp. °C m^3/d
			Chemicals （薬品添加）	Cl_2 %(pulp) other NaOH % " Hypro. % "	Cl_2 %(pulp) other NaOH % " Hypro. % "
	Pulp product	生　産　量	t/d,　t/m,		
	Flow sheet	生産工程表			

1-5-2

4	Pulp preparation	パルプ処理	Purchase pulp & waste paper 
	Equipment	設　備	Drum filter Decker machine Extractor
	Time built	設置時期	
	Stage number	段　数	
	Capacity	能　力	m^3　　t/Batch t
	Operation	操　業	Own pulp t/m Purchase pulp t/m Own waste paper t/m Purchase waste paper t/m Mix heating Separate Beating conc. % Freeness c,c, Inlet conc. % Outlet conc. % Temp. °C Pulp conc. %

	Flow sheet	生産工程表					
5	Paper machine	抄 紙 機	Head box → Flow box →	Wire part →	Press part →	Dryer →	Calender, Reel → Winder → Cutter
	Equipment	設 備	°Open type °Closed type	° Fourdrinier (長網) ° Cylinder (円網)	° Stage (段数)	° Multi dryer ° Yankee dryer	
				Wire width mm Wire length mm Wire mesh Vacuum gage	° Flat squeeze (フェルト搾水) Exist Not exist	Open hood Closed hood	
						Heat exchanger Exist Not exist	
						Condensate recovery Exist Not exist	

	Time built					Electric drive Mechanical drive Number of paper dryer Number of canvas dryer	
	Flow sheet	生産工程表					

Operation	操　業	(1) Head box (2) Flow box	Wire part	Press part	Dryer
		Pulp conc. (1) % (2) %	Wet·web. moisture %	Wet End moisture %	Dryer surface temp. °C at dryer
		Temp. (1) °C (2) °C Freeness (1) cc	White water conc. White water temp. °C	Times of felt washing /d	Dryer end paper moisture

Dryer end paper moisture

Weight \ Paper grade			
g/m^2	%	%	%
g/m^2	%	%	%
g/m^2	%	%	%

Paper grade （紙の種類）					
Basic weight （定　量）	g/m^2				
Result weight（実　量）	g/m^2				
Machine speed（機械スピード）	m/min				
Product （生 産 量）	t/d				
Steam consumption（蒸気使用量）	t/d				
Times of break（紙切回数）	time/d				
Check of paper weight（チェック回数）	time/d				

Machine coefficient	抄紙機効率	

	Steam Consumption Rate	蒸気原単位	
	Instrument Steam Sizing Chemical Paper	計　装	 Temp. Press. Flow. Temp. Flow. Weight. Moisture.
	Insulation	断　熱	Exist, Not exist, Good, Not good, mm.

2-1. Electric Power Management 電力管理

No.	Item	項目				
1	Name of Factory	工 場 名				
2	Date of Survey	調 査 日				
3	General	一 般				
	(1) Record of used power for every month	毎月の使用電力量（kWH）の記録	記録している done		記録なし not done（理由）	
	(2) Examination the cause for variance for used power	使用電力量が変化した理由の検討	検討している done		検討してない not done	
	(3) Stability of voltage and frequency of source	受電電圧，周波数の安定状況	安定してる stable		安定してない not stable	
4	Electric power specific unit (EPSU)	電力原単位				
	(1) Calculation for major product's EPSU monthly	毎月の主要製品の電力原単位の算出	算出してる Yes		算出してない No	
	(2) Preparation table on the right for every process and use	用途別・工程別に右表があるが	Output (A)	Used power (B)	EPSU (B/A)	ratio of electric power fee per total cost
			生産量(A)	電力使用量(B)	原単位(B/A)	生産費に占める電力割合費
	(3) Numerical EPSU target	電力原単位の目標値	決めている determined (value A/t)		決めていない not determined	
5	Load Factor	負 荷 率				
	(1) Record of hourly consumption of power	毎時間の消費電力の記録	記録してる done (max. (min. kW /H)		記録してない not done	
	(2) Improvement of load curve	日負荷の最大値を抑える対策	行なってる done		行なってない not done	
6	Value of power factor contracted	電力料金算定上の力率	80% under 未満	80 ~ 85%	85% over 以上	

7	Substation	受変電設備		
	(1) Measurement of transformer load	変圧器の負荷測定	Yes	No
	(2) Transformer exclusively for lighting	電灯用専用変圧器	Yes	No
	(3) Turning off transformer when off load	不要時の変圧器遮断	Yes	No
	(4) Improvement of power factor by static condenser	コンデンサーによる力率改善	Yes	No
8	Distribution system	配線設備		
	(1) Measurement of main circuit load	主回路別の負荷測定	Yes	No
9	Motor	電動機		
	(1) Measurement of load of motors over 15 kW	15KW以上の電動機の負荷測定	Yes	No
	(2) Periodically lubrication of gear and motor	ギヤや電動機の定期的な給油	Yes	No
	(3) Turning off motor when off load	無負荷時の電動機の停止	Yes	No
10	Motor driven machine	電動機応用設備		
	(1) Flow control of blower and pump	ブロワーやポンプの流量制御	Motor speed control 電動機の速度制御	
			Control of numbers of operating motor 台数制御	
			Damper or valve control ダンパー，バルブの開閉	
			Others その他	
	(2) Checking leakage of compressed air or water	圧縮空気や水のもれのチェック	Yes	No
	(3) Keeping adequate working pressure of compressed air	圧縮機の使用圧力は適正か	Yes	No
	(4) Keeping adequate discharge pressure of pump	ポンプの吐出圧は適正か	Yes	No

11	Lighting fittings	照明設備		
	(1) Cleaning lighting fittings	照明器具の清掃	Yes	No
	(2) Turning off unnecessary light	不要な照明の消灯	Yes	No
12	Electric welder	電気熔接機		
	(1) Static condenser exclusively for welder	専用の力率改善用コンデンサー	Yes	No
	(2) Transformer exclusively for welder	専用の変圧器	Yes	No
	(3) Keeping circuit balance of three phases	電源の各相のバランス	Yes	No
	(4) Cable length from welder to holder	溶接機の手元までの配線長さ	Yes	No

2-2. Transformer for (変圧器)

1	Name of Factory	工 場 名		2	Date of Survey	調査日
3	Type of Transformer	型 式	☐ Oil Immersed Self Cooling (油入自冷式) ☐ Dry Type (乾 式) ☐ Air cooling Forced Oil (送油風冷式) ☐ Others (その他)			
4	Number of Phase	相 数	☐ 3 Phase (三相) ☐ Single Phase (単相)			
5	Connection (Single Phase)	結線方法 (単相Tr.)	☐ Δ - 人 ☐ 人 - Δ ☐ Δ - Δ ☐ V - V			
6	Rated Output	定格出力	______ KVA, Number of Bank (バンク数) ______			
7	Rated Voltage, Rated Current	定格電圧 定格電流	Primary ____ V. ____ A Secondary ____ V, ____ A			
8	Rated Frequency	定格周波数	______ HZ.	9	% Impedance	パーセントインピーダンス ____ % At ____ KVA Base
10	Maker, Year Made	メーカと製造年				
11	Loss	損 失	Iron Loss (鉄損) ______ kW, Copper Loss At Full Load (全負荷銅損) ______ kW,			

Measurement Record (測定記録)

Time 時 間	Voltage 電 圧	Current 電 流	Apparent Power 皮相電力	Power 電力	Power Factor 力 率	Oil Temp. 油 温	Remarks 備 考
	V	A	KVA	kW	%	°C	

2-3. House Power Plant （自家用発電設備）

1	Name of Factory	工 場 名		2	Date of Survey	調査日	
3	Kind of Engine	エンジンの種類	☐Diesel Engine ☐Gas Turbine	☐Steam Turbine ☐Condensing turbine ☐Back Pressure Turbine ☐Extraction and Back Pressure Turbine			
4	Output of Engine	エンジン出力	______ PS (kW)	5	Fuel Consumption	燃料消費量	______ ℓ(Kg)/Hr.
6	Kind of Fuel	燃料種別	☐Coal ☐Heavy Oil	☐Diesel Oil ☐Others			
7	Caloric Value of Fuel	同上の発熱量	______ Kcal/ℓ(Kg)				
8	Rated Output of Generator	発電機の定格出力	______ KVA (kW)	9	Rated Power Factor	定格力率	______ %
10	Rated Voltage, Rated Current	定格電圧 定格電流	______ V	______ A			
11	Daily Record	運転日誌	☐Yes（有）	☐No （無）			

Measurement Record （測定記録）

Time 時間	Generated Energy 発電量	Fuel Consumption 燃料消費量	Steam Temp. 蒸気温度	Steam Pressure 蒸気圧力	Voltage 電圧	Current 電流	Power Factor 力率	Remarks 備考
	KWH	Kg	In. °C Out	In kg/ Out	V	A	%	

2-4. Lighting Fittings （照明設備）

1	Name of Factory	工　場　名		2	Date of Survey	調 査 日	
3	Lighting System	工場照明方式	☐ General （全般照明）	☐ General and Local（全般照明と局部照明）			
4	Method of Turning On and Off	点 滅 方 法	☐ Automatic（自動点滅） ☐ Both Automatic and Manual（自動手動の併用）	☐ Manual（手動点滅）			
5	Circuit Separation (In case of General Lighting)	全般照明の場合の回路方式	☐ One Switch per Room（1ルーム，1スイッチ） ☐ Several Switches per Room（1ルーム　複数スイッチ） ☐ One Switch per Line (Turn, Line by Line from Window side)（ライン毎に点滅）				
6	Kind of Lamp	ランプの種類	☐ Incandesent Lamp （白熱灯） ☐ Fluorescent Lamp (White)（白熱蛍光灯）	☐ Fluorescent Lamp (daylight color) 昼光色蛍光灯 ☐ Fluorescent Mercury Lamp（蛍光水銀灯） ☐ Others ______			
7	Cleaning Frequency of Lighting Fittings	照明器具の清掃頻度	______ Times/Year（回／年）				

Measurement Record （測定記録）　　　Time at AM / PM ______ （測定時刻）

Place（場　所）									
Illuminance（照　度）									
Kind of Lamp（ランプの種類）									
Wall Color（壁の色）									

Power Consumption for Lighting（照明用消費電力）　Day Time（昼間）______ kWH/H　Night（夜間）______ kWH/H　from daily record 日誌から

2-5. Motor Driven Machine ~ Over 15 kW （電動力応用設備～15KW以上）

1	Name of Factory	工場名	2 Date of Survey 調査日
3	Name of Equipment	設備名	Number of Similar Equipment 同種設備の数 ____
4	Kind of Motor	電動機の種類	☐ D.C.（直流） ☐ A.C.（交流） ☐ Inductor（誘導機） ☐ Syncronous（同期機） ☐ Wound Rotor ☐ Squirrel Cage ☐ Others ____
5	Rating of Motor	電動機の定格	Output（出力） ___kW, Voltage（電圧）____V, Current（電流） ____ A Frequency（周波数）____ Hz, RPM（回転数）____ rpm, Magnetic Pole（極数）____
6	Starting Method	起動方法	☐ Full-Voltage（直入） ☐ Star-delta（人-Δ） ☐ Rotor-resistance（二次抵抗） ☐ Others ____
7	Coupling Apparatus	伝導装置	☐ Direct（直結） ☐ Belt（ベルト） ☐ Gear（歯車） ☐ Others ____
8	Equipment	設備機械	☐ Pump（ポンプ） ☐ Blower（ブロワー） ☐ Compressor（コンプレッサー） ☐ Others ____
9	Kind of Flow and Density	流体名と密度	☐ Air（空気） ☐ Water（水） ☐ Others, ____ Density (or Specific Gravity)（密度又は比重） ____ kg/m^3 (lb/m^3)
10	Flow Control	流量制御	☐ Automatic（自動） ☐ Manual（手動） [☐ Valve（バルブ） ☐ Damper（ダンパー） ☐ Speed Control（速度制御） ☐ Others ____]
11	Speed Control	速度制御	☐ Motor（モーター） [☐ Pole Change（極数） ☐ Frequency（周波数） ☐ Voltage（電圧） ☐ Others ____] ☐ Mechanical（機械式）
12	Automatic Cutting-off (When Off-Load)	空転時の自動停止装置	☐ Yes（有） ☐ No（無）
13	Frequency of Lubrication	給油頻度	____ times/year（回/年） | 14 Frequency of filter cleaning 取入フィルター清掃 ____ times/Month

Motor driven machine 電動機応用設備

Name of machine

Date	Used power 使用電力				Used power /rated power x 100% 使用電力／定格電力	temp. of fluid °C 液体温度	Flow Q m^3/min 流量 Q' t/h		Fluid 流体		Valve Position バルブ開度 管径cm	Velocity of fluid m/s 流速	Estimated Load kW 推定負荷	Efficiency % 総合効率	Remarks (Sound Vibration Leakage Others) 備考
	Voltage V 電圧	Current A 電流	Power factor % 力率	Electric power kW 電力			Rated 機器の定格	Actual 測定値 max. min.	Pressure H' kg/cm^2 H m 圧力	Pipe Inner Diameter					

1) Required electric power of blower 送風機所要電力

$$P = \frac{A \cdot Q \cdot PT}{1{,}000 \cdot \eta \cdot 6.12} \ (kW)$$

PT: Total pressure (mmAq) 全圧, A: Allowance (1.1 ~ 1.3) 余裕率, η: efficiency of blower (0.72 - 0.78%) 送風機効率

2) Required electric power of pump

$$P = \frac{A \cdot \gamma \cdot Q \cdot H}{\eta \cdot 6.12} \ \text{or} \ P = \frac{Q' \cdot H'}{\gamma \cdot \eta \cdot 36.7} \ (kW)$$

A: allowance (1.05∿1.2) 余裕率, η: efficiency of pump ポンプ効率 (0.8∿0.85%)

3) Velocity of fluid 配管内流速

$$U = \frac{Q}{A} \ (m/sec)$$

Q: flow (m^3/sec) 流量

A: sectional area of pipe (m^2) 管内断面積

Adequate velocity

	velocity (m/sec)	pressure (Kg/cm^2)
City water 水道水	0.6 ∿ 1.5	1.8 ∿ 3.0
River water 一般水	1.5 ∿ 3.0	3.0 ∿ 10
Air 空気	8 ∿ 15	1 ∿ 2

2-6. Air Conditioner （空調設備）

1	Name of Factory	工場名	2 Date of Survey 調査日
3	Type of System	空調方式	☐ Central Air Conditioning（空気方式） ☐ Fan Coil Unit（水方式） ☐ Unit Air Conditioning（パッケージ方式）
4	Room Air Conditioned Room Size	室の状況 室の大きさ	Floor Space（床面積）＿＿＿ m^2, Room Volume（室容積）＿＿＿ m^3
	Number of person in the Room	室内人数	＿＿＿ 人
	Usage	用途	☐ Office（事務室） ☐ Works（工場） ☐ Others
	Room Temp.	室温	Actual Temp.（実測温度）＿＿＿ °C
	Air Flow	風量	Fresh Air Flow Induced（外気取入風量）＿＿＿ m^3/min, Circulating Air Flow（室内循環風量）＿＿＿ m^3/min.
5	Water Cooling Tower	クーリングタワー	Actual Temp.（実測温度）＿＿＿ °C, Wet Bulb Temp.（湿球温度）＿＿＿ °C, Flow（水量）＿＿＿ ℓ/min., Delivery Press.（吐出圧）＿＿＿ kg/cm^2G
6	Type of Refrigerating Machine	冷凍機の種類	☐ Compression Type（圧縮式） ☐ Absorption Type（吸収式）

Measurement Record（測定記録）

	Inlet Fan（外気取入ファン）	Circulating Fan（室内循環用ファン）	Cooling Tower Pump（ポンプ）	Cooling Tower Fan（ファン）	Refrigerating Machine（冷凍機） Compression Type（圧縮式）	Refrigerating Machine（冷凍機） Absorption Type（吸収式）
Rated（定格）	kW	kW	kW	kW	kW	Kcal/H
Actual（実測）	kW	kW	kW	kW	kW	Kcal/H

7	Insulation of roof and wall	屋根，壁の断熱	good	not good
8	Insulation of duct and pipe	ダクト，配管の断熱	good	not good
9	Tightness of window and door	窓，ドアの気密	good	not good
10	Separation heat generating equipment	発熱機器の分離	yes	no
11	Partial air conditioning in large room	大空間の中の空調を要する部分の隔離	yes	no
12	Heat recovery by total enthalpy heat exchanger	全熱交換器による熱回収	yes (Type)	no
13	Water spray on roof	屋根散水	done	not done
14	Starting and stopping time of air conditioner	装置の起動停止時刻	Starting time ________ Stopping time ________	
15	Stopping water pump when refrigerating machine stops	冷凍機停止時に冷却水ポンプの停止	stop (auto, manual)	not stop
16	Prevention over cooling and stopping when unnecessary	過冷防止，不要時の運転停止	yes	no
17	Setting most suitable temperature by climate	季節による設定温度の変更	yes	no
18	Control of induced fresh air	必要外気量の管理	yes	no
19	Checking temperatures of evaporation, condensation and pressure of refrigerating machine	冷凍機の蒸発温度，凝縮温度の管理，制御圧の管理	yes	no

20	Cleaning (Condenser)	清掃（冷凍用コンデンサー）	(done times/month) not done
21	Cleaning (Air Conditioner coil)	清掃（空調用コイル）	(done times/month) not done
22	Cleaning (Air Filter)	清掃（エアフィルター）	(done times/month) not done
23	Cleaning (Cooling Tower)	清掃（クーリングタワー）	(done times/year) not done

Equipment List

No.	equipment	type
1	Portable Doppler Flowmeter	PD3
2	Hotwire Anemometer	V-02-A700
3	Heat Insulation Tester	MH2
4	Oxygen Meter	OX61 (6232)
5	Pocket Thermometers	2542
6	Thermopetter	#400
7	Portable Radiation Thermometer	IR-HP2
8	Pocket Conductivity Meter	SC51
9	Pocket PH Meter	PH51
10	Working Efficiency Check Meter	ECM-IR
11	Lux-Meter	ANA-999
12	Clip-on AC Power Meter	2433
13	Clamp-on Power Hi Tester	3136
14	Integrator	3141
15	Digital Printer	3142
16	Micro Hi Corder	8202
17	Volt Slider	S-260
18	Multitester	3009
19	Digital Hygrometer	2577

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