1) Removal of shives, sand and other foreign substances

2) Improvement of formation

3) Uniform pressure to ensure high dewatering efficiency

4) Uniform evaporation and drying

5) Control of draw

The following points should be noted regarding technical problems involved in the equipment:

1) Selection of the equipment with insufficient functions (selection error)

2) Equipment not operating in conformity to the specifications

3) Neglected maintenance, inspection, repair, or performance checking of the equipment; therefore, required performances not fully used

4) Claim against electric failure not submitted to the section in charge inside or outside the company; technical improvement delayed

It is their duty to check if each function is working, to review the operation method and to improve it if something is wrong.

Table 8.2.5 Causes for Paper Breaking and Remedies

Places for paper breaking	Classifications	Causes	Measures	Equipment factor
1 Wet part				
(1) Couch	Fall from Couch	Excess moisture (Wet insufficient strength) Trimming water Cutting fault	Promotion of dewatering on wire	Dewater rectification on wire part Set up of pick up roll. High pressure of water jet
(2) Press	Breaking by press	Crushing.	Promotion of dewatering.	Line pressure up
		Roughened surface on plain roll.	Roll surface repair.	Grinding
		Mix of slime.	Removing the slime	Thoroughly cleaning
		Mix of adhesive substances	Separation, removal and dispersion	
	Uneven dewatering	Faulty formation	Correct	Flow rectify in Head-Box and wire part.
		Dirty blanket	Promotion of blanket wash.	Washing by showering, squeeze and dewater.
		Uneven line pressure	Roll crown correct	Grinding.
(3) Wet end	Fall in wet end	Faulty drawing	Drawing adjustment	
		Excessive moisture	Line pressure increase (Promotion of dewatering)	Set up of high pressure
		Mixing of shives.	Promotion of screening	
2 Dryer part				
(1) Yankee Dryer	Breaking due to faulty separation	Paper powder attached.	Effective use of the doctor	Dryer cleaner Bronze doctor use
		Damage on dryer surface	Polishing the surface	Dryer grinding.
	Breaking due to intrusion of foreign substances.	Mixing of shives and impurities	Promotion of screening	Strengthening of dedust equipment of centricleaner etc.
	Breaking by tension.	Faulty drawing	Drawing adjustment	Flow rectify in Head-Box & Wire
		Faulty formation	Correcting the part formation	

Multi-dryer	Breaking by tension.	Faulty drawing between groups.	Drawing adjustment	
	Edge breaking	Edge too dry	Improvement of dryer pocket	Pocket Ventilation
		Mixing of shives and impurities.	Promotion of screening.	Centricleaner Fine screen
		Trimming Water Cutting fault.	Water pressure increase.	
3 Calendar Part	Crushing	Faulty formation	Correcting the formation	Flow rectify in Head Box & Wire part.
		Incorrect roll crowing	Correct the roll crown	Grinding.
	Breaking by foreign materials	Mixing of shives and impurity	Promotion of screening	Centricleaner, Fine screen.
	Breaking by tension	-Faulty drawing	-Drawing adjustment.	
		-Faulty formation	-Correcting the formation	-Flow rectify in Head BOX and wire part
	Breaking in machine direction	Faulty formation and wrinkling	Improvement of dryer ventilation.	
		Uneven drying and wrinkling	Correcting the formation. Removing the dryer pressure	

b. Machine Failure

Machine failure in factory during its operation may be caused mainly by the insufficient maintenance. The problems found in general are: the steam leakage, bearing failure, motor burning, etc. To solve these problems, there must be schedule for planning the preventive maintenance to manage surely that all equipment will be operated steadily without failure or damage.

The causes as discussed here are just some of main causes that affect machine continuous operation. To stop operating the machine with any reasons at each time will lose the time to restart it or may waste so much time to repair or maintain. This will affect also the other systems such as: the boiler operation that causes some losses and continue affecting directly the factory profit. Thus, during the continuous operation of machine, the controllers for every part of the machine and its related, must pay more attention and be aware particularly, so that stopping of machine operation might not occur by any causes. In case of having accident to stop machine, they should manage or recover it immediately for being as usual, and let it restart operating as fast as possible. The person in charge of controlling the machine, or the unit takes responsibility to control the machine, must inspect and check the machine efficiency. Also they should manage the control system to point out or indicate the management by operation efficiency index. For the concept of making or investigation on daily management of Paper Machine.

$$\text{Paper Machine Operation Efficiency} = \frac{\text{Actual operation time (min)}}{\text{Operation time (min)}} \times 100\,(\%)$$

$$= 1 - \frac{D}{A-B-C} = \frac{A-B-C-D}{A-B-C} \times 100\,(\%)$$

A : Paper Machine Operation Plan by Production Plan (min/day)—Company budget

B : Down time of power failure by responsibility of electric power company (min)

C : Down time of machinery trouble or electric accident by responsibility of facility department (min)

D : Down time of operation trouble by responsibility of paper making department D can be further subdivided into Dx, Dy and Dz.

x = Paper break down time

y = felt washing down time by dirty

z = wire repair down time.

$$\text{preventive maintenance (PM) efficiency} = \frac{\text{operation time (min)}}{\text{actual production planning time (min)}}$$

$$= 1 - \frac{D}{A-B-C} = \frac{A-B-C-D}{A-B-C}$$

Paper Machine Efficiency (η)

Efficiency of Paper Machine consist of Operation Efficiency (η_1), Paper Make Efficiency (η_2) and Finishing Yield (η_3). And Sometime include Trim Efficiency (η_4)

So Total Efficiency (η) is as follows

$$= \eta_1 + \eta_2 + \eta_3 + (\eta_4)$$

The Operation Efficiency is the most effective for paper machine energy conservation.

1) The Operation Efficiency can be illustrated as follows.

Terms of Result Calculation			
Operation time (+ 24 = Operation days)		Machine stop time by unexpected Accident	Machine stop time Annual budget schedule
Actual Operation time	Machine stop time field Side Accident		
Operation Efficiency (η_2) $= \dfrac{\text{Operation time}}{\text{Actual Operation time}}$	• Paper breaking • Paper Grade exchange • Felt washing field. • Wire repair • Tools exchange • etc.	The stop time is excepted from paper machine There are electric accident, mechanical accident, stock preparation accident, and etc.	• Shut down • Machine rest day.

2) The Paper Making Efficiency can be illustrated as follows.

(1) Theoretical Finishing Basis Weight = Average Weight (g/m^2) × Average Trim (m) × Average speed (m/min) × operation time (min)

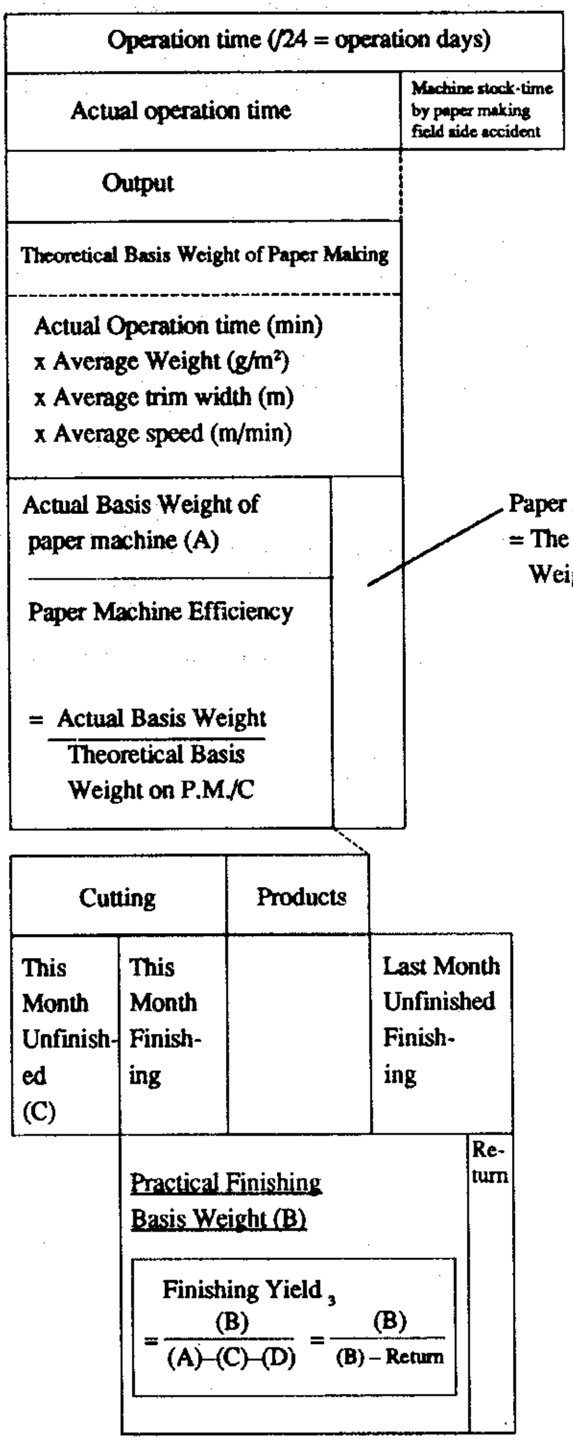
(2) Theoretical Daily Output (T/D) = Average Weight (g/m^2) × Average Trim (m) x Average speed (m/min) × 1440

(3) Basis Daily Output

$$= \frac{\text{Practical Finishing Basic Weight}}{\text{Operation Days}}$$

(4) Trim Efficiency $_4$

$$= \frac{\text{Average Trim}}{\text{Standard Trim}}$$



Paper machine loss
= The difference of Theoretical Basis Weight and Actual Basis Weight
= (Actual Basis Weight - Theoretical Basis Weight)
+ Air dry moisture

Efficiency
$= \eta_1 \times \eta_2 \times \eta_3 \ (\times \eta_4)$

$$\text{Weight (D)} = \frac{\text{Practical Finishing Basis Weight}}{\text{Theoretical Finishing Basis Weight}}$$

$$= \frac{\text{Standard Daily Output}}{\text{Theoretical Daily Output}}$$

Become shift according to the difference between the unfinished of the month and last month

(2) Use of High Efficiency Equipment

The existing condition of equipment and machine in operation will indicate energy efficiency and the production quality. Hence, the control system for machine operation at desired efficiency should be considered to improve for its better condition and higher efficiency. Such of these improvements are :

- Install the Distributed Control System (DCS)

- Install the scanner for measuring accurately on the moisture of paper, etc.

These equipment will help improving the operating condition of machine/equipment correspondingly and accurately. This will affect the efficient use of energy and increase of the production quality.

However, these equipment need high investment. So a steam flow meter of paper machine and an oxygen meter boiler exhaust gas that are basic important equipment should be installed firstly. The operating condition of Paper Machine is judged from analysis of these equipment.

Installation of a steam flow meter will provide data on steam consumption, thereby allowing comparison of steam consumption rates per 1 ton of production.

8.2.3.2 Pulping of waste paper and energy

(1) Pulping process of waste paper

The quality of recyced pulp is always subject to fluctuation and it has large size deviation (or dispersion).

Water paper is classified with general similarity in quality as in Table 8, 2, 6, after collected. But classified waste paper includes many kinds of base papers and various converted papers. Then recovered pulps are remarkably different in its characteristics from original ones and quality dispersion size is larger than virgin pulp.

So, waste recycled pulps cant't be used for the paper that demands quality stability.

Figure 8.2.11 is generally flow Sheet of Waste Paper Pulping.

By paper quality, a pulp quality is decided and waste paper quality and pulping method are decided.

(2) Waste paper and energy conservation

How much energy can be saved in pulping of waste pulp. In case of White woody paper, the calorie is compared with Virgin Pulp and waste paper pulp is referenced from Waste Paper Hand book, 1989.

	Combination rate	Calorie
a) In case of Virgin Pulp	BKP : 50% GP : 50%	2,730 kcal/pulp kg
b) In case of DIP (Drinking Pulp)	DIP : 100%	1,080 kcal/pulp kg

Energy consumption of DIP pulping is about 1/3 that of Virgin pulp pulping.

Still more, based on materials of JAPAN Paper Company Union, estimated net energy consumption is as follows:

Bleaching Chemical Pulp (BCP) : 2,450 kcal/pulp kg
Mechanical Pulp (GP) : 1,850 kcal/pulp kg
DIP (Drinking Pulp) : 675 kcal/pulp kg
According to calculation about same white woody paper
c) In case of Virgin Pulp : 2,150 kcal/pulp kg
d) In case of DIP : 675 kcal/pulp kg

(3) Energy conservation measure of waste paper pulp

A creation of quality condition should always take precedence over energy saving measure. Energy saving measure should not be brought to interfere with quality.

The factors of energy saving in paper making pulp include the following items:

- Impurities in Pulp
- Freeness of Pulp

Waste paper includes various impurities, and so we have to remove these impurities as much as possible.
Pulp freeness is an important factor that decides quality.
Freeness is controlled with refiners works of electric power, and considerable power is used for it.

a. Removal of Impurities

1) Adhesive materials

The main impurities belonging to synthetic sticky resin that concerns energy saving are as follows:
– Small piece of polyethylene laminate paper
– A.P.P (Atactic Polypropylene polymer) that is used for back adhesive agent of book
Adhesive agents of adhesive tape
Ink vehicle of synthetic rubber system and shives like knots and small pieces of union.

These adhesive materials bring about not only a decrease in output production efficiency down, but also faculty down of user. Adhesive materials that are mixed in sheet adhere to each other paper inner roll. Then rewinding paper causes paper break by its adhering in user side work.

2) Shives pitch obstacle

Shives, knots and unseparated pieces are in the way to vaporization of drying.
Projected shives and knots are not easily pressed in press roll. So, a moisture around the shives and knots are not removed and moisture content is high.
The vaporization of this part is inferior to other part and then when this part is vaporized the other part is over dried.

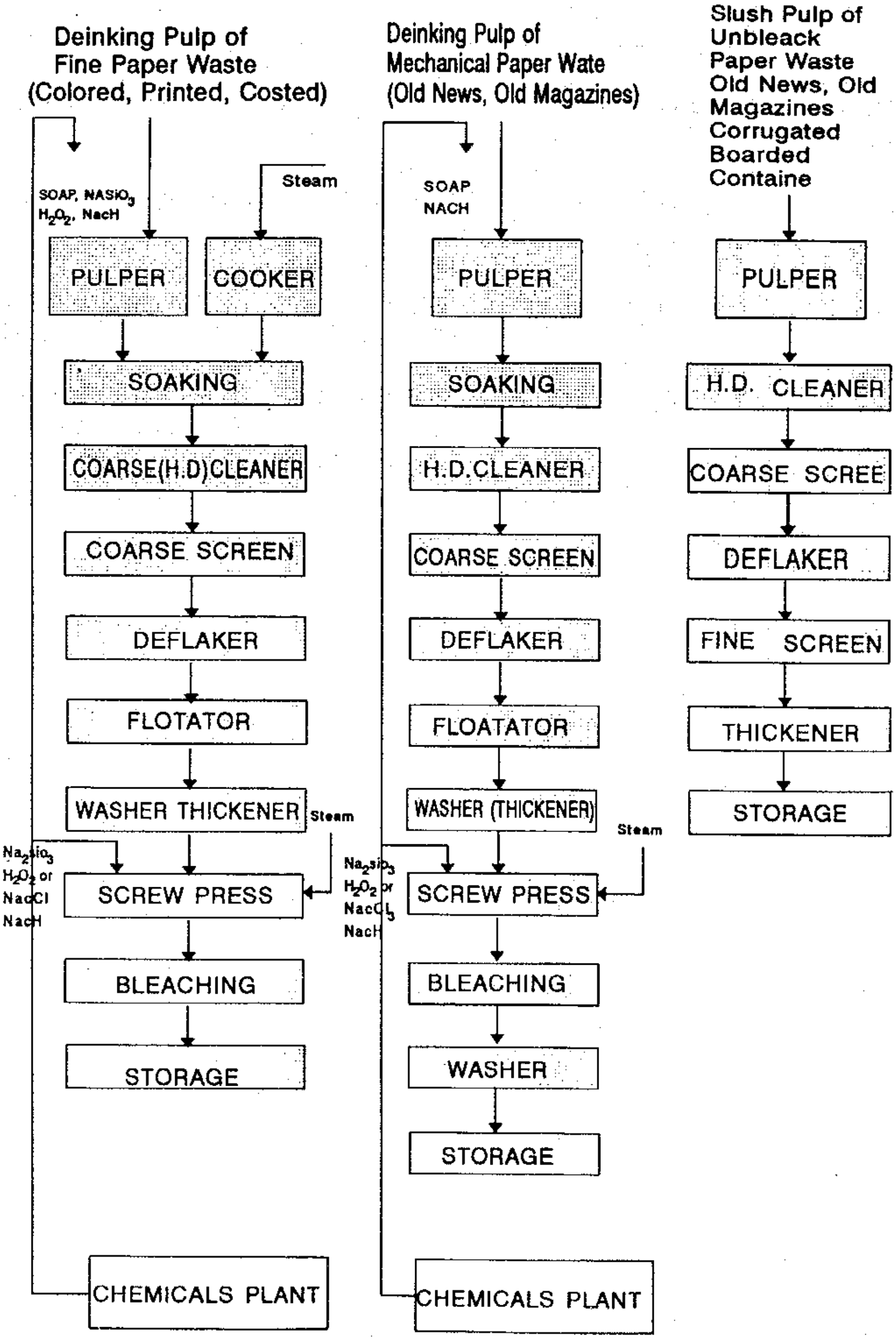
Table 8.2.6 The List of Japanese Standard Qualities of Waste Paper by Paper Recycling Promotion Center of Japan

STATISTICAL GROUP	GRADE NO.		CONTENTS
A. FINE PAPER WHITE SHAVINGS WHITE CARDS	1.	White shavings	Shavings and Sheets of White Unprinted Woodfree paper come from bookbinders, printers and sheeting Coverteries.
	2.	Cream shavings	Shavings and sheets of cream colored unprinted woodfree paper, come from book binderies, printers and sheeting coverteries.
	3.	Ruled lines shavings	Shavings and sheets of white or cream colored woodfree paper, having red or blue ruling or register mark, come from bookbinders, printers and sheeting coverteries.
	4.	Cards	Used tabulating cards made domestically or imported.
B. WHITE WOODY SHAVINGS WHITE MANILA	5.	High grade white Wood containing shavings	Shavings and sheets of white unprinted high grade wood containing paper come from book binderies printers and sheeting converteries.
	6.	White wood containing shavings	Shavings and sheets of white unprinted wood containing paper, come from bookbinders, printers and sheeting converteries.
	7.	White manila	Cuttings and sheets of uncolored and in colored manila board come from carton markers
C. FINE PAPER PRINTED	8.	Printed woodfree	White Woodfree paper, black printed, Computer Printout.
	9.	Color printed Woodfree	White woodfree paper, printed with various colors, including coated papers.
	10.	Woodfree shavings	Shavings of white uncoated and coated woodfree including some color paper, including some color printed, come printed from bookbinders and printers.
	11.	White Coated shavings	Shavings and sheets of unprinted coated paper, woodfree come from bookbinderies and printers.

STATISTICAL GROUP	NO.	GRADE	CONTENTS
D. QUIRES, WOODY PAPER PRINTED	12.	High grade color printed wood Containing shavings	Shavings of high grade wood containing white paper, printed with various colors, come from book binderies and printers.
	13.	Color printed wood containing shavings	Shavings of white wood containing paper, printed with various colors, come from binderies and printers.
	14.	High grade wood Containing waste	Sheets of high grade wood containing paper, come from bookbinderies and printers.
	15.	Colored Manila	Cutting of Manila board, printed with various colors, come from carton makers.
E. OLD NEWS	16.	News	Old news.
F. OLD MAGAZINES	17.	Magazines	Old magazines
G. KRAFT BROWNS	18.	New brown kraft Cuttings	Cutting of unprinted brown kraft paper, come from kraft paper sack factories.
	19.	Unprinted brown kraft	Waste sheets of unprinted brown kraft paper, come from kraft paper sack factories
	20.	Used brown kraft sacks	Brown kraft sacks, used for cements, chemicals, fertilizers, foods and others.
	21.	Kraft lined Corrugated Waste	New kraft corrugated Cuttings, old kraft Corrugated containers, mainly imported.
H. OLD CORRUGATED CONTAINERS	22.	Corrugated Container waste	Old Corrugated Containers.

STATISTICAL GROUP	NO.	GRADE	CONTENTS
I. BOX BOARD CUTTINGS	23.	Mill wrapper	Wrapping paper, used for news print rolls and other rolls.
	24.	White paperboard cuttings	Cuttings of white paperboard, come from carton box makers.
	25.	Chipboard Cuttings	Cuttings of chipboard and colored chipboard, come from carton box makers.
	26.	Carton Box Waste	Cuttings of straw board come from carton box makers, and used carton boxes of white paperboard, chipboard, colored chipboard.

Figure 8.2.11 Waste Paper Pulping Flow Sheet



b. Control of Freeness

The freeness of pulp is one factor for determining the paper quality. The freeness value is the property that specifies the saturation of pulp whether it is well saturated or not and how much it can saturate. If freeness is high value, it implies low saturation. The freeness value depends on refining the pulp. On pulp making process, electricity is used to beat the fibre of pulp and make fibrillations. The greater fine pulp in refine process, the less value of freeness will be. Sometimes to refine pulp more than it needed will cause waste of electricity use. Thus, we should give the importance to refining the pulp at property to have an effect on reducing electricity consumption in period of refining and also on paper quality. Sheet formation and paper strength are also controlled by freeness value. A control of pulp freeness is done by Refiner. The refining electric power of refiner is much spent. It is about 20% of total electric power in pulp paper integrated mill.

Generally energy consumption of freeness control is considered as follows:

In case of Double Disk Refiner (DDR)
BNKP : 100 kwh/pulp ton/ 100 cc
BLKP : 50 kwh/pulp ton/ 100 cc

These are the difference of mill location, maker and kind of refiner. And then each mill should keep unit electric power consumption of freeness low and manage daily pulp quality.
In case of Z CO., LTD, the freeness and paper quality are shown in Table 8.2.7, the individuality of thing is very low in pulp freeness in of machine chest.

Generally, the freeness of news paper making is 380-400 cc (csf) and writing and printing paper is 450-800 cc (csf).

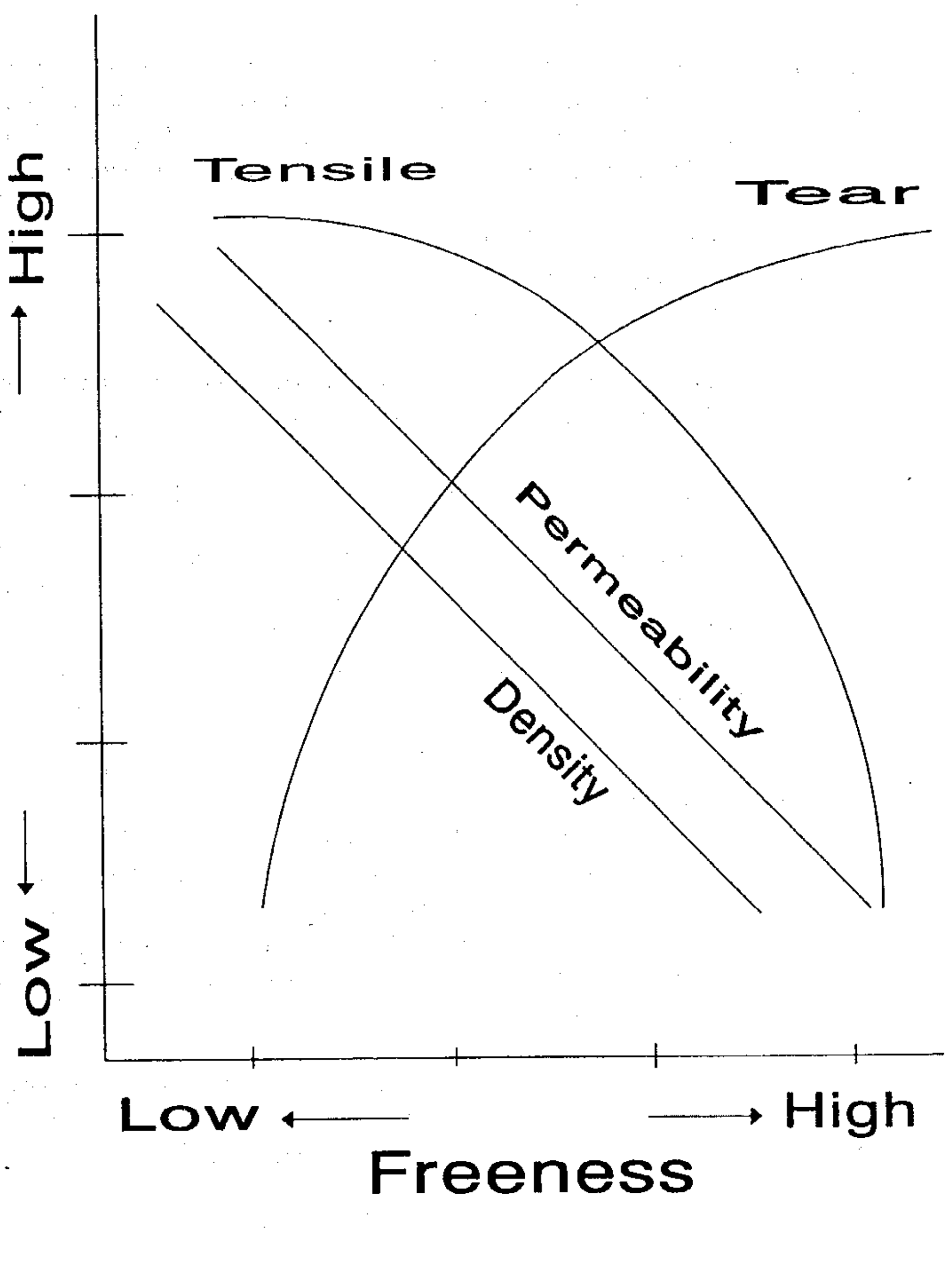
In case of Test paper, the density is very low regardless of low freeness. The reason seems to be that pressure cannot be increased by crushing of wet web.

A common sense of correlation in freeness and paper strength are as in Figure 8.2.12. But we found out many contradictions from comparison with test paper and writing & printing paper of Table 8.2.7

Table 8.2.7 Freeness and Paper Quality

Paper Grade Pulp Condition		Test Paper	Writing & Printing
Waste Paper		(News paper)	(Writing & printing shaving)
Defiberated Freeness		495 cc	565 cc
Machine Chest Pulp			
Refined Freeness		200 cc	350370 cc
Finished Paper			
Defiberated Freeness		345 cc	470 cc
<u>Paper quality</u>			
Basis (g/m²)		60	70
Thickness (mm)		0.17	0.11
Density		0.35	0.64
Tensile Strength	C.D	–	3.4
(kg)	M.D	–	5.0
Tearing Strength	C.D	12	16
(g)	M.D	8	8
Permeability (soc)		15	3

Figure 8.2.12 Freeness and Paper Characteristics
(Canadian Standard Freeness)



The comments for Table 8.2.7 and Figure 8.2.12 are as follow.

1. The relation between Density and Permeability is not preserved on this table. Of course, the quality is different between both grades or kind of pulps.

2. This test paper is made extremely bulky in spite of school's test writing use. Generally, school test writing paper is made steady for easy writing and rubbing endurance to surface scuffing by eraser. So, its freeness tends to be made low but this test writing paper is made too low. In case pulp freeness is made too low, the following will occur.

   1) Electric power energy is much consumed.
   2) Paper density is done too high.
   3) Paper permeability is done too high.

   But according to Table 8.2.7 density is very low and permeability is high compared with Writing & printing paper.

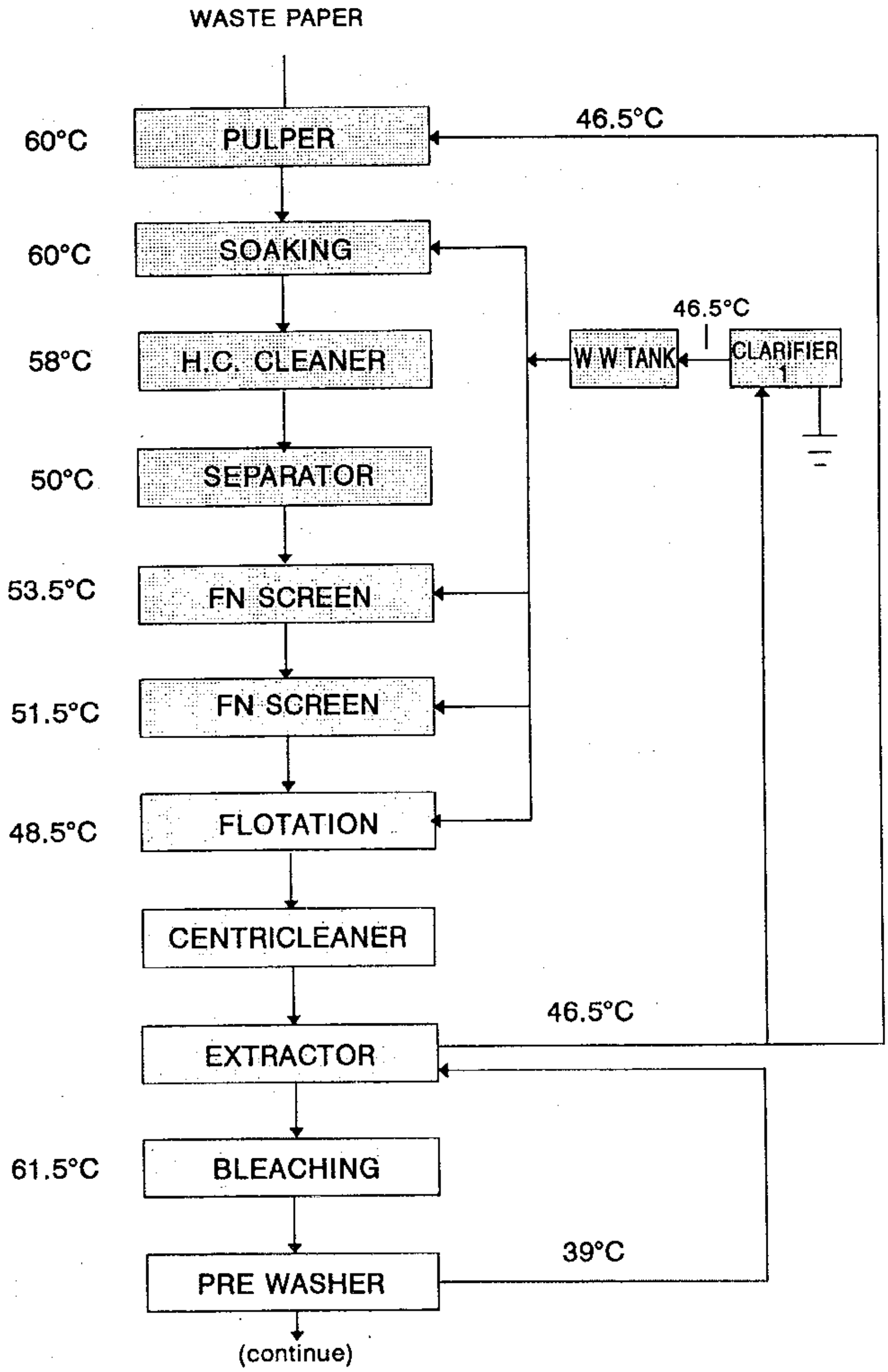
   Test Writing Paper and P & W Paper, are different in kind of pulp, the first stage freeness, finished freeness, etc.
   We can't summarily say, it seems. The pulp freeness is set too low.
   Company should look again at the relation of freeness and paper strength. Refining energy consumption for freeness control is very large, generally.

8.2.3.3 Circulation of white water

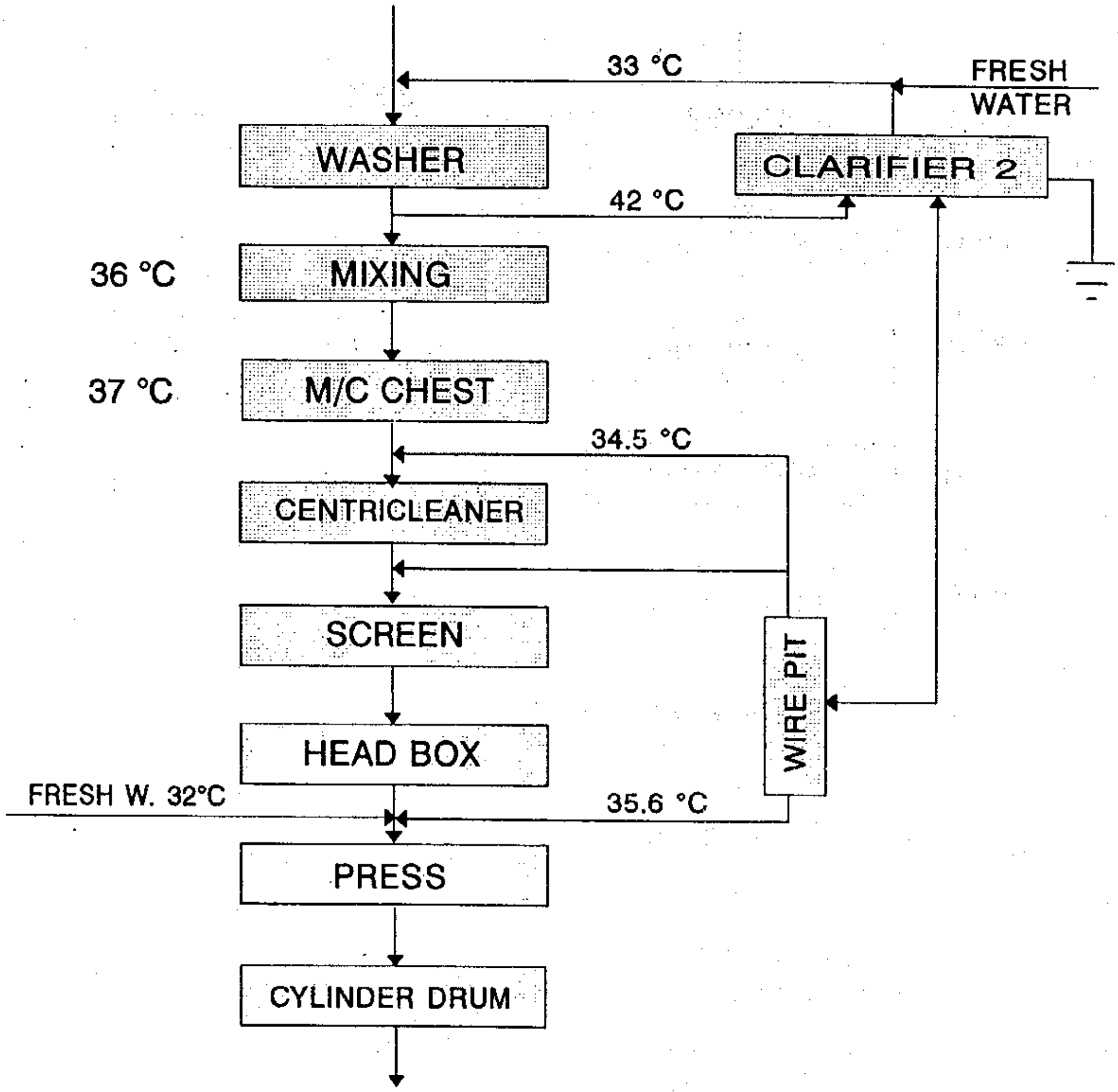
The amount of water used in the paper plant has a serious impact on energy consumption and environmental pollution.
To reduce the amount of new water and to increase the amount of circulating white water is to reduce the amount of waste water. This will give the effects that the waste water treatment equipment load is reduced. Furthermore increase of circulation rate of white water allows raising of the pulp temperature, which will upgrade the efficiency of dehydration sheet formation and dewatering in the press part. So it saves the steam consumption in the dryer and reduces energy loss by raising the system temperature.

Figure 8.2.13 shows the measurement of process temperature from the pulper to the press part of No. 6 m/c. The pulp temperature in bleaching process is about 62°C, but is about 42°C at the washer. This is because much new fresh water at temperature 33°C is used.

Figure 8.2.13 PM #6 Process Temperature



(continue)


33 °C
FRESH
WATER
WASHER
CLARIFIER 2
42 °C
36 °C
MIXING
37 °C
M/C CHEST
34.5 °C
CENTRICLEANER
SCREEN
WIRE PIT
HEAD BOX
FRESH W. 32°C
35.6 °C
PRESS
CYLINDER DRUM

8.2.3.4 Paper making process

(1) Promotion of Line-pressure increase in press part

1. If the moisture of wet sheet that passed press part can be decreased by 1%, the steam quality used in dryer can decrease by 4 - 5%.
   Now, finished paper moisture is 7% and wet sheet moisture is 61% at dryer entrance. If wet sheet moisture can be 1% decreased to 60%, the evaporation water quantity (WE) per 1 kg will be as follows:
   in case of wet sheet moisture 61% WE 61 = $\frac{61-7}{39} = \frac{54}{39}$ = 1.384 kg
   in case of wet sheet moisture 60% WE 60 = $\frac{60-7}{40} = \frac{53}{40}$ = 1.325 kg
   By decreasing the dewater rate, steam consumption decreases about 1.384 - 1.325 × 100 = 4.3%

2. Flat line-pressure

   Press rolls have to be finished at appropriate crown. The roll is bent with pressure of both ends and then the nip is large on both ends.
   Reasonable roll crown has uniformity nip width that is rectangular to range of all width.

(2) Dryer cylinder temperature

Because of limit of time for surveying, the team inspected only No 6 M/C. No. 6 Machine Dryer cylinders are divided into 5 groups. Steam pressure on each group is shown in Figure 8.2.14. Figure 8.2.16 - 8.2.18 show the picture of these dryers.

The results of dryer cylinder temperature measuring by radiation thermometer of No 6 M/C. are shown in Table 8.2.8 and Figure 8.2.19 - 8.2-22. The measuring point was divided into 5 points which are operating side (F), driving side (B), and center side (f, M, R). Steam inlet surface pipe and condensate surface pipe were also inspected by this radiation thermometer, the emissivity value of which was adjusted by using contact thermometer. Figure 8.2-15 shows details of these measuring points.

Table 8.2.8 Results of Surface Temperature of Dryer Drum · Inlet Steam and Outlet Surface Temp. of Condensate

Top Drum.

Drum No.	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38
F	58	65	100	87	101	105	103	103	99	103	101	89	103	103	95	101	111	82	109
f	56	64	87	70	98	87	91	93	90	91	97	90	100	102	80	95	93	78	90
M	54	60	85	62	83	95	86	80	88	93	90	91	93	85	66	65	96	79	101
R	50	–	–	–	100	87	95	–	–	–	–	–	–	–	–	–	–	–	–
B	50	57	83	60	100	100	90	93	95	90	93	92	93	98	83	97	95	79	90
inlet	102	103	104	105	104	98	110	108	111	109	112	117	111	111	115	113	126	116	123
outlet	100	92	100	98	102	97	107	97	101	104	108	103	105	108	108	105	111	111	98

Bottom Drum

Drum No.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37
F	51	55	40	51	87	94	106	104	107	105	105	104	107	106	99	97	113	113	115
f	48	51	47	61	95	85	97	95	101	95	98	95	99	110	98	83	100	97	90
M	47	49	51	55	96	105	90	97	97	83	93	92	97	97	67	79	90	94	92
R	44	47	45	50	92	87	86	96	95	80	–	–	–	–	–	–	–	–	–
B	49	51	48	49	90	100	95	93	102	85	100	85	86	85	103	83	95	100	97
st. in	100	104	52	91	95	105	110	96	117	113	112	110	112	113	113	115	125	123	120
Dr. out	93	102	48	83	91	99	107	93	108	103	109	106	110	108	106	109	120	114	116

Remark. Drum No. 24 Steam leak
No. 5 Valve close.

Figure 8.2.14 No. 6 M/C Dryer Cylinder Side View

Top	2	4 6 10	12 28	30 32	34 36 38
Bottom	1 3	5 9	11 27	29 31	29 35 37
Steam Pressure	0.5 Kg/cm^2	0.66 kg/cm^2		1.55 kg/cm^2	
Group of Drum	1 st Group No. 1-3	2 rd Group No. 4-10	3 rd Group No. 11-28	4 th Group No. 29-32	5 th Group No. 33-38

Figure 8.2.15 Measuring Points of Dryer Drum

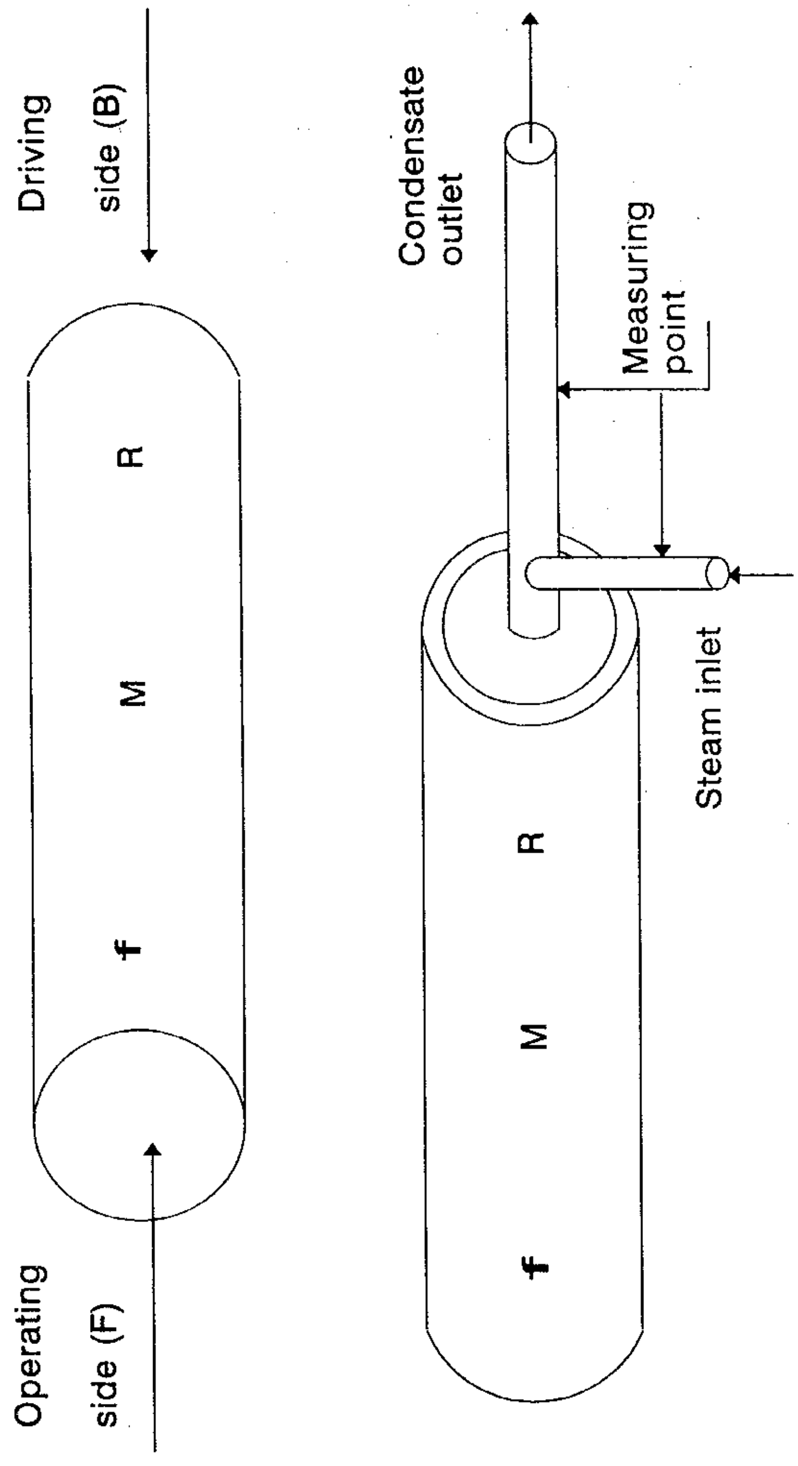


Figure 8.2.16 No. 6 Paper Machine Side View

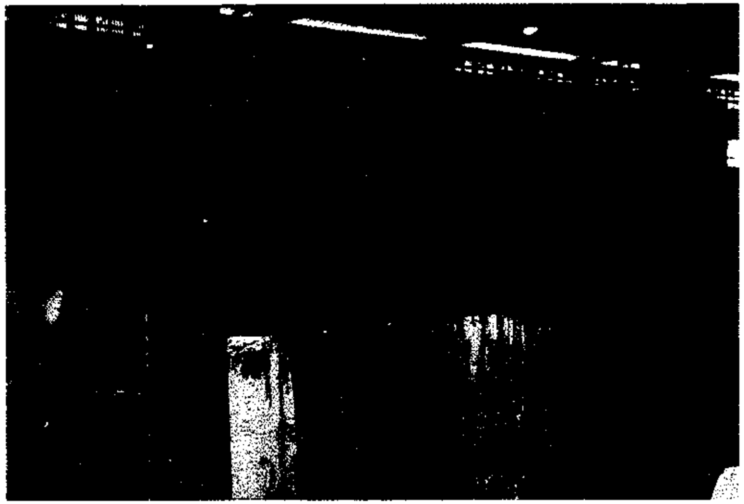
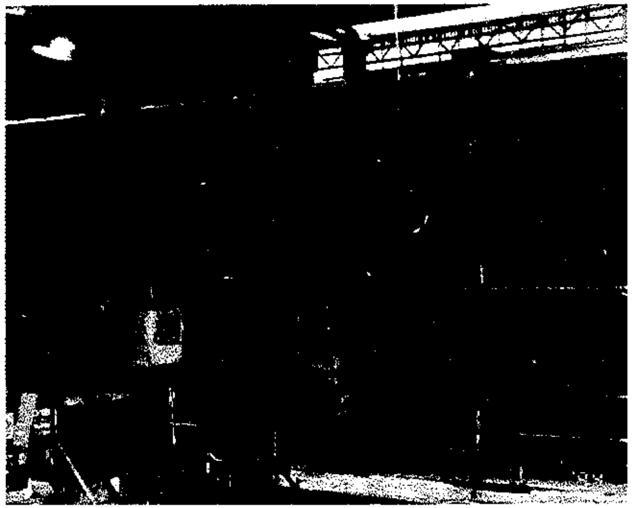


Figure 8.2.17 No. 6 Paper Machine Side View



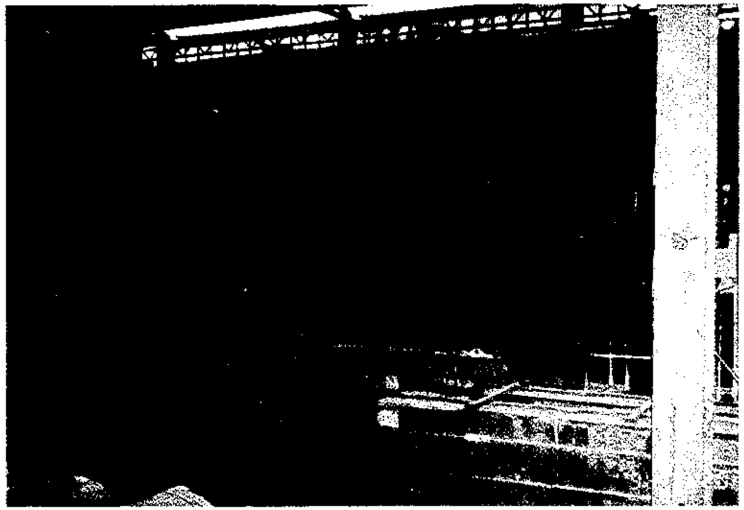


Figure 8.2.18 No. 6 Paper Machine Side View

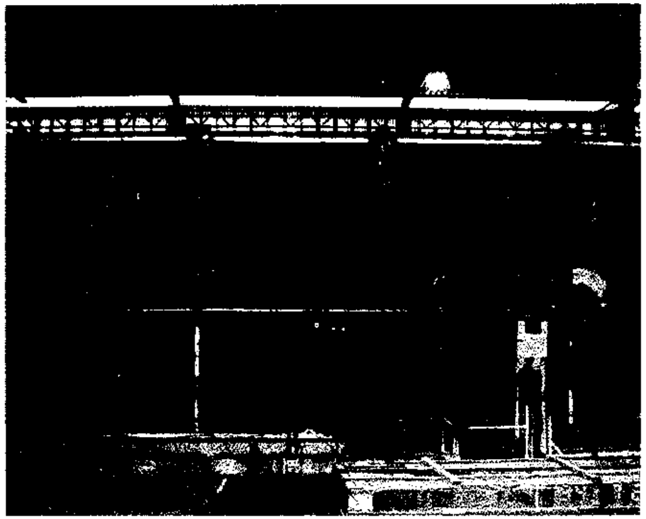


Figure 8.2.19 Disk Temp. of Dryer

(OPERAT & DRIVE SIDE)

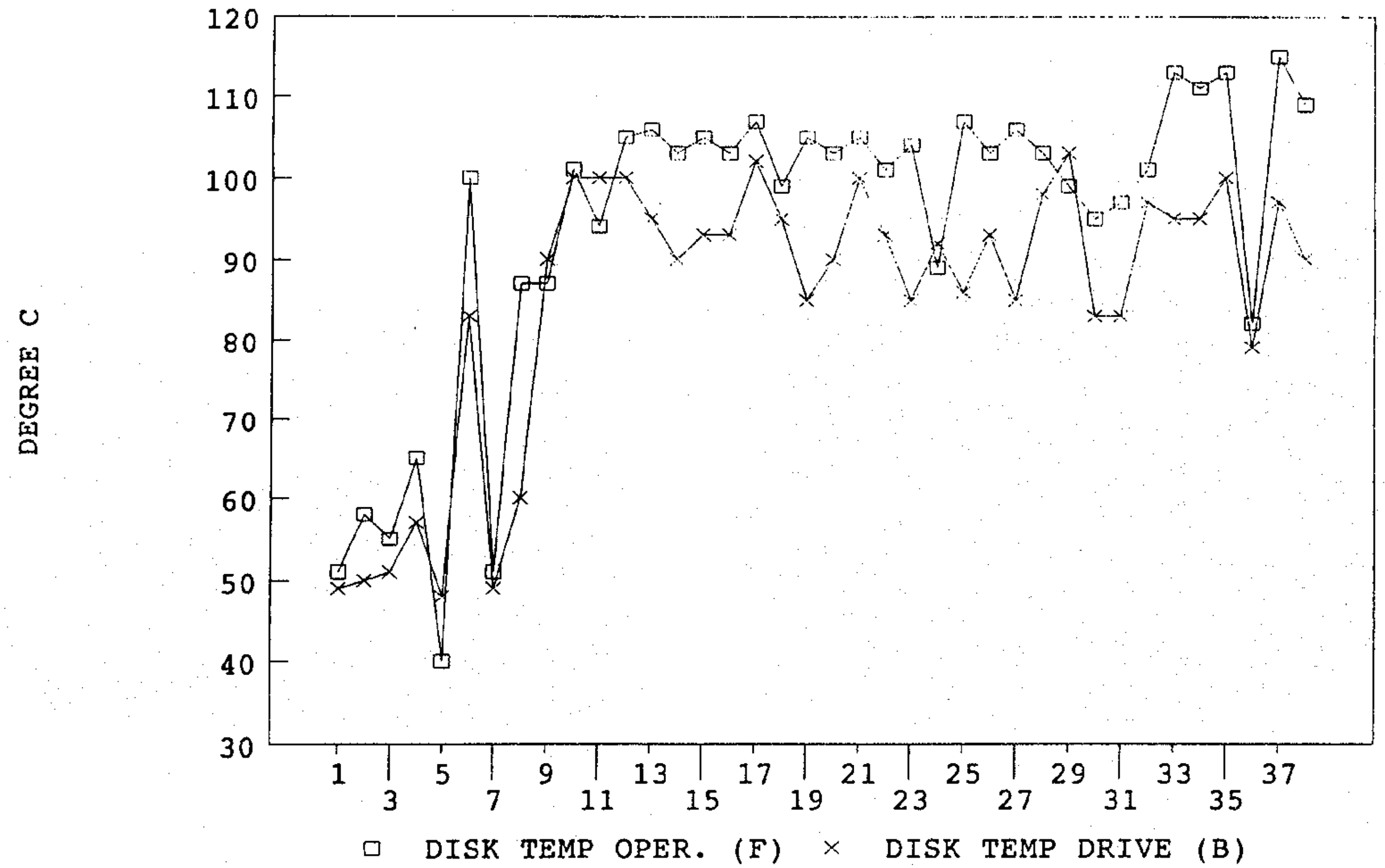


Figure 8.2.20 Dryer Surface Temperature

(SURFACE OF DRYER AT MIDLE PART)

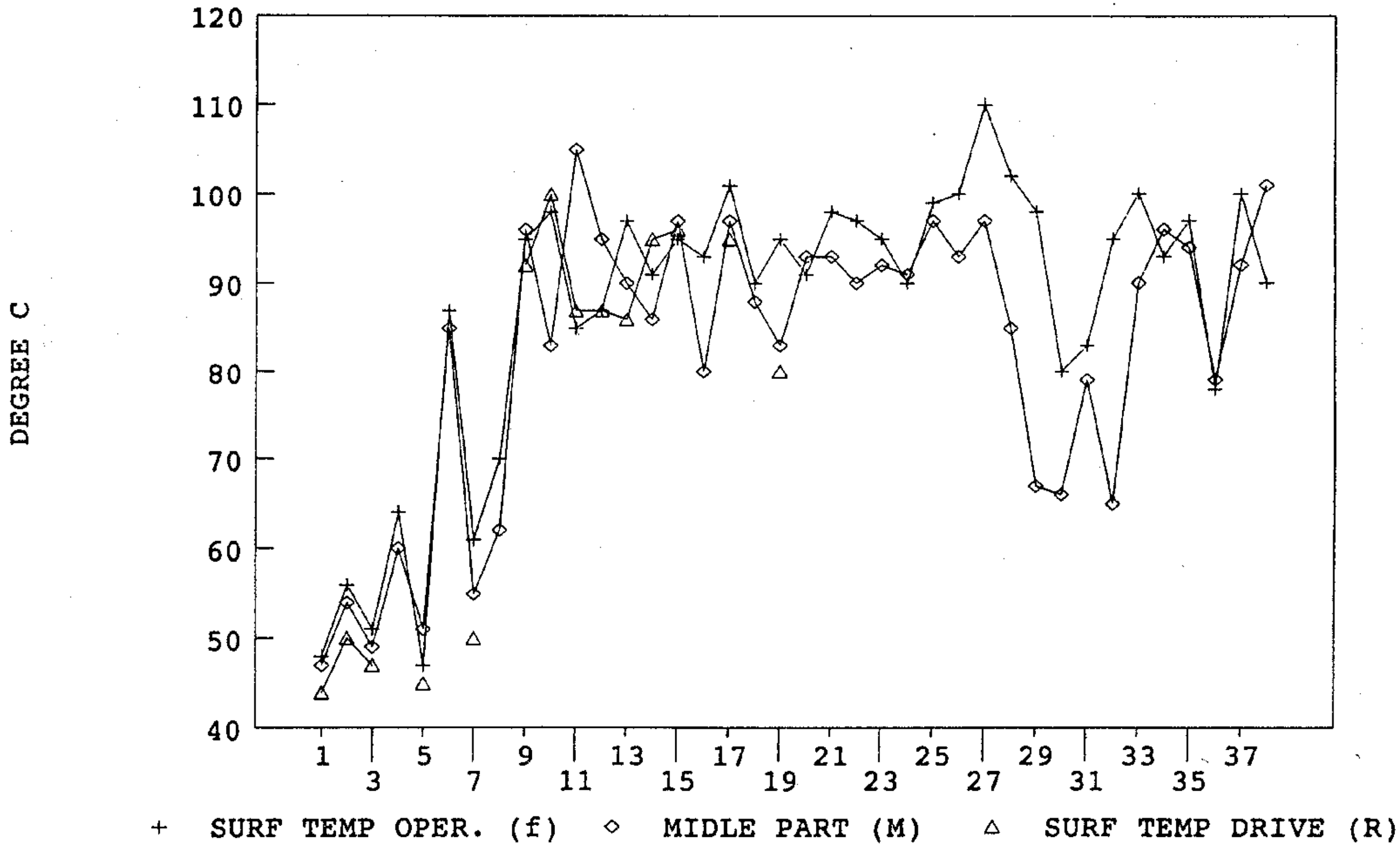


Figure 8.2.21 Steam Inlet & Outlet

(OPERAT & DRIVE SIDE)

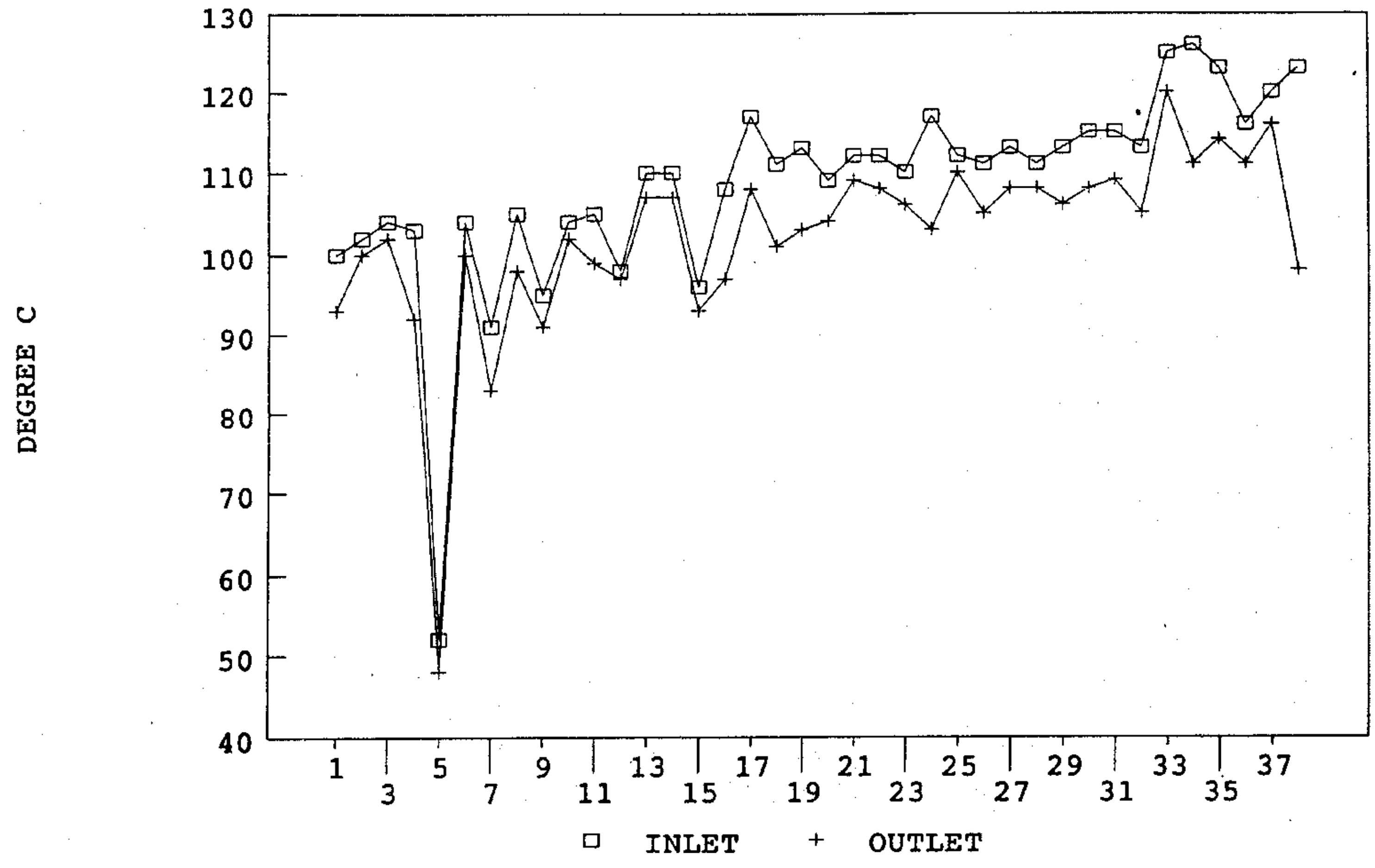


Figure 8.2.22 Average Dryer Surf. Temp.

(SURFACE OF DRYER AT MIDLE PART)

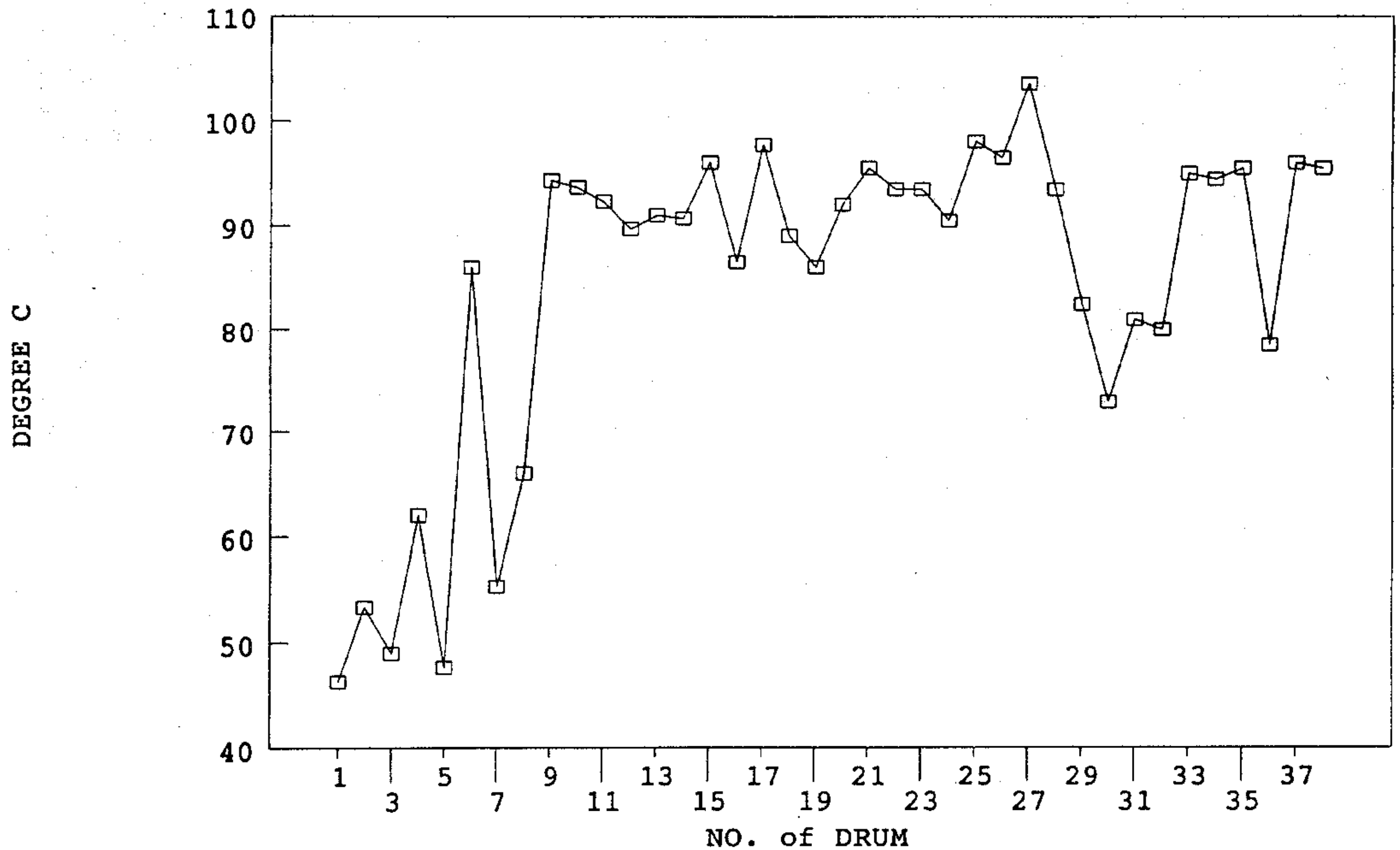
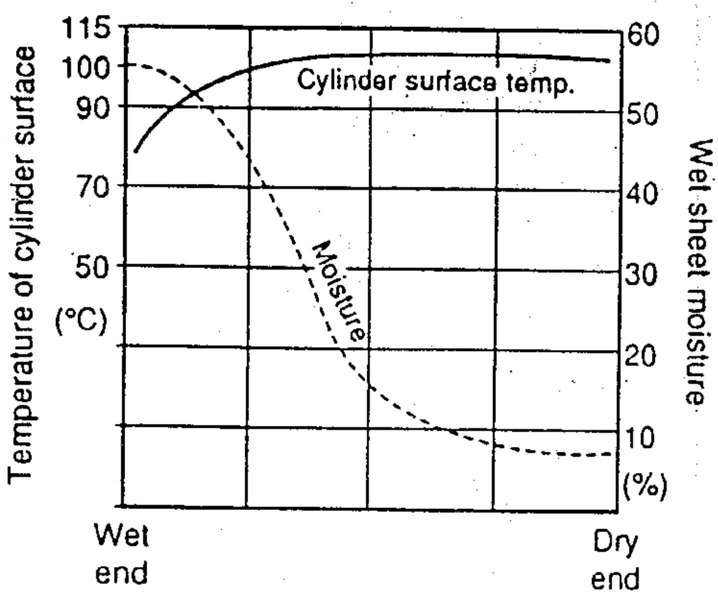


Figure 8.2.23 Wet Sheet Moisture & Cylinder Surface Temp.



As seen from the data of measurement shown in Table 8.2.8, some dryer cylinders have abnormal loss of temperatures at their surfaces as the following:

- Cylinder No. 5, its surface temperature in loss due to closing the steam valve.
- Cylinder No. 7, since supplying the steam to cylinder is bad.
- Cylinder No. 24, because of a steam leakage.

The results of such measuring data as these can allow calculating the average surface temperature of dryer cylinders and making the chart shown as in Figure 8.2.22. It is obviously indicated that heat transfer from dryer cylinders to paper will be not evenly smooth and constant. For example, the temperatures of dryer cylinder No. 5 - No. 9 will go down before rising, and go down again at cylinder dryer No. 24 and also at the cylinder No. 29 up to No. 33 before rising at last range of dryer cylinder until the dryend. The characteristics of these surface temperatures indicated that states of heat transfer of dryer cylinder are still inappropriate. The characteristic of proper heating transfer from cylinders to paper should be the same as shown in Figure 8.2.23. The temperature should be constant from the start up to the dry end without any reduction, and then rise. When the temperature goes up and reaches a maximum, it keeps constantly at one range before slightly going down in the last range of Dryend. Upon this, the moisture at the starting point keeps on reducing up to the last point of Dryend, the moisture will slightly increase. The proper moisture of paper should be in range of 6%, but the moisture of paper produced by the paper machine No. 6 has only 1.5%-1.6% at Dryend.

The excessively low moisture of paper has an effect on the quality and strength of paper. If the paper is too dry, paper breaking will occur easily. Moreover, the moisture content that is reduced will also affect the product weight, incur reduced sale-value, and directly affect to the factory profits. As the recommendations to improve deficiencies found, including to maintain the characteristics of heating as indicated in Figure 8.2.23, improvements should be done as follows:

Heating by dryer cylinders No. 5 - No. 9 must be improved without a decrease in heating and by keeping temperature rising continuously.

Heating by cylinders No. 29 - No. 32 must be improved and corrected to maintain the level of temperature at constant. Supplying the steam to cause interruption of temperature should not be let to occur.
Heating by cylinder No. 33 up to No. 38, steam feeding to these dryers must be reduced slightly so that temperature at the least range can be reduced as well. In case no size press is used, heating at this range may be unnecessary.

To operate on such improvements as those needs checking and measuring, or installing the meters for measuring the steam volume usage and the moisture content of the paper.

(3) Dryer capacity

Dryer capacity is studied in form of moisture evaporation per m^2 of drying area (g/m^2-hr). The result from calculation is compared with standard value which is 160 g moisture per sqm^2 per hr.

a. Data for calculation

Dimension of Heating Cylinder	=	$\phi = 1.5$ m L = 4 m	
Number of Cylinders	=	38	Cylinder
Speed	=	200	m/min
Moisture in wet end	=	60.92	%
Moisture in dry end	=	1.63	%
Product output	=	2.6	ton/hr

$$\left(60\frac{g}{m^2} \times 3.614\ M \times 200\ m/min \times \frac{60}{10^2}\ \frac{min}{hr} = tons/hr\right)$$

b. Evaporated moisture quantity

Bone dry paper in dry end	=	[2.6 × 0.9837]	
	=	2.55762	ton/hr.
Moisture in dry end	=	2.6 - 2.55762	
	=	0.04238	ton/hr.

Moisture in wet end $= \dfrac{2.55762 \times 60.92}{39.08}$

$= 3.986952$ ton/hr.

Evaporated moisture $= 3.986952 - 0.04238$

$= 3.944572$ ton/hr.

$\fallingdotseq 94.56$ ton/day

Double check by Measuring Relative Humidity of fresh air and Humidity of Exhaust and flow of exhaust.
Data from measuring of fresh air and exhaust air of No. 6 m/c are shown in Table 8.2.9 and Table 8.2.10 respectively

Table 8.2.9 Result of Average Measuring Data of Fresh Air

Location of measuring	Operation Side				Driving Side			
	Wet bulb temp. °C	Dry bulb temp. °C	%RH	Absolute humidity kg/kg drying	Wet bulb temp. °C	Dry bulb temp. °C	%RH	Absolute humidity kg/kg drying
Group 1 (No. 1 - No. 3) Amb. temp 34°C	32	38.5	60.4	0.028	31.5	34.5	92	0.033
Group 1 (No. 4 - No. 10) Amb.temp. 34°C	34	39	73	0.033	31	36.5	68	0.027
	35	41.5	65	0.033	34.5	38.5	77	0.033
Group 3 (No. 11 - No. 28) Amb.temp 35°C	30.5	41	47	0.023	34.5	42	62	0.032
	39	49	50	0.049	37	45	60	0.043
	35.5	48.5	44	0.032	37	43	68	0.049
Group 4 (No. 11 - No. 28) Amb. temp. 34.5°C	31.5	38	62	0.035	33	40.5	59	0.029
	31.5 38	62	0.035	33.5	40.5	61	0.03	
Average	33.63	41.69	57.9	0.03	34	35.25	68.38	0.03

Average Relative Humidity of Fresh air = 63.14 %
Average Dry bulb temp. = 38.47 (101.25°F)
Average Absolute Humidity = 190 Grain/lb air = 0.03 kg moisture/kg dry air

Table 8.2.10 Result of Measuring Data of Exhaust

No. of Duct.	1	2	3
Cross Section Area	1.18 m^2	1.26 m^2	0.82 m^2
Exhaust Air Velocity	1.01 m/s	12.2 m/s	10.7 m/s
Flow of Exhaust Air	714 m^3/min	919.25 m^3/min	526 m^3/min
	608.18 Nm^3/min	781.79 Nm^3/min	447.1 Nm^3/min
	729.82 kg Air/min	938.15 kg Air/min	536.52 kg Air/min
Humidity (%RH)	79%	64%	45%
Absolute Humidity	0.065 kg moisture kg dry air	0.049 kg moisture kg dry air	0.038 kg moisture kg dry air
Temperature (Dry bult)	47.5 °C	48 °C	48 °C
Moisture Evaporated	0.065 - 0.03 =0.035 kg moisture kg dry air	0.049-0.03 =0.017 kgm kg air	0.038-0.03 0.008 kgm kg air
	1533 kgm/hr	1069.5 kgm/hr	257.52 kgm/hr

Total flow of evaporated moisture of exhaust air
= 1533 + 1069.5 + 257.52
= 2,860 kg/hr = 2.86 tons/hr
compare with evaporated moisture of paper = 3.94 tons/hr
unbalance moisture = 3.94 - 2.86 = 1.8 tons/hr
The unbalance moisture = 1.08 tons/hr is based on dispersion of vapor around the machine. The reason for it is that Dryer's ventilation is not in good condition because Side Wall of Hood is imperfect without repair.

c. Heating Surface of Cylinder

Heating Surface of each cylinder

$$= 3.14D \times L = 3.14 \times 1.5 \times 4 = 18.847\ m^2$$

Heating Surface of total cylinders

$18.857\ m^2 \times 38 = 716.566\ m^2$

Evaporation quantity to unit Heating Area.

94.56 ton/day $\div 716.566\ m^2 = 132.6\ kg/m^2 \cdot day$

Standard evaporation ratio is about 160 kg/m²·day in case of machine design for Printing & Writing paper making. It may be supposed that this paper machine is not equal due to capacity lack in wire part or press part. Or, it seems that they are intentionally abliged to productivity saving. In the present condition of machine operation the heating area is satisfactory in the following area.

94.56 ton/day $\div 160\ kg/m^2 \cdot day = 591\ m^2$

And then the machine does not need to use same cylinders as follows:

$(716.566\ m^2 - 591\ m^2) \div 18.46\ m^2 = 6.6$

The machine does not need 6 ~ 7 cylinders for saving energy.

By the following countermeasures, dryer evaporation ratio must be increased.

Evaporation	Measures	Major points
Heat conductivity	Cleaning the dryer surface of attached foreign substances	Effective use of the doctor to remove
	Discharge of drain and non-condensable gas from the cylinder	(1) Effective use of the drain discharge syphon (2) Drain and air has poorer heat conductivity than cast iron.
Uneven drying	Pressure control	Pressure control Section and header pressure detection
	Temperature control	Temperature control Detection of surface temperature by sensor
	Installation of BM meter	Measurement and control of paper moisture, weight, thickness
Ventilation	Adjustment of air flow line inside the dryer	Correction of hood form
	Reduction of thermal resistance, promotion of dispersion	Higher air temperature for dispersion, Lower humidity and higher speed
	Removing pocket of ventilation	Ensuring uniformity in the cross direction

d. Exhaust and Ventilation Control

Relation of Vaporization quantity and Exhaust quantity in Dryer. Vaporization quantity (Volume) in a paper machine dryer Hood is introduced from the following formula by quantity of paper making and moisture rate of dryer inlet or outlet:

$E = P \times W_1 - W_2/100\text{-}W1$

E = Vaporization quantity (ks/h)

P = Paper Production Quantity in Unit time (Vs/h)

W_1 = Wet end moisture rate in Dryer inlet (%)

W_2 = Dry end moisture rate in Dryer outlet (%)

As air Volume of Exhaust Fan is controlled by dew point of inner Hood.
Exhaust quantity is introduced from the following formula by dew point and vaporized moisture quantity

$G = E/X_2 - X_1$

G : Exhaust Air Volume (kg/kg)

X_1 : Absolute Humidity of charged Fresh air to Hood (kg/h)

X_2 : Absolute humidity to dew point in Hood outlet (kg/kg)

X_2 can change with operating circumstances. G of Exhaust air Volume can be decreased by changing to high dew point.
So, keep dew point as high as possible.

(1) the electric power cost is decreased
(2) the unit steam consumption is decreased
(3) the deviation of paper moisture is decreased

(4) Dryer ventilation

a. Fresh air

Fresh air for Dryer Ventilation carries out the vapor that evaporated from the wet sheet.

Duties of Dryer Hood are to evaporate paper from the wet sheet and exhaust it to outdoor as soon as possible.

Generally, paper machine dryers have to evaporate 1.5 ~ 2.0 ton moisture to ton of paper. For getting high drying efficiency, volume of air has to be kept at minimum.

The needed air volume for ton of paper is as follows:

In case of nonhood = 75 ~ 80 ton
Semi-closed type = 50 ~ 60 ton
Closed type = 25 ~ 30 ton

By improving of hood

(1) Volume of exhaust and charge air is decreased.

(2) Exhaust fan and duct are smaller, so electric consumption of fan is reduced.

(3) Heat efficiency is increased by decrease of waste heat loss.

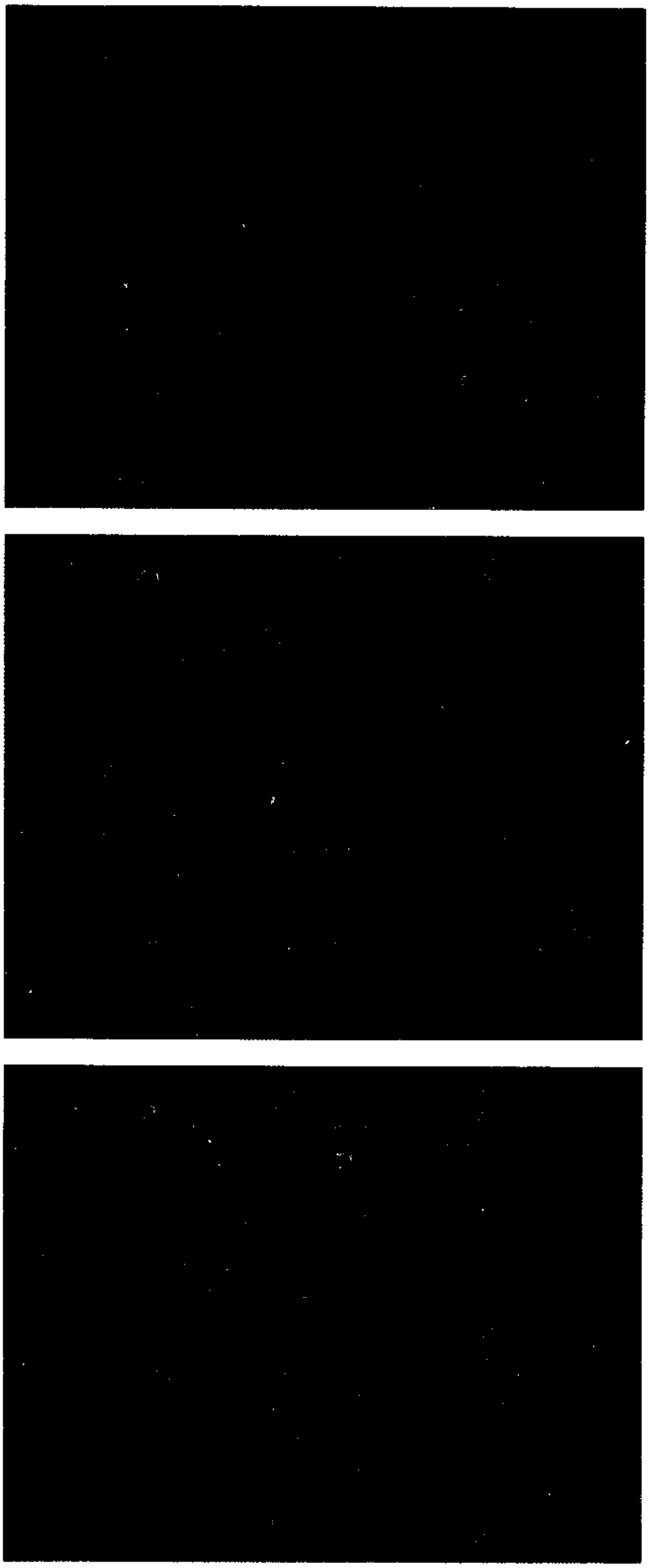
(4) Inequal drying of cross direction is improved.

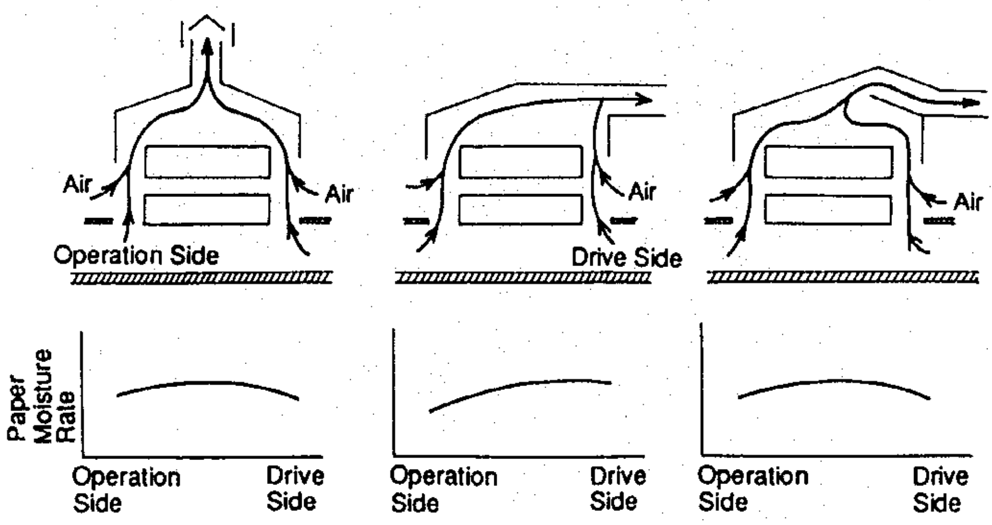
(5) Working environment of paper making room is improved

(6) Preventing the air to pass through allows preventing turbulence in current of ventilation. It can also prevent influx of foreign matters in open air.

To reach these from the both sides of paper machine it should be closed with curtain plastic hood which can remove easily when the machine needs such service as repair and also maintenance from time to time. Example of Hood is shown in Figure 8.2.24

Figure 8.2.24 Air Flow or Paper Moisture Profile in Different Hood Types





(5) Drainage system

a. Steam Supply System of Dryer Cylinder Drum

The drainage system of No 6 M/C is shown in Figure 8.2.25. The corresponding cylinders are divided into five groups; 3 cylinders in the 1st group (No. 1 - No. 3), 7 cylinders in the 2nd group (No. 4 - No. 10), 18 cylinders in the 3rd group (No. 11 - No. 23), 4 cylinders in the 4th group (No. 24 - No. 32), and 6 cylinders in the 5th group (No. 11 - No. 38). The steam pressure is controlled by reducing valve. Main steam pressure 5.5 kg/cm^2 (80 psi) is reduced in the 1st group by 0.5 kg/cm^2, in the 2nd and 3rd groups by 0.6 kg/cm^2, and in the 4th and the 5th groups by 1.55 kg/cm^2

Condensate System of this machine is collected to the same condensate tank and then pumping to Boiler House.

From this state it is recommended that cylinder Drums should be divided into 3 Groups in which Ratio of Cylinder is approximately 5 :11: 22 in Group 1st, 2nd and 3rd, respectively.

Figure 8.2.25 No. 6 M/C Drainage

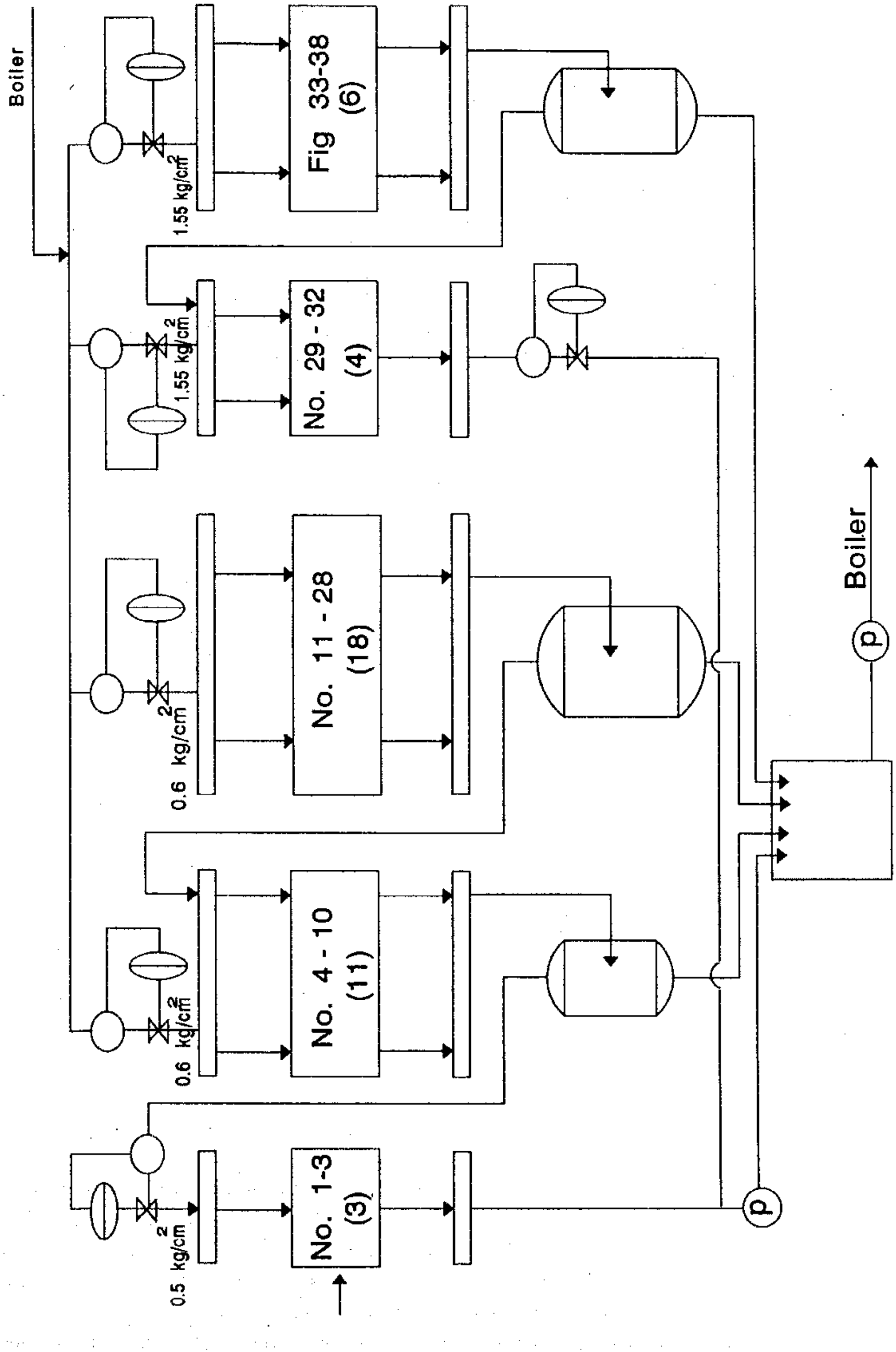
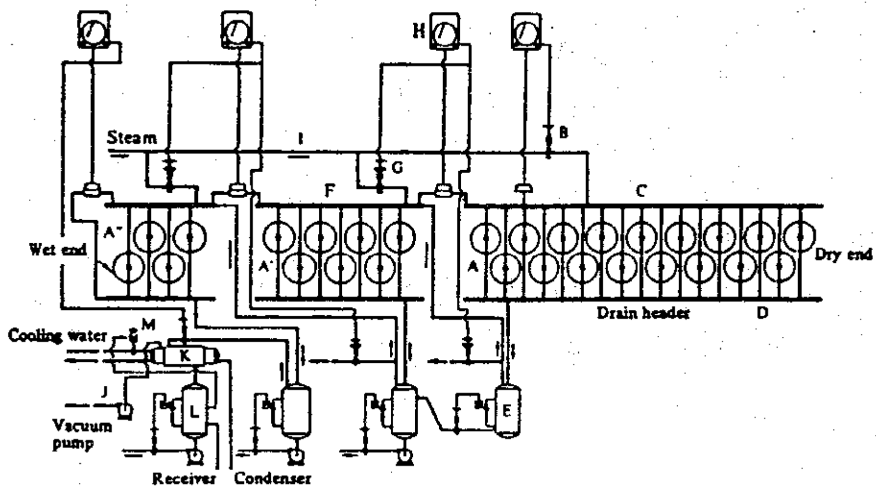


Figure 8.2.26 Typical Third Group Drainage System
(Blow Through System)



A : First group dryer (A' : second group dryer, A": third group dryer)
B : First group control valve
C : First group steam header
D : First group condensate header
E : First group condensate receiver tank
F : Second group steam header
G : Second group control valve
H : First group and second group differential pressure controller
I : Main steam pipe
J : Non-condensing gas ejection vacuum pump
K : Condenser
L : Receiver tank
M : Cooling water control valve

b. Condensate measuring

The steam consumption of the machine cannot be measured directly, because the machine has no steam flow meter installed. The condensate measuring was done during the time of surveying by using empty tank, from which the result (of measuring) is 0.1147 m^3/min = 6.88 m^3/hr. which is estimated to be equal to steam consumption = 6.88 ton/hr. The output of product of that day was 2.6 tons/hr. (output = 60 g/m^2 × 3.61 m × 200 m/min × 1,440/10^6 tons/g). The steam consumption rate per product output is 6.88/2.6 = 2.65 ton steam/ton product output.

8.2.3.5 Steam system

(1) Steam pipe and valve

A total nine valves - The main steam piping of boiler house is about 8 m × 2 line length of steam pipe, and a valve on the top of boiler and eight steam header valves - and part of the feed water and fuel oil pipe for boiler are left uncovered. They must be insulated. None of the steam valve and flange were insulated despite their large surface area. A newly installed pipe line is insulated well.

Poor insulation of pipe around the paper machine M/C #6 attracted our attention. Repair and insulation must be systematically provided to the equipment from the boiler up to the paper machine in order, even if this takes a long time.

Steam pressure of pipe around the paper machine M/C #6 at the dryer part runs at 6.2 kg/cm^{2}G. Although flash steam is used, its pressure level is not made clear. A pressure sure gage should be placed in good repair. There was almost no steam leakage observed of pipe around the paper machine M/C #6 but slight steam leaks were found at the gland, valve at main steam pipe line. The velocity of steam is similar to that of sound. It will enlarge the clearance by erosion and increase the volume of leaking steam. They should be repaired as soon as possible.

They are problems of steam pipe and valves around the Boiler #2. If the nine valves of 3 ~ 6 inch diameters are insulated, then heat loss will be reduced by the following amount by Table 8.2.11;

Table 8.2.11 Effect of Insulation

Equipment	Heat loss		Heat loss
	without insulation	with insulation	reduced by:
once dia. 3 inch valve	679.0 kcal/h	135.8 kcal/h	543.2 kcal/h
two dia. 4 inch valve	1,753.7 kcal/h	350.8 kcal/h	1,402.9 kcal/h
two dia. 5 inch valve	2,365.3 kcal/h	473.1 kcal/h	1,892.2 kcal/h
four dia. 6 inch valve	5,945.5 kcal/h	1,189.1 kcal/h	4,756.4 kcal/h
		Total	8,594.7 kcal/h

This reduction of 8,594.7 kcal/hour in heat loss is equivalent to a saving of 17.4 kgs/h or 0.23 percent in steam as compared with the quantity evaporation.

As seen on Table 8.2.12, if a factory invests for insulation, using fibre-glass insulator, then heat loss will be reduced about 80 %, and will get money saving of about 29,240 baht/year. When insulator and operation costs are about 10,978 baht, then the payback period is 0.38 year.

Table 8.2.12 Cost of Insulation

	Side	Number	Equivalent pipe length to Valve		Temp.	Heat loss		Insu. thick -ness	Insu. +oper- ation	Total
	mm		m	total	°C	Watt/m	total W	mm	Bt/m	Baht
Valve O 3"	76.2	1	1.25	1.25	164	631.8	789.8	50	603	754
Valve 4"	101.6	2	1.27	2.54	164	803.0	2,039.6	50	773	1,963
Valve 5"	127.0	2	1.40	2.80	164	982.5	2,751.0	50	846	2,369
Valve 6"	152.4	4	1.50	6.00	164	1,152.5	6,915.0	50	982	5,892
						Total	12,495.4			10,978

Without insulating ;

Heat loss per year = $12{,}495.4 \times 8{,}400 \times 3.6 \times 10^{-6}$

= 377.86 GJ/year

After insulating by fibre glass ;

Heat loss reduced 80%= 302.29 GJ/year

Compare with heavy oil = $302.29 / 9{,}627 \times 4.187 \times 0.831$

Energy saving = 9,024.62 kg. fuel/year

Heavy oil price = 3.24 Bt/kg. fuel

Money saving = 29,240 Bt/year

Payback period = 10,978 / 29,240

= 0.38 year

Table 8.2.13 Equivalent Pipe Length to Valve or Flange (Unit: m)

Piping Parts	1"	1.5"	2"	2.5"	3"	4"	5"	6"
Flanged Globe Valve (10 bar)	1.22	1.11	1.11	1.23	1.25	1.27	1.40	1.50
Flanged Globe Valve (20 bar)	1.21	1.20	1.28	1.50	1.56	1.58	–	1.78
Flanged Sluicc Valve (10 bar)	1.15	1.31	1.22	1.16	1.31	1.20	1.27	1.35
Flanged Sluicc Valve (20 bar)	1.32	1.23	1.53	–	1.63	1.50	–	1.92
Pressure Reducing Valve (10 bar)	1.67	1.49	1.55	1.60	1.66	1.58	1.91	1.76
Control Valve (10 bar)	1.84	1.56	1.60	–	1.54	–	–	1.48
Flange (10 bar)	0.53	0.47	0.44	0.42	0.42	0.39	0.44	0.45
Flange (20 bar)	0.54	0.47	0.49	0.46	0.50	0.46	–	0.56

Table 8.2.14 Heat Loss in Watt per Metre of Bare Pipe

TEMP DIFF TD	NORMINAL PIPE DIAMETER/OUTSIDE DIAMETER IN MM.														
	10.00	20.00	25.00	32.00	40.00	50.00	65.00	80.00	100.00	125.00	150.00	200.00	250.00	300.00	350.00
	21.70	27.00	34.00	42.70	48.60	60.50	76.30	89.10	114.30	139.80	168.80	219.10	273.00	323.80	355.60
20	19	23	26	34	38	46	60	64	80	96	113	144	175	204	223
30	30	37	45	54	61	74	91	104	129	155	163	231	282	329	368
40	43	52	63	77	86	105	128	147	183	219	258	327	398	464	505
50	67	69	83	102	114	138	169	193	241	288	340	430	524	610	664
60	71	86	105	128	143	173	212	243	303	362	427	541	658	768	865
70	87	105	128	155	174	211	258	296	396	441	520	659	803	936	1018
80	103	125	152	185	207	261	307	352	439	525	620	765	956	1115	1213
90	120	146	177	216	242	293	359	412	514	614	725	918	1119	1305	1421
100	138	168	204	249	279	338	414	475	592	709	887	1060	1292	1507	1641
110	157	191	232	283	317	385	472	542	676	809	964	1210	1475	1721	1874
120	177	216	262	320	358	434	533	612	763	914	1079	1368	1668	1947	2120
130	198	241	293	358	401	486	597	685	856	1024	1210	1535	1873	2186	2381
140	220	268	326	398	446	541	684	763	953	1141	1348	1711	2088	2485	2655
150	243	296	360	440	493	598	735	844	1055	1264	1449	1896	2315	2704	2945
160	267	325	396	484	542	658	809	930	1162	1393	1646	2091	2554	2964	3250
170	292	356	433	529	594	721	887	1019	1274	1528	1807	2296	2605	3278	3572
180	318	388	472	577	648	787	958	1113	1392	1670	1976	2511	3089	3588	3909
190	345	421	513	628	704	865	1054	1211	1516	1819	2162	2737	3346	3913	4264
200	374	456	566	680	763	928	1143	1314	1649	1975	2388	2974	3687	4254	4637
210	403	492	600	735	825	1003	1236	1422	1781	2138	2532	3222	3942	4612	5028
220	434	530	646	792	889	1082	1334	1534	1923	2309	2765	3482	4262	4988	5439
230	466	570	695	852	956	1164	1435	1652	2071	2488	2948	3755	4598	5382	5869
240	500	611	695	914	1026	1250	1542	1775	2226	2675	3171	4040	4949	5794	6320
250	534	653	745	978	1099	1339	1653	1903	2388	2871	3403	4389	5316	6226	6792
260	570	698	798	1046	1175	1433	1769	2037	2557	3075	3646	4650	5700	6678	7235
270	608	744	909	1116	1255	1530	1889	2176	2733	3288	3900	4976	6102	7150	7802

NOTE : TD = PIPE SURFACE TEMP. – AMBIENT TEMP. (30 DEGREE C)

8.2.3.6 Boiler

(1) Outline of Boiler

a. Boiler Specification;

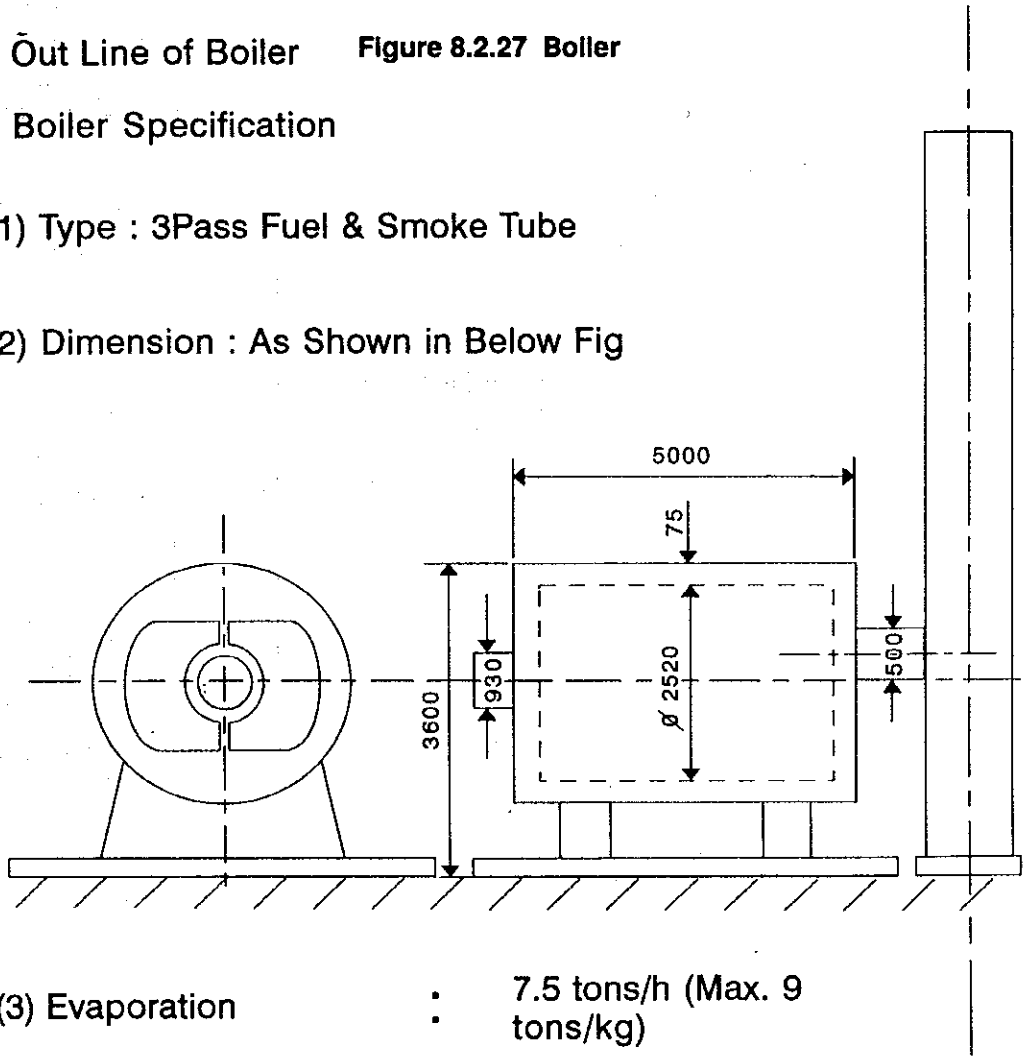
a) Out Line of Boiler

Figure 8.2.27 Boiler

a-1) Boiler Specification

(1) Type : 3Pass Fuel & Smoke Tube

(2) Dimension : As Shown in Below Fig



(3) Evaporation	:	7.5 tons/h (Max. 9 tons/kg)
(4) Steam Pressure	:	7.0 Bar (Rated)
(5) Fuel	:	Heavy Oil (Hh=10,221Kcal/h)
(6) Heating Surface	:	180 m^2
(7) Date of Manufacture	:	1976

Figure 8.2.28 Outline of Boiler

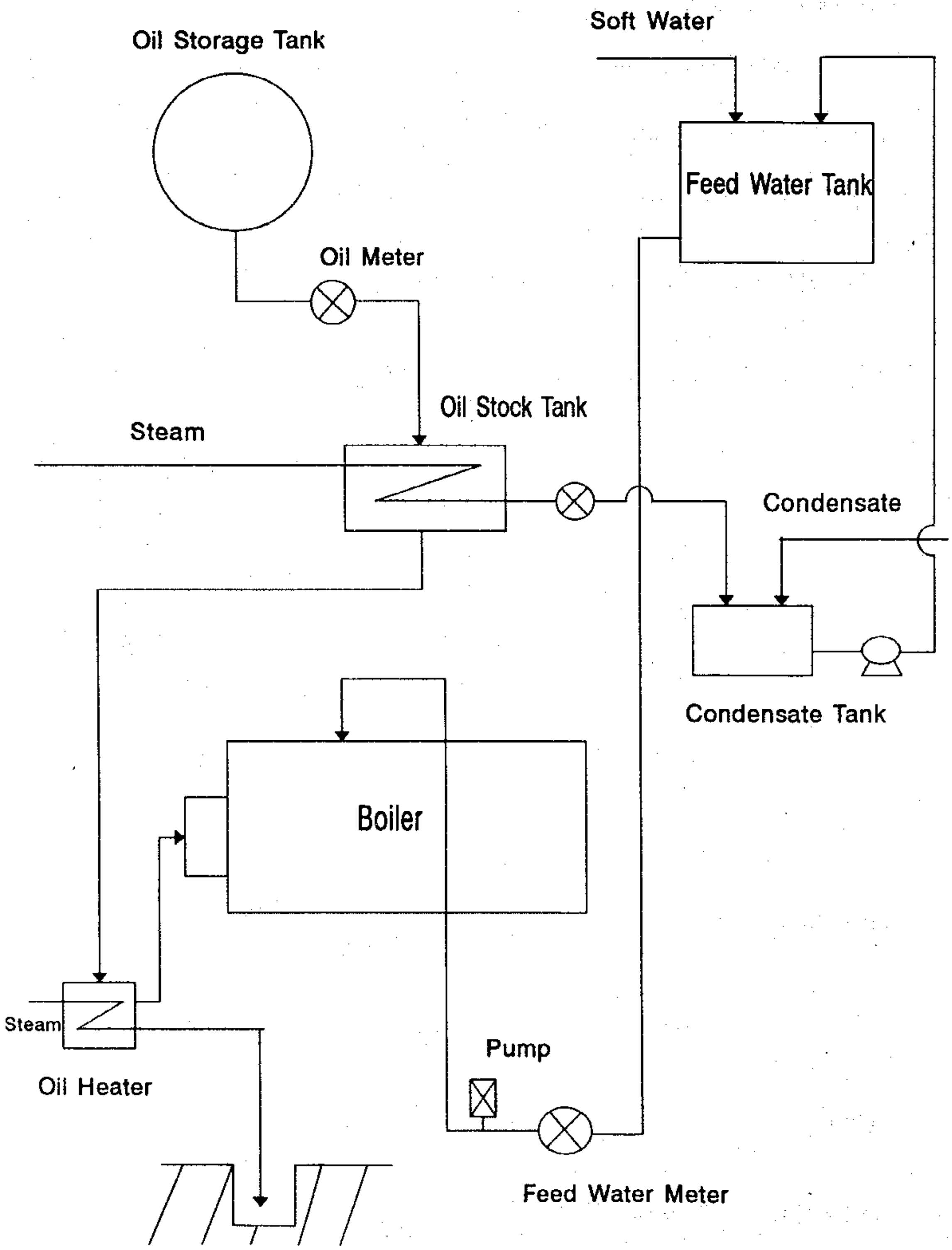
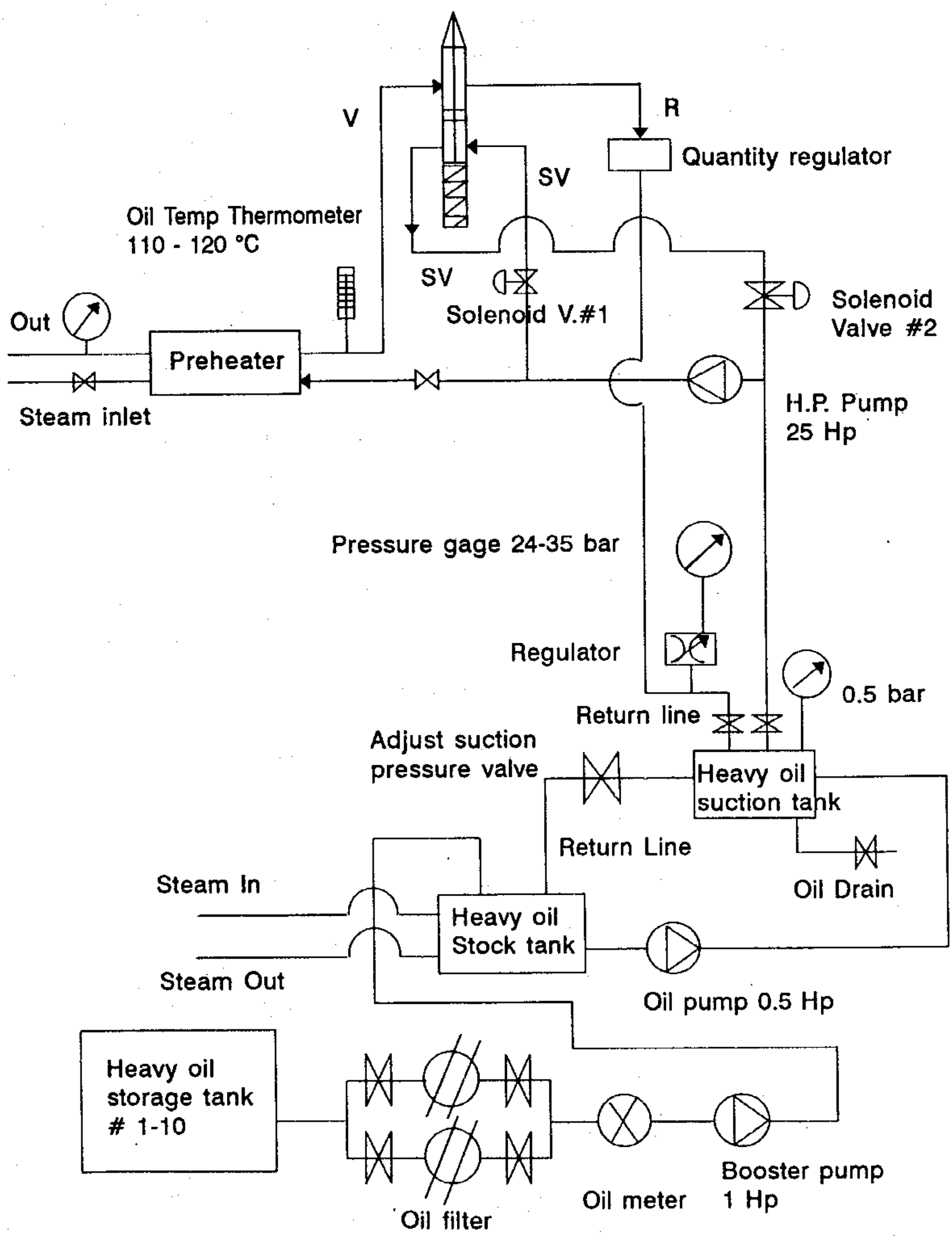


Figure 8.2.29 Heavy Oil of Boiler #2



(2) Results of measurement

a. The heat balance was calculated using the data collected for two hours from 3:00 pm to 5:00 pm on 20 July 1994. The details of the data are as follows.

1)	Kind of fuel	C-heavy oil	
2)	Fuel flow rate	582	l/h
3)	High calorific value	10,221	kcal/kg
4)	Specific gravity of fuel at 15 °C	0.995	
5)	Fuel temperature at oil flow meter	42	°C
6)	Fuel temperature at burner	120	°C
7)	Ambient temperature	29	°C
8)	Exhaust gas temperature	252	°C
9)	Oxygen content in exhaust gas	4.8	%
10)	Feed water flow rate (factory data)	7.5	t/h
11)	Feed water temperature	66	°C
12)	Steam pressure	6.2	kg/cm^2
13)	Dryness of steam (estimate)	0.98	
14)	Temperature of outer surface of Boiler ;		
	Burner side	133.5	°C
	Shell side	42	°C
	Rear side ;		
	insulating part	63.2	°C
	non-insulating part	273	°C

b. Present Condition of Boilers ;

Visiting the factory we found that there exist 5 boilers and 4 paper machines (M/C). Boiler #1 up to Boiler #4 are operated coincidentally by running the 3 boilers with one boiler with as a spare alternately based on appropriation/situation. Boiler #2 and #5 consume heavy oil while Boiler #1, 3 and 4 consume sawdust. The steam generated by Boiler #1 up to Boiler #4 will be supplied to the paper machines at M/C #4 up to M/C #6 but Boiler #5 generates steam to supply for M/C #7. (Figure 8.2.30) All of Boilers are in good condition and good combustion.

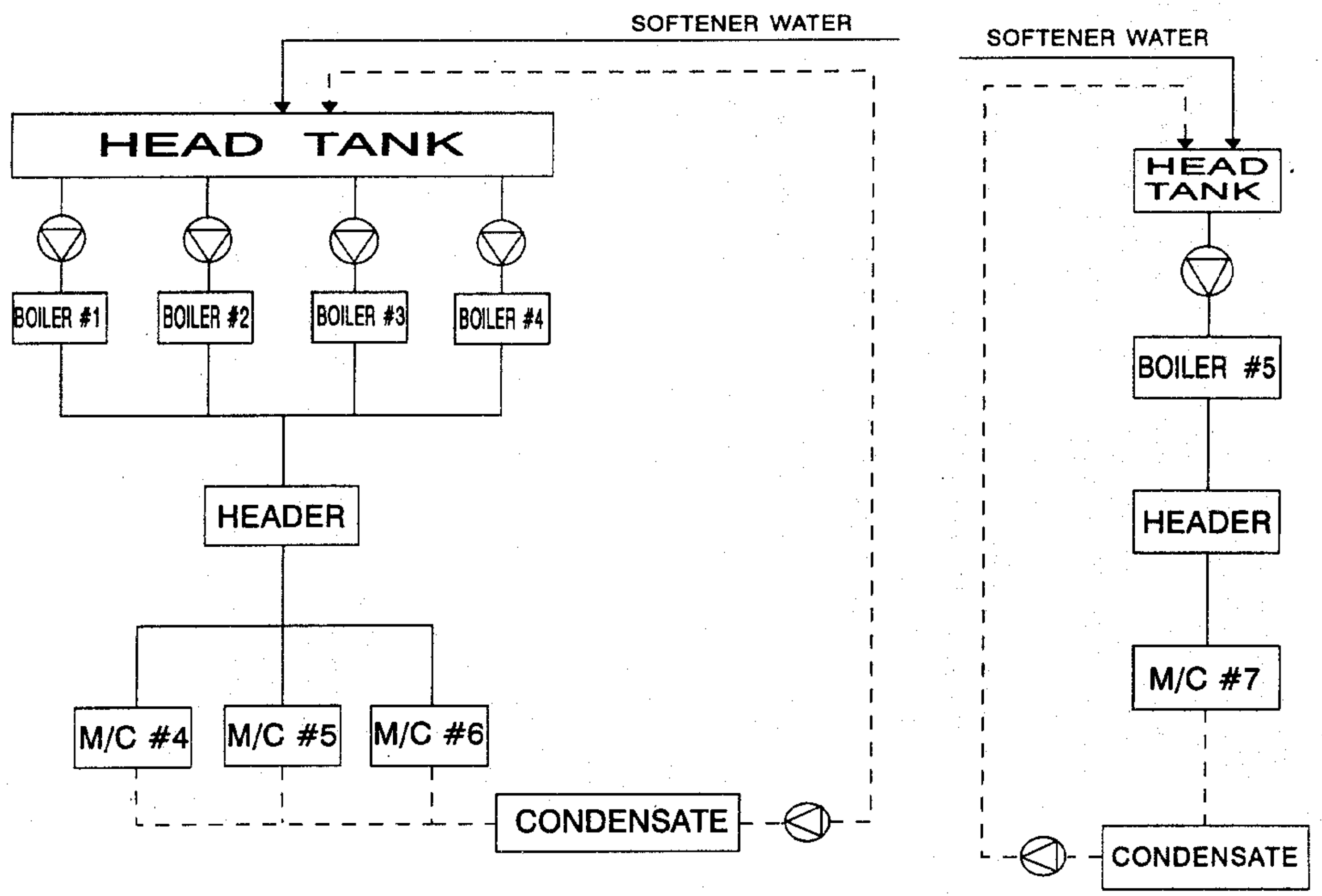
The steam generated at the rated level, working level, evaporating capacity, steam pressure, including fuel used are shown in the Table 8.2.15 ;

Table 8.2.15 Operation Data of Boiler

Item	Rated level					Working level				
Boiler No.	1	2	3	4	5	1	2	3	4	5
Evaporative capacity t/h	10	9	8	8	12	4.67	7.5	2.58	2.5	–
Steam pressure kg/cm²G	7	7	7	7	7	6.7	6.2	6.9	6.8	–
Fuel of type						saw dust	heavy oil	saw dust	saw dust	heavy oil

In energy auditing for this factory, we will consider mainly Boiler #2. After investigation on Boiler #2 we found that, it is under a good maintenance, particularly its related equipment and accessories, and various measuring meters. In addition, there is periodic data recording as well. Recording such data is very useful to calculation of water consumption per fuel used in an hour for rough estimation, e.g. volume of water entering boiler per an hour divided by the heavy oil consumed in an hour. The result can indicate roughly standard performance of boiler.

Figure 8.2.30 Energy Flow Chart



c. Boiler water quality management ;

The boiler water quality is inspected once a month by entrusting to a professional inspection company. Table 8.2.16 shows the data of soft water, feed water, boilers water and condensate.

Table 8.2.16 Water Quality of Boiler

Sampling date 27/4/94	Feed water	Boiler water					Soft water	Con-densate
Boiler No.	1-4	1	2	3	4	5	1-4	1-4
pH	8.34	11.19	11.40	11.27	11.15	11.49	7.71	8.98
Electric conductivity (micromohs/cm)	160	3,510	5,700	3,840	2,820	7,750	367	18.60

The pH values of boiler water for all of boilers are at normal average and should keep on continuously at this level. The values of electric conductivity for Boiler #1, 3 and 4 are also at normal level except for Boiler #2 and Boiler #5 which values 7,750 and 5,700 micromhos/cm are too high. A factory should manage to make them 5,000 micromhos or less/cm by means of blowing off the boiler water to increase and check related feed water concurrently. Since electrical conductivity of the boiler water got extremely high value it hindered heat transfer, shortening the life of the boiler. Quality control of the boiler water by blow off is indicated by the following equation.

$$Fb = \frac{Fc}{Bc - Fc} \times 100$$

where, Fb = Blow rate (%)

Bc = Electric conductivity standard in boiler water

Fc = Electric conductivity in feed water

The feed water before pumping or supplying into boiler should be filtered out of sand and impurities or suspensions mixed with that water. This will reduce the hardness value of feed water. To make sure of performance of feed water to be at the standard, it is necessary to check or test including performing water treatment to get the standard value by adding some chemicals, for example.

As seen on Table 8.2.16, the pH values of feed water are at normal average as well as the electric conductivity is also in normal condition. These should keep on continuously at this level and it is advisable for the company staff to inspect the boiler water once a week.

To recover condensate for feed water, this factory could make condensate recovery as 100 % of the total condensate, and get the feed water at high temperature of 66°C. Since the condensate recovery pipe and the feed water tank are not insulated, so these still cause heat losses from this part. A factory should manage for feed condensate recovery pipe and water tank insulation to save fuel consumed by boiler. This will help extension of operating time for life span of boilers and help raising the temperature of feed water as well.

(3) Calculation of heat balance

a. Heat input ;

Heat input per kg. of fuel is calculated.

1) Fuel flow rate

Specific gravity of fuel, d_{15} at 15°C is 0.995,
Specific gravity of fuel, dt at t °C can be obtained by the following equation;

$$dt = d_{15} - 0.00065 \times (t - 15)$$

therefore,

$$\begin{aligned} dt &= 0.955 - 0.00065 \times (42 - 15) \\ &= 0.937 \\ &= 582 \text{ l/h} \times 0.937 \\ &= 545 \quad \text{kg/h} \end{aligned}$$

2) Combustion heat of fuel (Hl)

$$Hl = Hh - 600\,(9 \times H + \text{water content})$$

where, Hh = High calorific value of fuel oil
H = Hydrogen content of fuel oil (%)
Standard content of Hydrogen is 11% in case of C-heavy oil

$$\begin{aligned} Hl &= 10{,}221 - 600\,(9 \times 0.11) \\ &= 9{,}627.0 \quad \text{kcal/kg. fuel} \end{aligned}$$

3) Sensible heat of fuel (Q1)

Assuming that the mean specific heat of C-heavy oil is 0.45 kcal/kg °C

$$\begin{aligned} Q1 &= 0.45 \times (120 - 29) \\ &= 41.0 \quad \text{kcal/ka. fuel} \end{aligned}$$

4) Total heat input (Qi)

$$Qi = Hl + Q1$$
$$= 9{,}627.0 + 41.0$$
$$= 9{,}668.0 \quad \text{kcal/kg. fuel}$$

b. Heat output ;

Heat output per kg. of fuel is calculated as follows:

1) Heat content of steam (Qs)

Enthalpy of wet steam is 649.9 kcal/kgs at 6.2 kg/cm^2G

$$Qs = (7{,}500.0 / 545.0) \times (649.9 - 66.0)$$
$$= 8{,}035.2 \quad \text{kcal/kg. fuel}$$

2) Heat taken away by exhaust gas (Qg)

Amount of exhaust gas
Theoretical air volume (Ao) and theoretical combustion exhaust gas volume are calculated from the fuel calorific value according to the Boil's equation.

$$Ao = (12.38Hl / 10{,}000) - 1.36$$
$$= 10.56 \quad m^3N\text{/kg. fuel}$$

$$Go = (15.75Hl / 10{,}000) - 3.91$$
$$= 11.25 \quad m^3N\text{/kg. fuel}$$

Air ratio (m)

$$m = 21 / (21 - O_2)$$
$$= 1.3\ \%$$

Therefore, $G = Go + (m - 1)\,Ao$
$$= 11.25 + (1.3 - 1) \times 10.56$$
$$= 14.42 \quad m^3N\text{/kg. fuel}$$

Assuming that mean specific heat of exhaust gas is 0.33 $kcal/m^3N\ ^{\circ}C$

$$Qg = 14.42 \times 0.33 \times (252 - 29)$$
$$= 1{,}061.2 \quad \text{kcal/kg. fuel}$$

3) Heat radiation from boiler surface (Qr)

Table 8.2.17 Heat Loss from Boiler Surface

	Temp.	Surface area	Heat loss	Heat loss
	(°C)	(m^2)	kcal/m^2h	kcal/h
Burner side	133.5	5.60	1,476.3	8,267.3
Shell side	42.0	41.94	100.2	4,202.4
Insulated Part	63.2	5.10	350.0	1,816.6
Non-Insulated Part	273.0	0.31	5,266.4	1,632.6
			Total	15,917.9

where ;

Fuel consumption = 545 kg/h
Qr = 15,917.9 / 545
= 29.2 kcal/kg. fuel

4) Other heat loss (Ql)

Ql = Qi - (Qs + Qg + Qr)
= 9,668.0 - (8,035.3 + 1,061.2 + 29.2)
= 542.3 kcal/kg. fuel

5) Total heat output (Qo)

Qo = Qs + Qg + Qr + Ql
= 8,035.3 + 1,061.2 + 29.2 + 542.3
= 9,668.0 kcal/kg. fuel

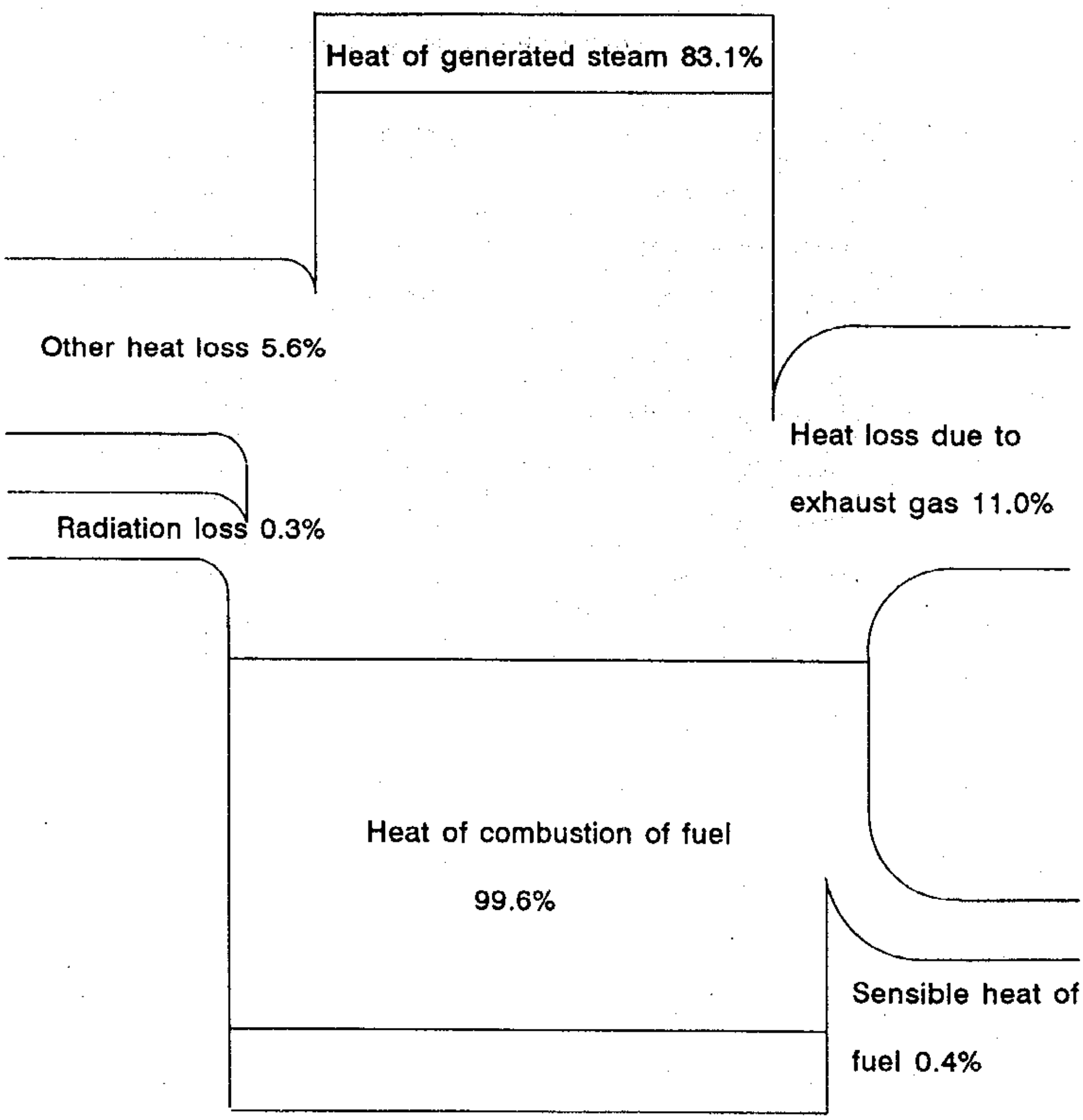
(4) Heat balance table

a. The data shown above are summarized in Table 8.2.18 ;

Table 8.2.18 Heat Balance of Boiler

Heat input	kcal/kg	%
Calorific value of fuel	9,627.0	99.6
Sensible heat of fuel	41.0	0.4
Total	9,668.0	100.0
Heat output		
1) Heat of generated steam	8,035.3	83.1
2) Heat loss due to exhaust gas	1,061.2	11.0
3) Radiation loss	29.2	0.3
4) Other heat loss	542.3	5.6
Total	9,668.0	100.0

Figure 8.2.31 Heat Balance Diagram



$$\text{Evaporation fuel ratio} = \frac{7500 \text{ kgs/h}}{545 \text{ kg/h}}$$

$$= 13.76 \text{ kgs/kg.fuel}$$

b. Consideration on the results of heat balance;

Calculation for heat balance of Boiler # 2 will get the current efficiency of Boiler #2, which is 83.1% (Table 8.2.18) and evaporation fuel ratio is 13.76 kgs/kg. fuel which shows a good operation. Heat losses are quite low especially at the walls of boiler due to their better insulations. However, some equipment such as a valve on the top of boiler and a valve at steam header are not yet insulated. If they are improved to be well insulated, it will help as one measure of energy conservation. Moreover, the heavy oil that is used as fuel is mixed with high impurities, so the oil filter should be checked periodically. If the oil filter is plugged or full with some impurities, it should be cleaned immediately to get better oil circulation.

Measuring the exhaust gas temperature at the stack of Boiler #2, the average temperature is about 252°C (Figure 8.2.32) which is higher than standard exhaust gas temperature of boiler. This temperature should be maintained constantly for not being higher than 220°C which is the standard for boilers consuming liquid fuel and having evaporative capacity 5 to 10 tons per hour (Table 8.2.20).

An air ratio of Boiler #2 is 1.3% at a combustion, which shows stability and a good rating as standard requirement, an average O_2 content is 4.8% (Figure 8.2.33) and standard deviation is 0.17% calculated with the population of O_2 data as 56. The performance standard of boilers consuming liquid fuel and having evaporative capacity 5 to 10 tons per hour should be at 1.2 ~ 1.3% (Table 8.2.19), which should be kept at this level constantly.

Due to using both new and old boilers that need distinctive maintenance a factory must make an individual measurement after the annual maintenance just finished. And then, it must record them as standard values for comparison with the new value measured again in usual running time. The measurement values to refer to as standard should be measured when all equipment are operating at full load.

The boilers in continuous operation will have values of O_2 content and exhaust gas temperature getting higher coincidentally. Therefore, whenever the measured values indicate some abnormality or are getting higher, the improvement and correction must be arranged and managed in order to get values equal to standard as we set up or require.

Hence, a factory must have to record data and each value as being statistic references and utilization in their regular operation. Temperature of each boiler is various therefore the standard temperature of Boiler #2 uses the temperature in a condition of just after the periodical maintenance.

To maintain the level of an exhaust gas temperature at the stack and an air ratio for being at standard level, we should advise controller of Boiler #2 or any boilers to observe more often at the stack. If black smoke, or soot and pollutants are blown off or emitted from the stack all the times, it indicates that an exhaust gas temperature and an air ratio are unusual from normal conditions. The improvement and recovery should be managed and operated as fast as possible.

Table 8.2.19 Standard Air Ratio of Boiler, Revision on 93/7/28

Division	Load rate	Standard air ratio		
	%	solid fuel	liquid fuel	gaseous fuel
For electric industry	75~100	1.2~1.3	1.05~1.10	1.05~1.10
Evaporation: more than 30t/h	50~100	1.2~1.3	1.05~1.15	1.00~1.15
Evaporation : 10 to 30 t/h	50~100	1.2~1.3	1.20~1.25	1.20~1.25
Evaporation : 5 to 10 t/h	50~100	-	1.20~1.30	1.20~1.25
Evaporation: less than 5 t/h	50~100	-	1.20~1.30	1.20~1.25

Standard of air ratio; Since the air ratio is influenced by the type of fuel, the load factor and the composition of control devices, these points must be considered for setting of the standard, the values of Japanese Standard are shown in the Table 8.2.19.

Table 8.2.20 Standard Exhaust Gas Temperature of Boiler

Division	Standard exhaust gas temp. (°C)		
	Solid fuel	Liquid fuel	Gaseous fuel
For electric industry	–	145	110
Evaporation: more than 30t/h	200	200	170
Evaporation : 10 to 30 t/h	250	200	170
Evaporation : 5 to 10 t/h	–	220	200
Evaporation: less than 5 t/h	–	250	200

Exhaust gas temperature standard; The heat efficiency of boilers is generally at a higher level compared with an industrial furnace and the exhaust gas temperature is also at a relatively lower level. A large size boiler equipped with a waste heat recovery unit is in a favorable economical condition and has the exhaust gas at a lower temperature. A gaseous fuel generally has a lower sulfur content and heat recovery from the exhaust gas comes to extent of lower exit temperature.

In the Japanese exhaust gas temperature standard, the standard of an exhaust gas temperature by capacity and by fuel is determined in consideration of these points as shown in Table 8.2.20.

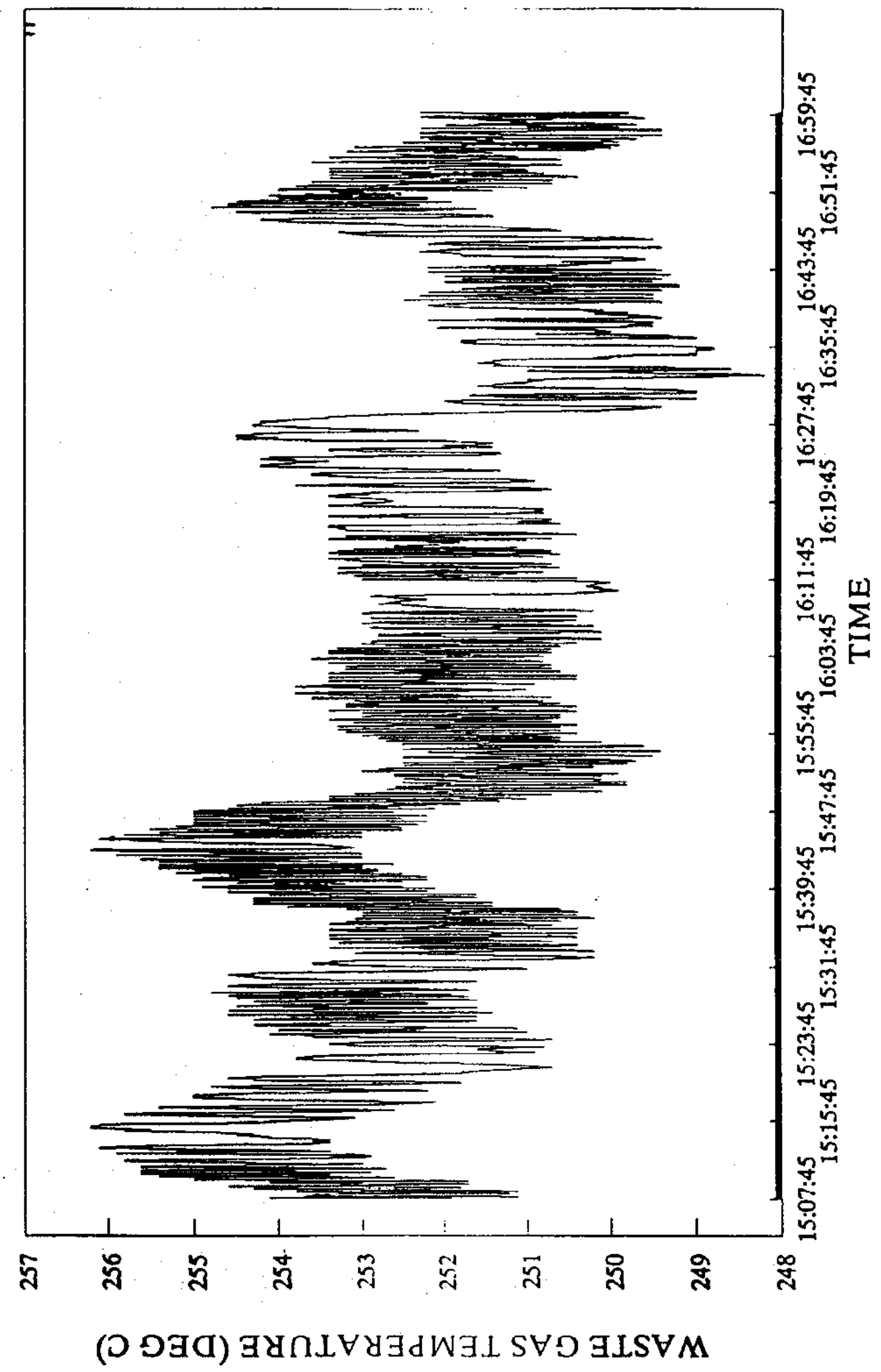
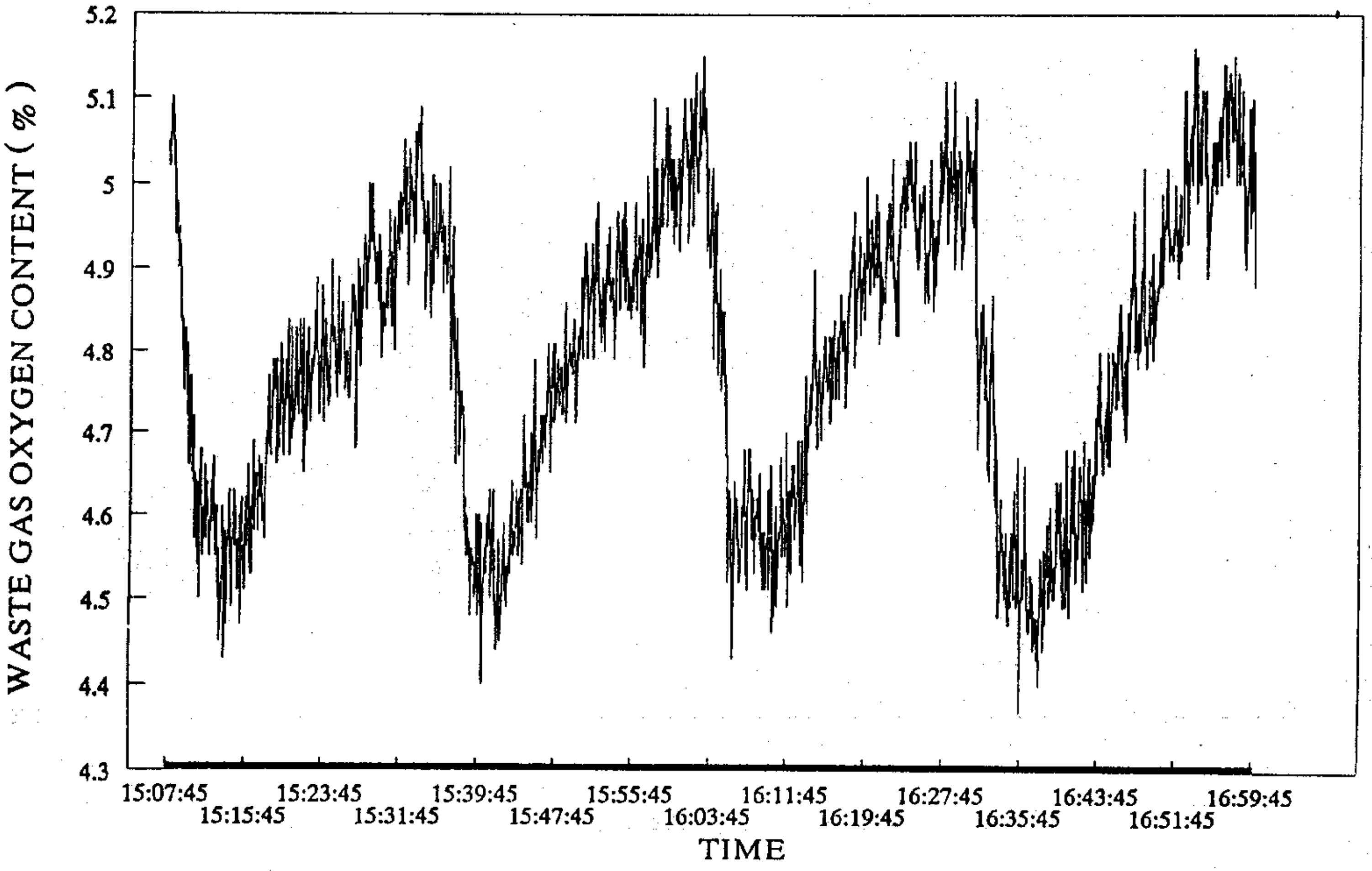


Figure 8.2.32 Waste Gas Temperature of Boiler

Figure 8.2.33 Waste Gas Oxygen Content of Boiler



8.2.3.7 Circumstance of electric power consumption

(1) The Principal Data Relating to Power Consumption

These are as follow:

Power company	– PEA.
Peak demand :	
On peak (18:30pm-21:30pm)	– 6,280 kW. (Jul'93)
Partial peak (8:00am-18:30pm)	– 6,320 kW. (Jul'93)
Off peak (18:30pm-8:00am)	– 6,280 kW. (Jul'93)
Electric consumption	– 42,674,639 kWh/y. (Jul'93-Jun'94)
Load factor	– 79 %
Power factor	– 73 %
Transformers	– 14,900 kVA in all.
Energy consumption rate	– 1,028 kWh/ton. (in 1993)
Electricity price rate: (effective Dec.1, 1991.)	
Demand charge:	
On peak (18:00-21:30)	– 305 Baht/kW.
Partial peak (08:00-18:30) (charge only excess on peak)	– 63 Baht/kW.
Off peak (21:30-08:00)	– No demand charge.
Energy charge:	– 1.07 Baht/kWh.
Average electricity price	– 1.57 Baht/kWh. (Jul'93-Jun'94)

Electric data per month as shown in Table 8.2.21.

Table 8.2.21 Electric Data per Month

Month	Peak Demand (kW) On	Peak Demand (kW) Partial	Peak Demand (kW) Off	Electric. Consumption (kWh)	Other Expense (Baht)	Electric. Expense (Baht)	LF (%)	Average (Bt/kWh)
Jul'93	6280	6320	6280	3922720	127096	6242327	83.4	1.59
Aug	5560	6520	6320	3638591	–67677	5581895	75.0	1.53
Sep	5600	6320	6440	3682880	–68501	5625540	79.4	1.52
Oct	5421	6300	6220	3907360	–72677	5817198	83.3	1.48
Nov	5200	5920	6000	3712863	–69059	5535064	85.9	1.49
Dec	5248	6016	6096	3578144	–66553	5411085	78.9	1.51
Jan'94	5248	6000	5968	3204641	221440	5298421	71.8	1.65
Feb	5200	5918	6064	3292320	227499	5384666	80.8	1.63
Mar	5200	5968	6064	3292320	117206	5274374	73.0	1.60
Apr	5200	5968	6064	3292320	011852	5169019	75.4	1.57
May	5376	6080	5984	3568880	340114	5842847	78.9	1.63
Jun	5184	5936	5952	3581600	539836	6000644	83.6	1.67
Total	64717	73318	73452	42674639	1240576	67183080	—	—
Avrg.	5393	6110	6121	3556220	103381	5598590	79.1	1.57

Source : Monthly electric bills of Z Co., Ltd.

Remark : The calculation of average electric price,

Average electric price = Total electric expense/kWh

= {(305*Pon) + [63*(Ppa-Pon)] + (1.07*kWh) + Other expense/kWh

= {(305*64717) + [(73318 – 64717)*63] + (1.07*42,674,639) + 1,240,576} / 42,674,639

= 1.57 Baht/kWh

(2) Electric Consumption of Each Division

The data of electric consumption of each division are recorded on June '94. These data are as follows:

Table 8.2.22 Electric Consumption of Each Division

	Product (t/day)	Electricity consumption kWh	%
PM4	20	280,791	7.8
PM5	28	585,931	16.4
PM6	60	1,929,680	53.9
PM7	60	759,649	21.2
Office	—	25,549	0.7
	168	3,581,600	100

Source : Z Co., Ltd.

The consumption of PM.6 is more than 50 percent of total electric consumption due to the large number of equipment and high capacity, and PM.4 is about 8% to low load.

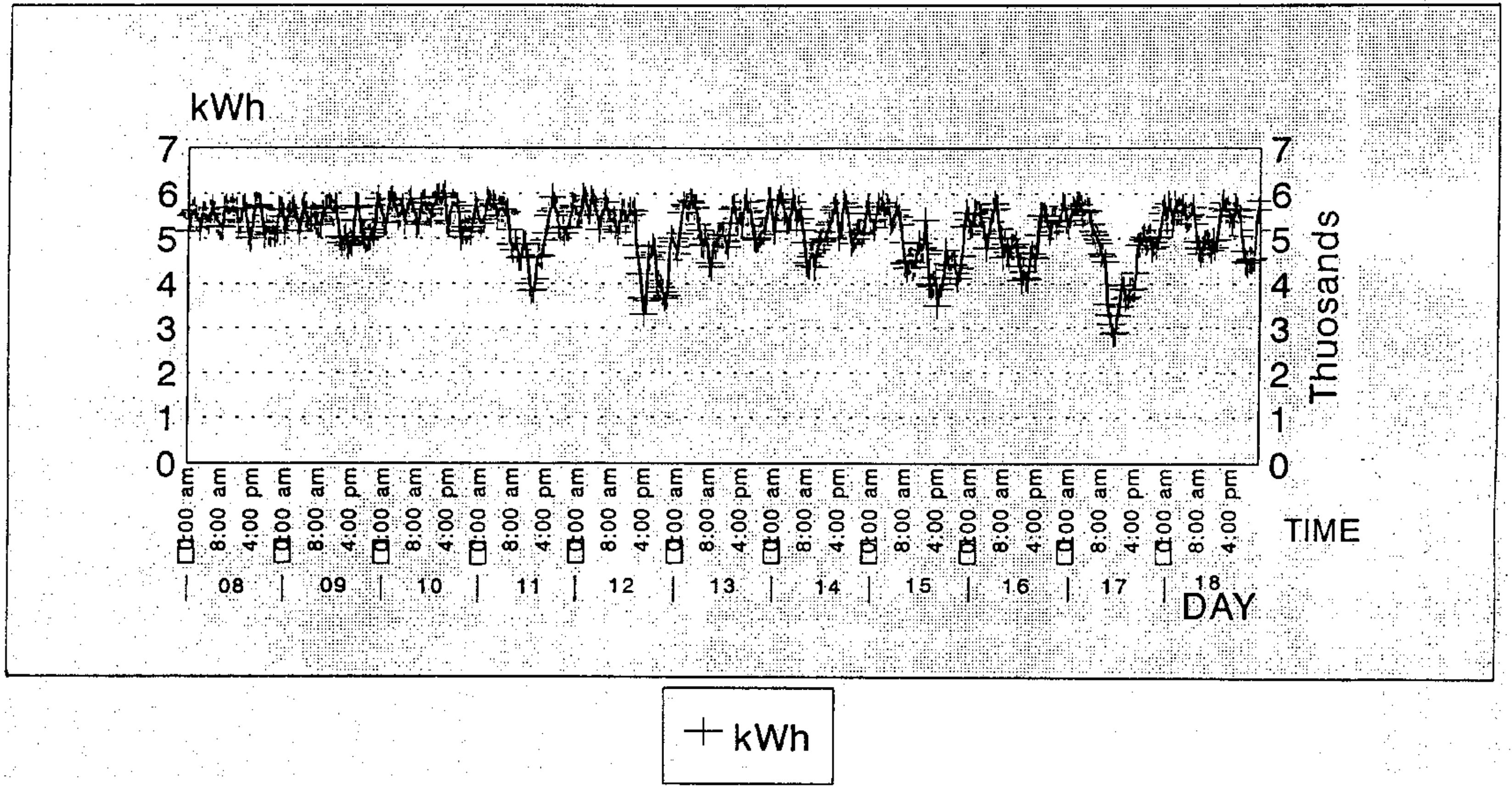
(3) Load Curve of the Total Electric Consumption

Having got the data on the total electricity consumption of a factory through its recording since 8-18 August 1994, we took them to make load curve diagram as shown in Figure 8.2.34, Figure 8.2.35, and Figure 8.2.36.

Figure 8.2.34 indicates the features of electricity consumption in a factory as a whole during August 8-18,1994. The curve shows that electricity used was too low on some day and was high on some day as well. This means that the arrangement on electricity conservation is not good enough and must have to make correction and improvement.

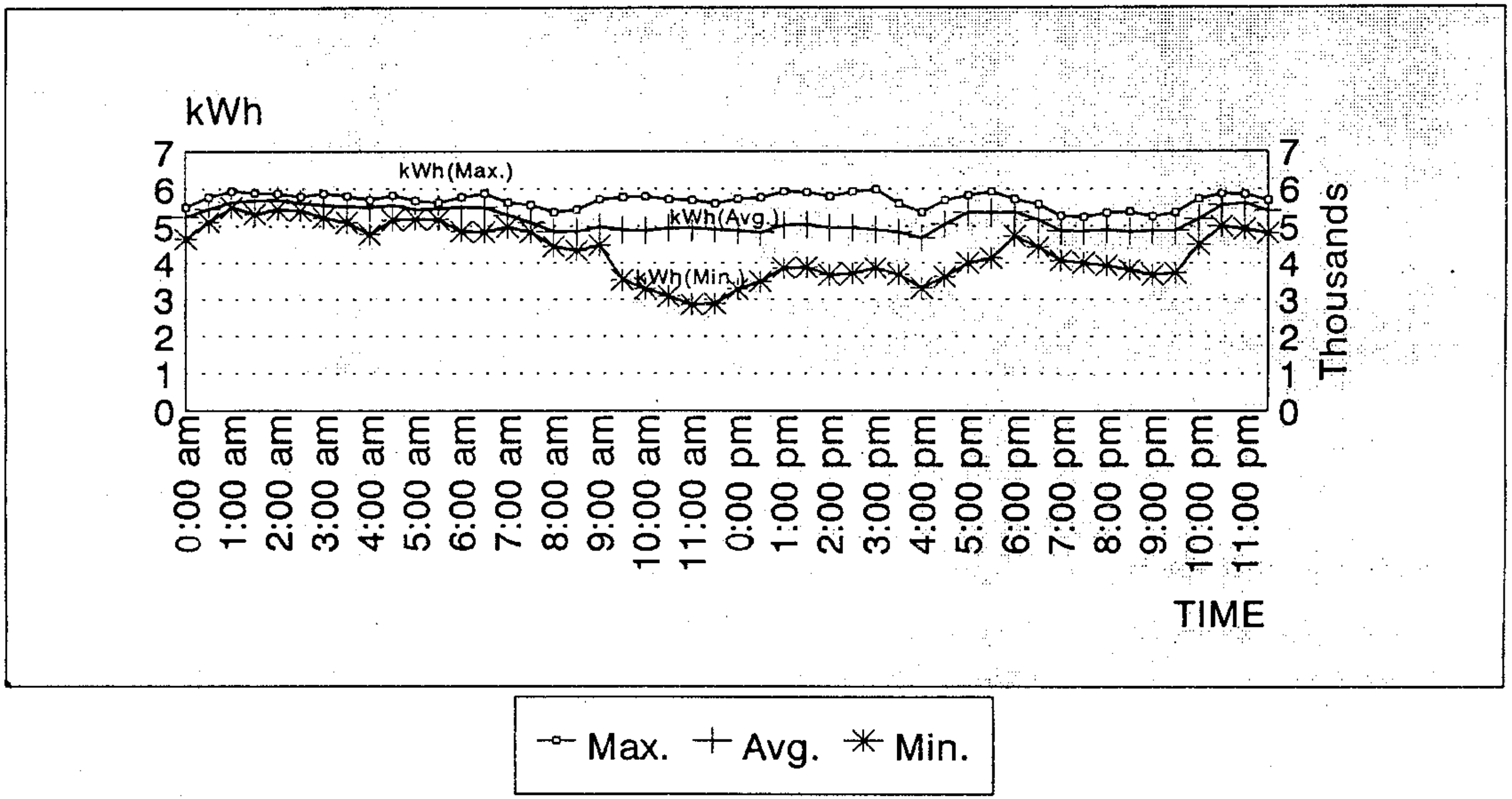
Figure 8.2.35 shows load curve fluctuating within 24 hours of a factory. In one hour of load curve during August 8-18, 1994, we will calculate an average value for each value of the maximum, the average, and the minimum. For example, at the maximum value we calculate its average during 8-18 Aug, within one hour at the same time each day. Then we get an average maximum value to plot curve. Following the maximum to get same time maximum value, minimum value is done in the same way. We could see from the curve that during 10:30 p.m. to 9:00 a.m. the fluctuation of electricity use is in narrow range. This means the feature of electricity consumption is on a good trend since using the electrical equipment is in good control with no scatter. And during 9:00 a.m. to 10:30 p.m., the fluctuation is very wide, which means using the equipment cannot be controlled because of so many scatters. Therefore, if a factory has made a schedule for recording the use of equipment in order, the fluctuation will be corrected narrower.

Figure 8.2.34 Energy Consumption Load Curve



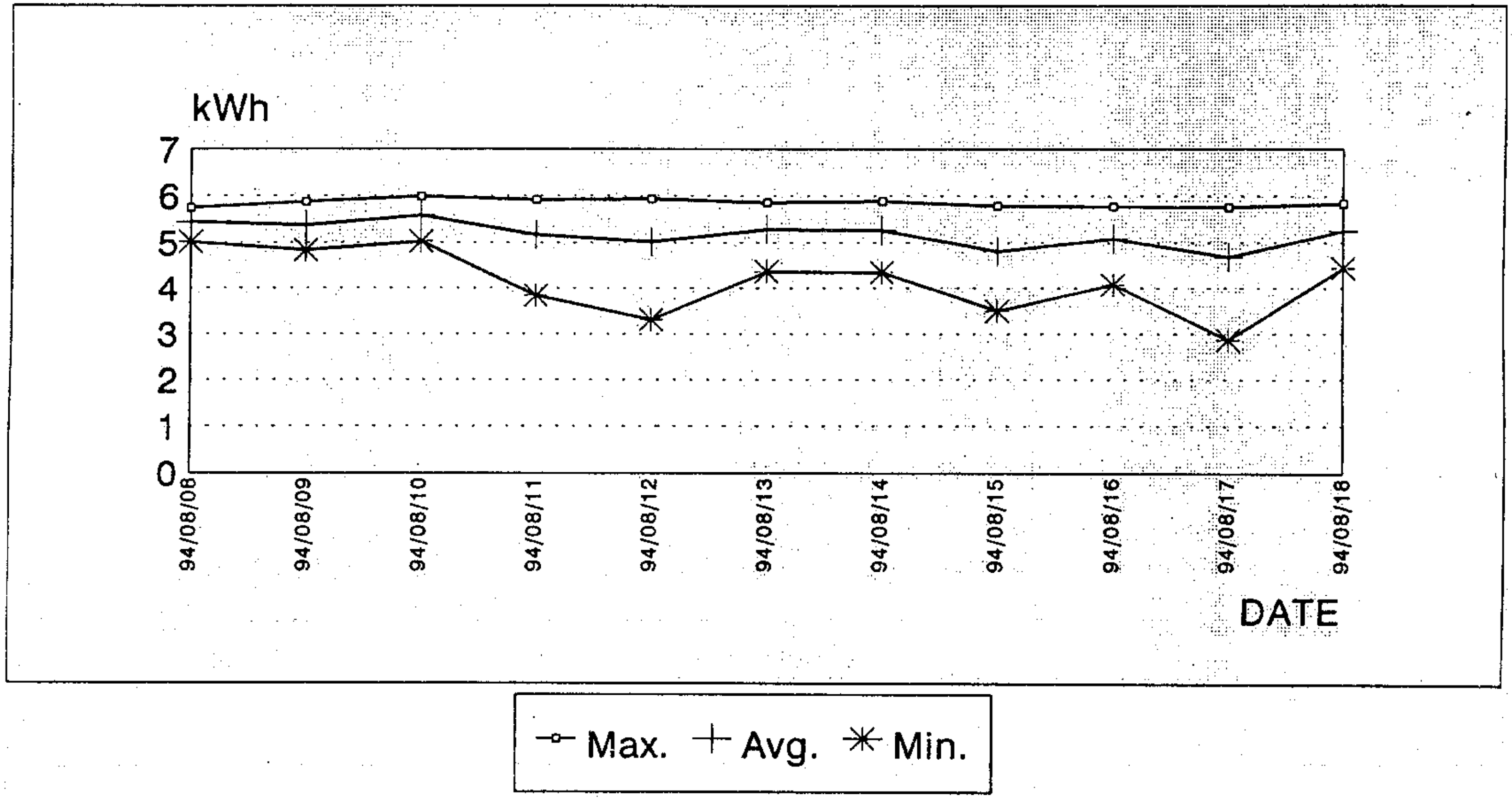
94/08/08 - 94/08/18

Figure 8.2.35 The Fluctuation Load Curve



94/08/08 - 94/08/18

Figure 8.2.36 The Fluctuation Per Day of Load Curve



00.00 am. - 12.00 pm.

This affects that electricity can be saved.

Figure 8.2.36 shows the load curve of the same feature as Figure 8.2.35 but plotting in form of daily load curve of fluctuation.

(4) Result of Measurement of Major Load

Several types and many of electrical equipment are in use in a factory, but no measuring meter for each equipment to indicate its electricity consumption is provided, so that we could measure only the major equipment. The measurement on each equipment for its rating and electricity consumption is as shown in Table 8.2.23 and 8.2.24. We found that every transformer has low P.F. in range of 45%-83% which needs improvement as discussion on the next topic. Transformer No. 6 (2,500kVA) supplies the secondary voltage to two kinds of motor, one kind rating voltage motor is 440 volts. Motor rating voltage is 380 volts received from step down transformer (440/380 V.) 300 kVA.

Table 8.2.23 Rating of Major Load

	Machines	Load (kW)	Rating Voltage (V)	Ampere (A)
1	Main TR1 PM4	1600 kVA	400	
2	Main TR2 PM5	1600 kVA	400	
3	Main TR3 PM6	2000 kVA	600	
	3.1 Wire couch (DC)	225	600	305
	3.2 Calendar (DC)	115	600	245
4	Main TR4 PM6	2000 kVA	400	
	4.1 MCB 51			
	4.2 MCB 52			
	4.3 MCB 53			
	4.4 MCB 54			
	4.4.1 FN screen1	55	380	105
	4.4.2 FN screen2	55	380	105
	4.4.3 Pulper	150	380	295
	4.5 MCB 57			
	4.6 MCB 58			
	4.6.1 Air comp.	150	380	
	4.7 MCB 59			
5	Main Tr5 (PM6)	2000 kVA	400	
	5.1 Hydra pulper	225		
6	Main Tr6 (PM6)	2500 kVA	440	
	6.1 AC fan pump	172	380	
	6.2 Vac. pump #11	130	380	215
	6.3 Vac. pump #13	130	380	215
	6.4 Vac. pump	90	380	144
	6.5 Refiner	335	380	612
	6.6 Fan pump #1	185	380	343
7	Main Tr7	1600 kVA	400	
	7.1 Pulper	150	380	295
	7.2 Vacc. pump	55	380	105
	7.3 Clean. pump	55	380	105
8	Main Tr.8	1600 kVA	400	
	8.1 Ver. screen	130	380	237
	8.2 Ver. screen	93	380	174
	8.3 Paper Mach. (DC)	185	380	

Table 8.2.24 Result of Measurement of Major Load

	Machines	Load (kW)	Voltage (V)	Ampere Is (A)	Ampere Ir (A)	Ampere It (A)	PF (%)
1	Main TR1 PM4	1008	365	1943	1943	1943	82.1
2	Main TR2 PM5	1000	420	1950	1950	1950	70.5
3	Main TR3 PM6	160	476	411	433	429	45.7
	3.1 Wire couch (DC)		476	100			
	3.2 Calendar (DC)		476	60			
4	Main TR4 PM6	936	386	1635	1773	1610	83.7
	4.1 MCB 51	177	387	486	486	486	54.3
	4.2 MCB 52	125	388	240	240	240	77.5
	4.3 MCB 53	17	384	33	33	33	77.5
	4.4 MCB 54	233	382	534	534	534	66.9
	4.4.1 FN screen1	36	380	68	68	68	80.4
	4.4.2 FN screen2	26	381	55	55	55	71.6
	4.4.3 Pulper	66	376				
	4.5 MCB 57	83	382	177	192	190	67.3
	4.6 MCB 58	150	388	290	325	290	74.0
	4.6.1 Air comp.	145	383	254	254	254	86.0
	4.7 MCB 59	9	381	25	25	25	57.0
5	Main Tr5 (PM6)	218	393	485	505	482	65.3
	5.1 Hydra pulper	92	399	227	220	220	59.6
6	Main Tr6 (PM6)	907	430	1890	1890	1890	64.0
	6.1 AC fan pump		430	155			
	6.2 Vac. pump #11		430	135			
	6.3 Vac. pump #13		430	165			
	6.4 Vac. pump		430	95			
	6.5 Refiner		430	335			
	6.6 Fan pump #1		430	155			
7	Main Tr7	616	389	1078	1161	1089	82.4
	7.1 Pulper	148	384	272	272	272	81.8
	7.2 Vacc. pump	39	385	75	75	75	78.0
	7.3 Clean. pump	48	384	90	90	90	80.2
8	Main Tr.8	602	391	1203	1342	1275	69.8
	8.1 Ver. screen	73	382	128	128	128	86.2
	8.2 Ver. screen	70	382	125	125	125	84.6
	8.3 Paper Mach. (DC)	180	383	350	350	350	77.5

(5) Single Line Diagram

The transformers are shown in Figure 8.2.36, Figure 8.2.37 and Figure 8.2.38. These are all of factory and major motors of each transformer are as shown in the following.

Figure 8.2.37 Single Line Diagram of Transformers

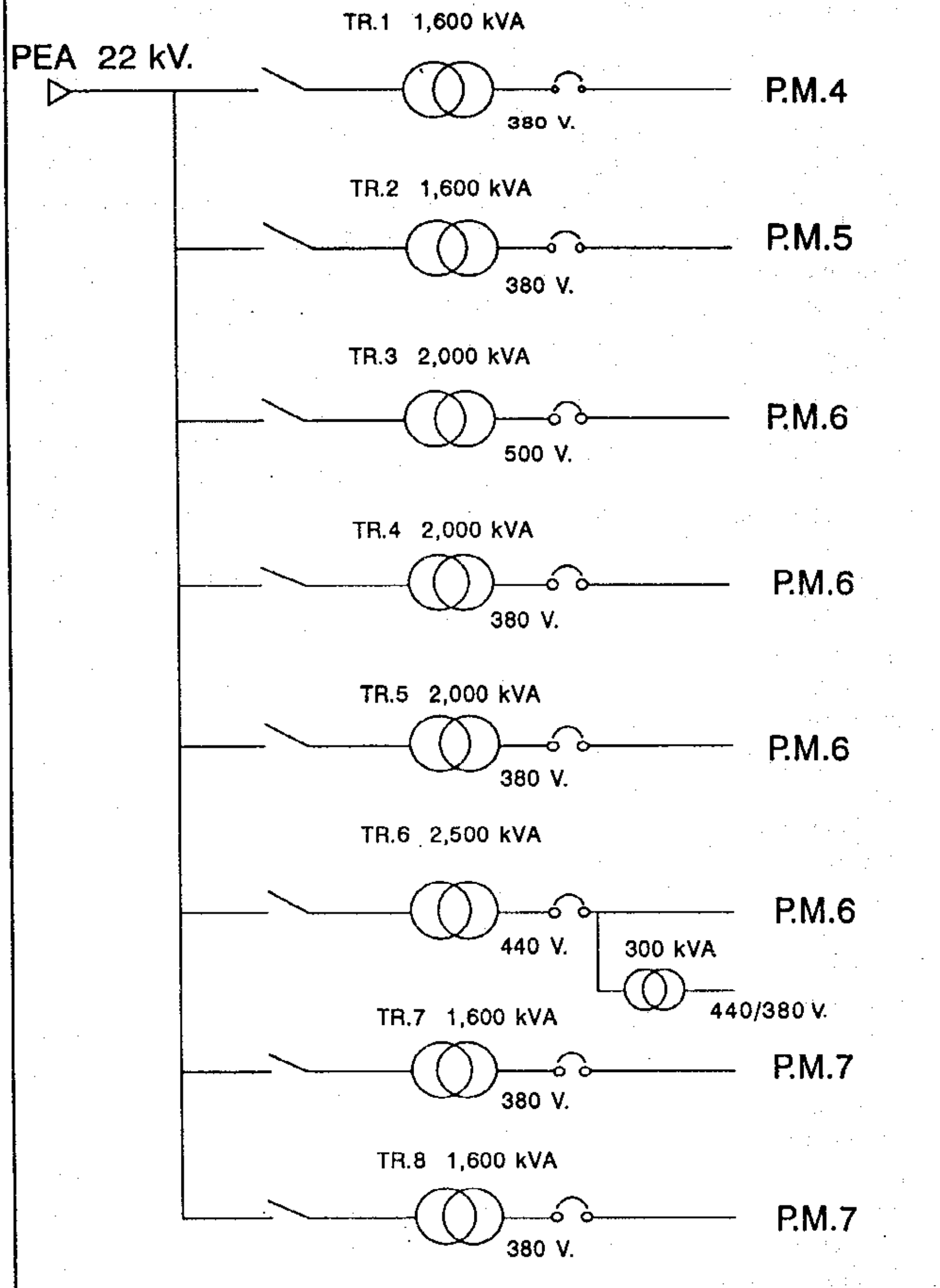


Fig. 8.2.36 Single Line Diagram of Transformers

Figure 8.2.38 Single Line Diagram of TR.3, 4

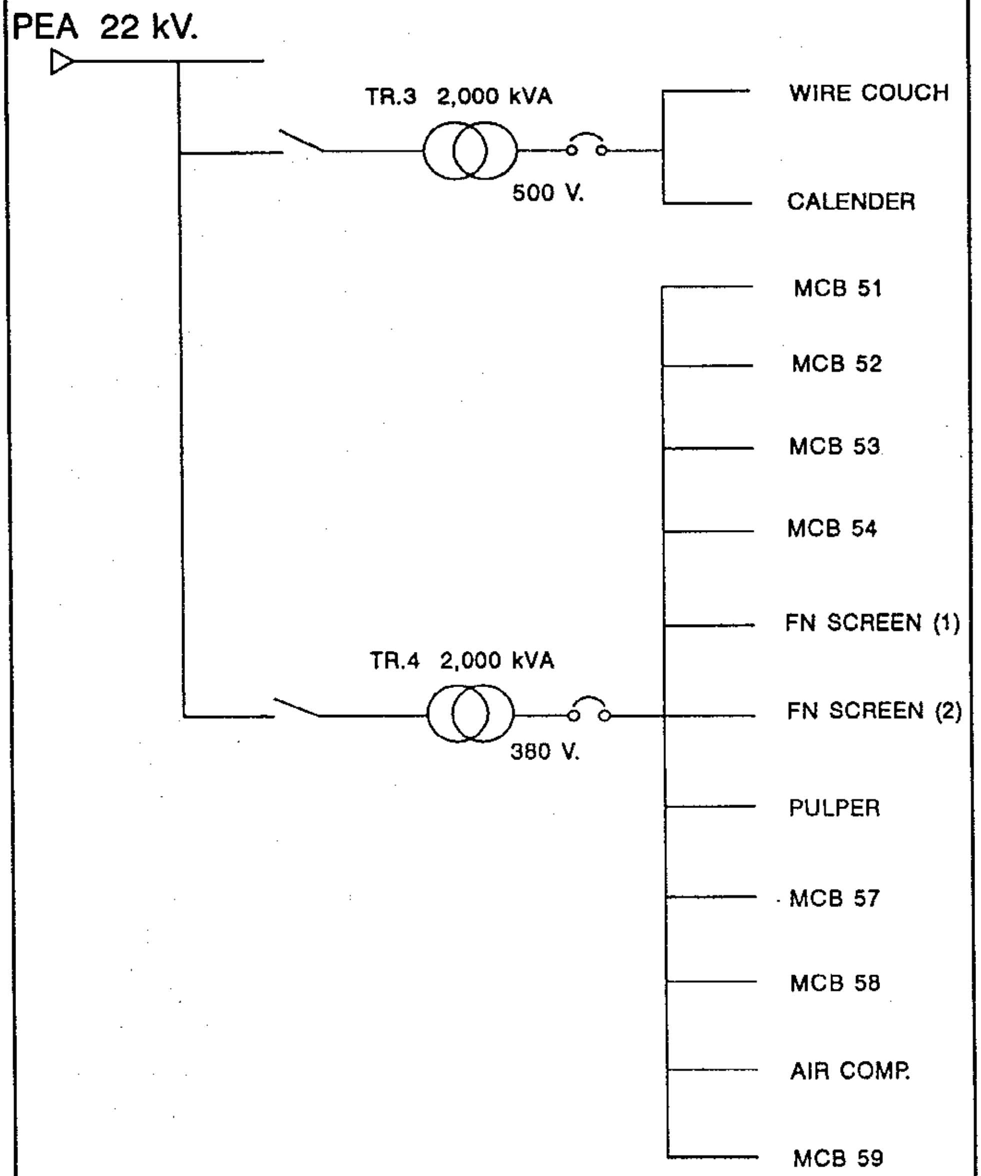


Fig. 8.2.37 Single Line Diagram of TR.3,4

Figure 8.2.39 Single Line Diagram of TR. 5, 6, 7, 8

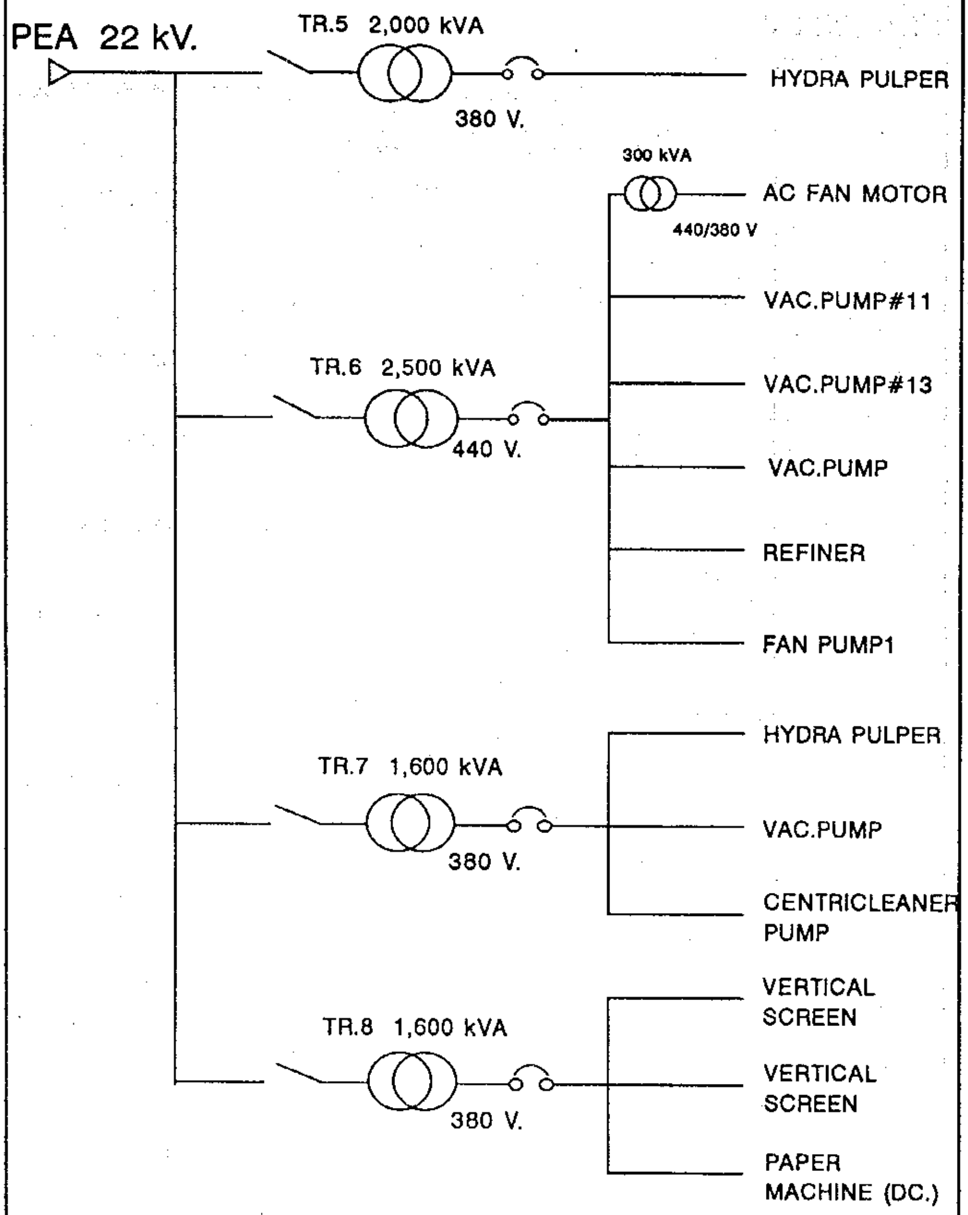


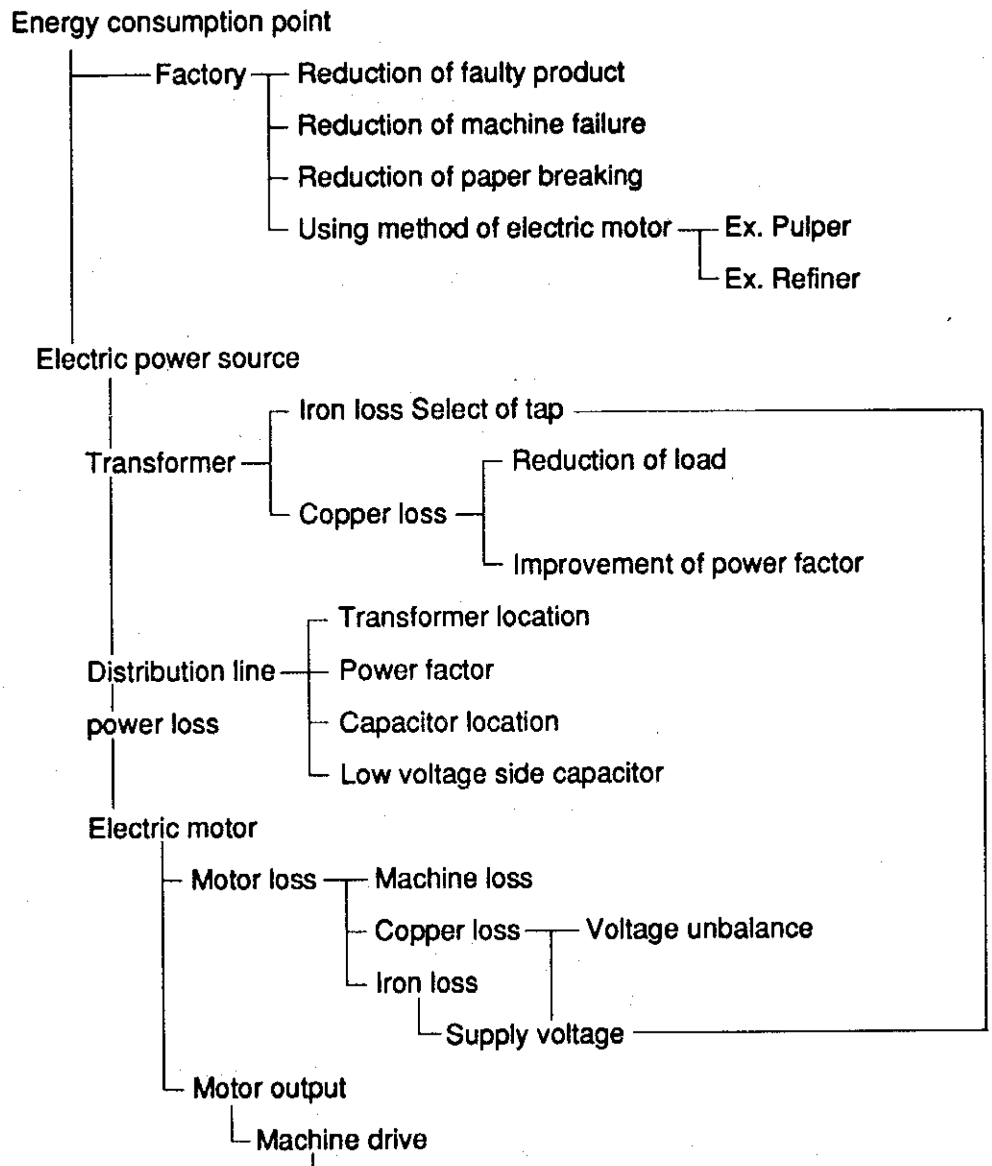
Fig. 8.2.38 Single Line Diagram of TR.5,6,7,8

8.2.3.8 Problems, countermeasures and effect in electric power

(1) Energy Consumption Point

Outline of factory's energy consumption point is shown in Figure 8.2.40.

Figure 8.2.40 Energy Consumption Point



(to continue next page)

Machine drive

- Ex. Paper machine
  - Machine drive
    - Paper load
    - Windage loss
    - Machanical loss
      - Friction loss
        - Lubrication
      - Coupling
        - Chain
        - Belt
- Ex. Pump
  - Pump loss
  - Water head
    - Load head
    - Water duct head
  - Water quantity
    - Load water volume
    - Leakage water
- Ex. Pupler
- Ex. Refiner

(2) kWh/ton Improvement

a. Management of kWh/ton

Electric power consumption (kWh) is explained with the next formula.

$$kWh = \Sigma\,(\text{each load kW}) \times (\text{operation hour}) = \Sigma\,(kW) \times (H)$$

If it is necessary to reduce electric power consumption (kWh),

1) it has to reduce each load electric power (kW).
2) it has to reduce each load operating hour (H).
   (example, pulper and refiner load)
3) it has to reduce all loss and process improvement. It is necessary to check each load characteristic and operating condition and process control. Sometime, it is possible to

select operating condition, select suitable load, and to shorten operating time, to decrease failure and loss. It will bring about a great result to accumulate small improvements.

Finally, it is necessary to reduce electric power consumption unit kWh/ton. The paper cost is a function of productivity and kWh/ton value. It is an important index of management.

b. Reduction of faulty products

The factory's faulty product volume is shown in the next Figure 8.2.41 and Table 8.2.25.

The faulty paper product volume is 6% against total input paper volume. Energy consumption is in proportion to input volume. Using faulty paper product volume energy is completely lost. Therefore, it is necessary to reduce faulty product volume for energy consumption.

Faulty product volume percentage shows directly company's quality control level.

Figure 8.2.41 Factory's Faulty Product

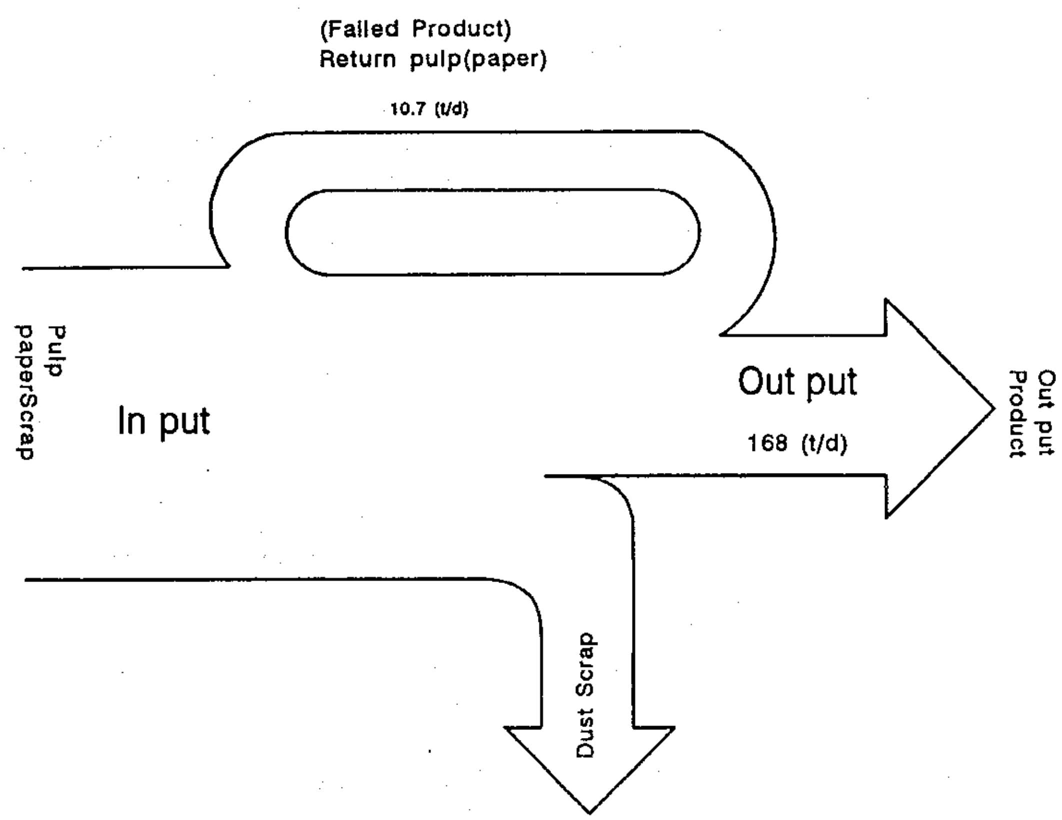


Table 8.2.25 Factory's Faulty Product

	A.Product Volume (t/D)	B. Fail Volume (t/D)	P = B/(A+B) (%)
P.M.4	20	1.2	5.7
P.M.5	28	0.3	1.1
P.M.6	60	6	9.1
P.M.7	60	3.2	5.1
	168	10.7	6.0

Energy Consumption $\propto$ In Put

Therefore, it's necessary to reduce fail Volume for energy conservation.

c. Reduction of paper breaking

Table 8.2.26 shows result of electric power consumption unit (kWh/ton) against paper breaking frequency per day.

Electric power consumption unit differs by machine and process. But, it is understood that Figure 8.2.42 shows one tendency. The paper breaking is related to faulty paper and faulty product directly. Therefore, it is necessary to reduce paper breaking frequency. It is necessary to approach paper breaking into zero.

d. Pulper driving

Pulper is a machine of high electric power consumption. Therefore, it is necessary to drive it carefully.

1) Pulper driving and demand meter relation

Next, driving condition cases are explained for easy understanding.

Number of driving pulpers: 2
Driving time: 20 min.
Not driving (stopping) time: 40 min.

Four case (I, II, III, IV) result is shown in Figure 8.2.42.

The result shows that it is most economical not to drive machines at the same time. It is an important point to be noted.

2) Factory has many pulpers

If these pulpers are driven at same time, the demand meter will measure high demand value. Therefore, it is necessary to reduce the number of pulpers driven at the same time. It is necessary to concentrate control, to control simultaneous driving of pulpers.

Table 8.2.26 Operation of Each Division

	Electric Power Consomption (kWh/Month)	Paper Product Volume (ton/Month)	Electric Power Consumption Unit (kWh/ton)	Paper Breaking (frequency/day)
P.M. 4	280791	20 x 30	468	6
P.M. 5	585931	28 x 30	698	15
P.M. 6	1929680	60 x 30	1072	6
P.M. 7	759649	60 x 30	422	3

Figure 8.2.42 Paper Breaking

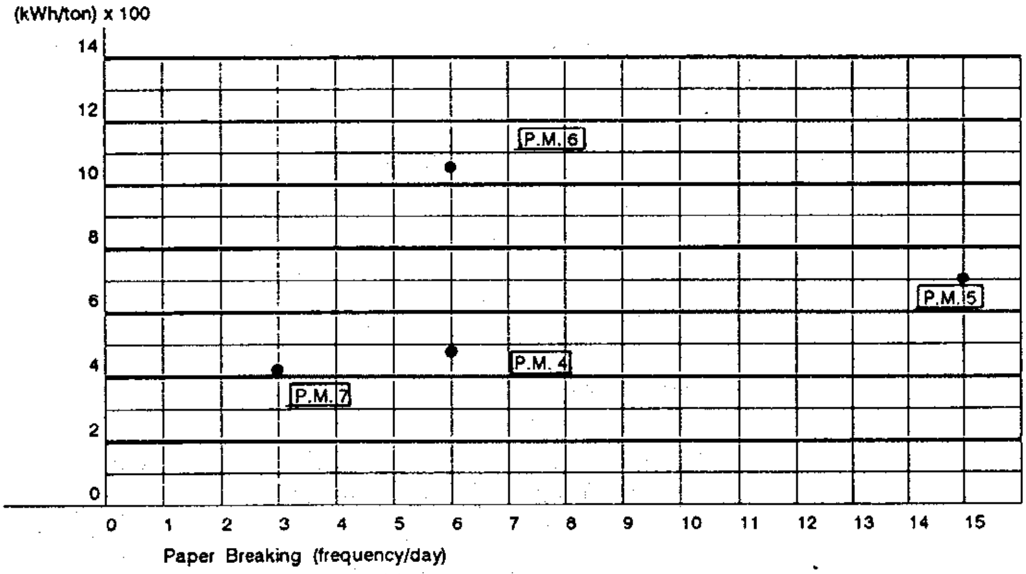
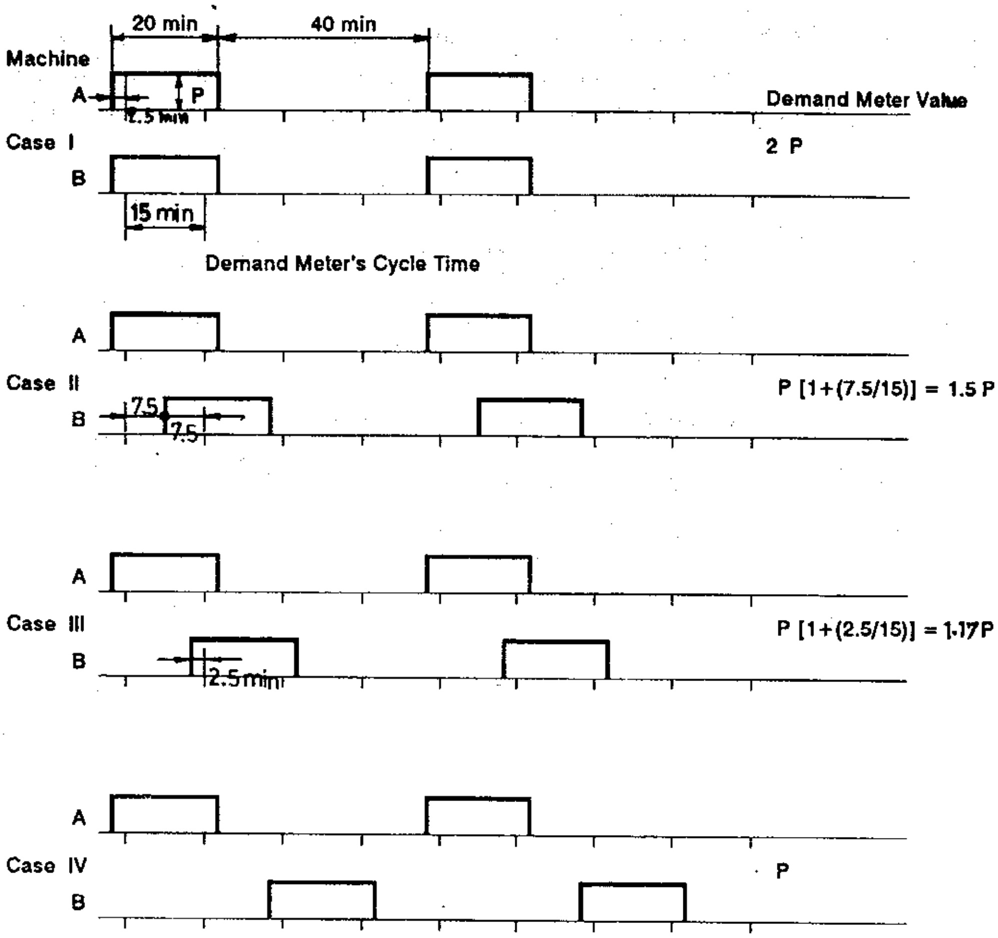


Figure 8.2.43 Driving Time of Pulper



3) According to factory's information, pulper of PM.7 operating time hour is 16 hours.

If it is possible to operate for 21 hours,
21 hr. = 24 hr. - 3 hr.(P_{ON} time)

Simple idea is to reduce charge volume,
from A to 16/21 A = 0.76 A

Note, A is current charging volume.

It is possible to reduce pulper driving electric power directly. Therefore, it is possible to reduce electric power consumption.

Because kWh varies with electric power(kW).

4) Pulper driving control panel has no control timer to drive pulper.

Therefore, pulper driving time has to fluctuate, not controlled by constant driving time. If driving time is fluctuated, electric power consumption must be fluctuated.

Because kWh varies with time.

It is necessary to put control timer, and it is possible to control pulper driving time.

5) It seemed that the factory have not many effective data. Economical drive, good operating point, and good driving are necessary.

Pulper driving power consumption may be changed.

- pulp material
- pulp volume
- water volume and
- driving time

After getting data, please check your driving condition, please analyze getting data. It is necessary to choose most economical driving point.

6) P_{ON} time electricity charge is very high. Pulper's electric power is also high. Therefore, pulper driving is necessary to avoid P_{ON} period time using chest effectively.

e) Refiner driving

1) The paper's freeness level of the factory is low.

It shows one possibility of electric power reduction. Therefore, it will be got to adjust supply liquid volume or driving time of refiner. Freeness relates to paper quality. Please check freeness and paper quality. It is expected to reduce electric power consumption by good condition of supply liquid and driving time.

2) Refiner electric power consumption level is high. Therefore, it is necessary to avoid driving at P_{on} time period using chest effectively.

f) Machine failure reduction

According to questionair reports, the factory's average shutdown time is shown in Table 8.2.27.

Presently, average shutdown time is 13.6% of total hour. It is necessary to drive high efficiency. So, continuous drive is necessary.

Not continuous drive but intermittent drive provides low efficiency drive.

Low efficiency drive results in energy consumption loss. Therefore, it is necessary to reduce machine failure, to operate machine continously. Continuous machine operation will be obtained by doing good preventive maintenance.

Table 8.2.27 Shutdown Time of Paper Machine

		Steam Consumption (ton)	Electric Power Consumtion (kWh/Month)	Water Consumption (ton)	Writing of Printing Paper (ton/day)	Board Paper (ton/day)	Average Frequency of Paper Break (per day)	Average Shut Down Time (min/day)			
								Failure	Power Failure	Cleaning	Total
P.M. 4	unbleached waste 100%	54	280791	1000	-	20	6	200	10	25	235
								235/1440 = 0.163			
P.M. 5	BNKP 20% BLKP 80%	86	585931	1000	28	-	15	90	10	24	124
								124/1440 = 0.086			
P.M.6	Bleached waste 80% BNKP 20%	270	1929680	3300	60	-	6	180	4	4	188
								188/1440 = 0.131			
P.M.7	waste 100%	96	759649	3300	-	60	3	200	10	25	235
								235/1440 = 0.163			
Total		506	3556051	8600	88	80	30	782/(4 x 1440) = 0.136			782

Reference : Questionnaire for Z CO., LTD.

Note : 1440 = 60 min x 24 hour

g) Electric power

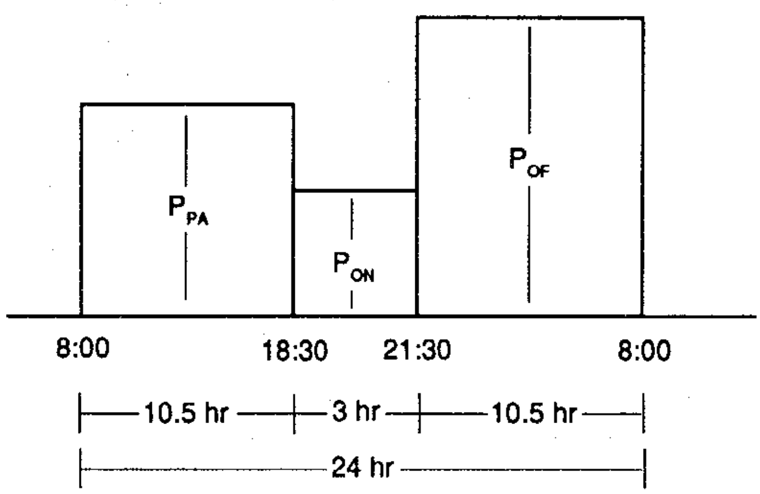
The relation of on-peak, partial peak, off peak and electricity fee can be explained by next formula.

$$Y_1 = 305P_{ON} + 63(P_{PA} - P_{ON}) + 1.07 \times (kWh)$$
$$= 242P_{ON} + 63P_{PA} + 1.07 \times (kWh)$$

It is possible to consider product volume to vary in proportion to electric power consumption (kWh).

Electric power consumption is explained by the next formula .

Figure 8.2.44 Period of Peak Demand



$$Y_2 = 10.5P_{PA} + 3P_{ON} + 10.5P_{OF}$$

But, it is assumed that each level is constant at P_{ON}, P_{PA} and P_{OF} level, and one month = 30 day.

Y_2 formula is inserted in Y_1 formula.

$$Y'_1 = 242P_{ON} + 63P_{PA} + 1.07\,[(10.5P_{PA} + 3P_{ON} + 10.5P_{OF}) \times 30]$$

Based on P_{PA} value, $P_{PA} = 1$, changing of P_{ON} and P_{OF} value, some calculation result is shown in Table 8.2.28.

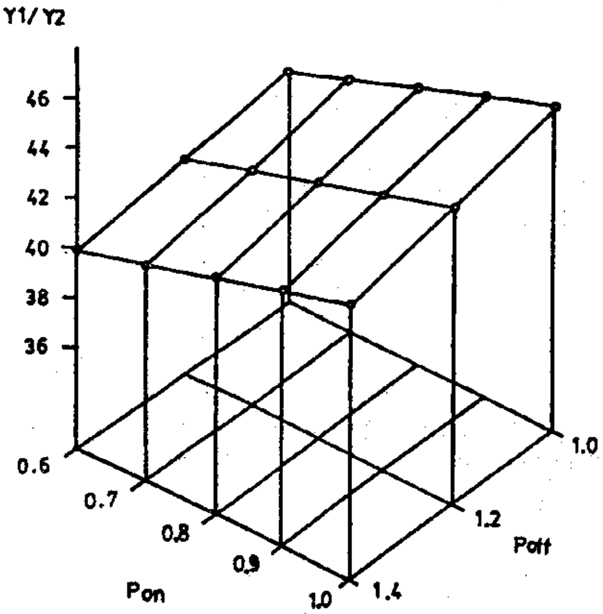
Table 8.2.28 Relation of P_{PA}, P_{ON}, P_{OF} and Y'_1/Y_2

P_{PA}	P_{ON}	P_{OF}	Y_2	Y'_1	Y'_1/Y_2
1	0.6	1.0	22.8	940.08	41.23
		1.2	24.9	1007.49	40.46
		1.4	27.0	1074.9	39.81
1	0.7	1.0	23.1	973.91	42.16
		1.2	25.2	1041.32	41.32
		1.4	27.3	1108.73	40.61
1	0.8	1.0	23.4	1007.74	43.07
		1.2	25.5	1075.15	42.16
		1.4	27.6	1145.56	41.40
1	0.9	1.0	23.7	1041.57	43.95
		1.2	25.8	1108.98	42.98
		1.4	27.8	1176.39	42.16
1	1.0	1.0	24.0	1075.40	44.81
		1.2	26.1	1142.81	43.79
		1.4	28.2	1210.22	42.92

Y'_1/Y_2 is a function of (electric price/product volume).

Result of Table 8.2.28 is shown in Figure 8.2.44.

Figure 8.2.45 Relation of Electric Price/Product Volume and P_{on} P_{off} Value



It shows that most economical case is P_{ON} down and P_{OF} up. P_{ON} down is possible to stop pulper and refiner at P_{ON} time by using chest effectively. But actually, power is not constant at level P_{ON} P_{PA} and P_{OF}, sometimes fluctuates. Additionally, sometimes machine stops. Therefore, actual product volume is explained in the next formula.

$$Y'_2 = k(10.5P_{PA}k_1 + 3P_{ON}k_2 + 10.5P_{OF}k_3)$$

k = coefficient

k_1, k_2, k_3 = coefficient (operating hour rate)

Y_2 only is explained in $k = k_1,= k_2,= k_3 = 1$ case.

Electric power consumption unit on kWh/ton value is changed by k, k_1, k_2, k_3 value.

Therefore, it is necessary to manage k_1, k_2, k_3 value to approach 1 suppressing k value.

Next, the following have to be done.

(1) Reduction of faulty product volume
(2) Reduction paper breaking — continuous
(3) Reduction machine failure stop — operating
(4) Quality control (QC)
(5) Total productive maintenance (TPM
(6) Management of factory

(3) Improvement of Power Factor

The load of each transformer was measured to find the power factor and determine the capacity of the capacitor which will be inserted into each transformer to improve the power factor.

The results of the measurement and calculation are as shown in the following Table 8.2.29 and Table 8.2.30.

Table 8.2.29 Before Improvement of Power Factor

Tr. no.	Capacity (kVA)	Apparent Power (kVA)	PF	Transformer Copper Losses (W)
1	1,600	1,228	0.82	14,019
2	1,600	1,418	0.71	14,132
3	2,000	350	0.46	1,149
4	2,000	1,118	0.84	7,924
5	2,000	334	0.64	681
6	2,500	1,440	0.63	9,964
7	1,600	748	0.82	4,576
8	1,600	862	0.70	6,028

Table 8.2.30 After Improvement of Power Factor

Tr. no.	Capacity (KVA)	Apparent Power (KVA)	PF	Transformer Copper Losses (W)	Capacitor use (Kvar)
1	1,600	1,059	0.95	10,437	375
2	1,600	1,053	0.95	7,792	675
3	2,000	168	0.95	264	260
4	2,000	986	0.95	6,167	300
5	2,000	230	0.95	322	180
6	2,500	952	0.95	4,494	800
7	1,600	649	0.95	3,445	220
8	1,600	632	0.95	3,237	425

When a capacitor is inserted into each transformer, copper loss and apparent power become reduced as shown in following Table 8.2.31.

Table 8.2.31 The Result of Saving

Tr. no.	Capacitor use (kVar)	Saving Energy (kWh/y)	Saving Cost (Baht/y)	Investment (Baht)
1	375	31,376	49,261	95,175
2	675	55,532	87,175	167,925
3	260	7,752	12,170	66,600
4	300	15,395	24,171	76,850
5	180	3,143	4,935	44,840
6	800	47,918	75,232	198,000
7	220	9,909	15,557	58,840
8	425	24,456	38,396	106,750
Total	3,235	195,481	306,897	814,980

Having measured all of eight transformers in the factory (as shown in the foregoing Table 8.2.24, we could see that their power factor values averaged quite low at ranges between 46%-84%.

In an analysis on improving the power factor as the detail calculation shown in the appendix A, we will improve a power factor of Transformer as shown in the above table through improving their power factor to be 95% for all of eight transformers, by installing capacitors at the secondary of transformers. The expenses for installing these capacitors (not included Tr.5) will include installation cost and equipment cost for totally 770,140 Baht. This will help a factory to save electrical energy in total of 192,338 kWh/year, amounting to 301,962 Baht/year as saving cost (or money saved).

Seeing the above table, we found that the investment cost to install a capacitor at Tr.5 will take a payback period for 7.5 years which is not economical cost effective. Furthermore, this has the least effect to line loss as shown at Tr.5 in the following theme, so that a factory will not have to manage for power factor improvement at Tr.5.

Tr.3 of PM.6 will load from DC motors only which has a major motor to drive a midshaft and we can see a low value of load factor only at 46%.

Installing of Capacitor

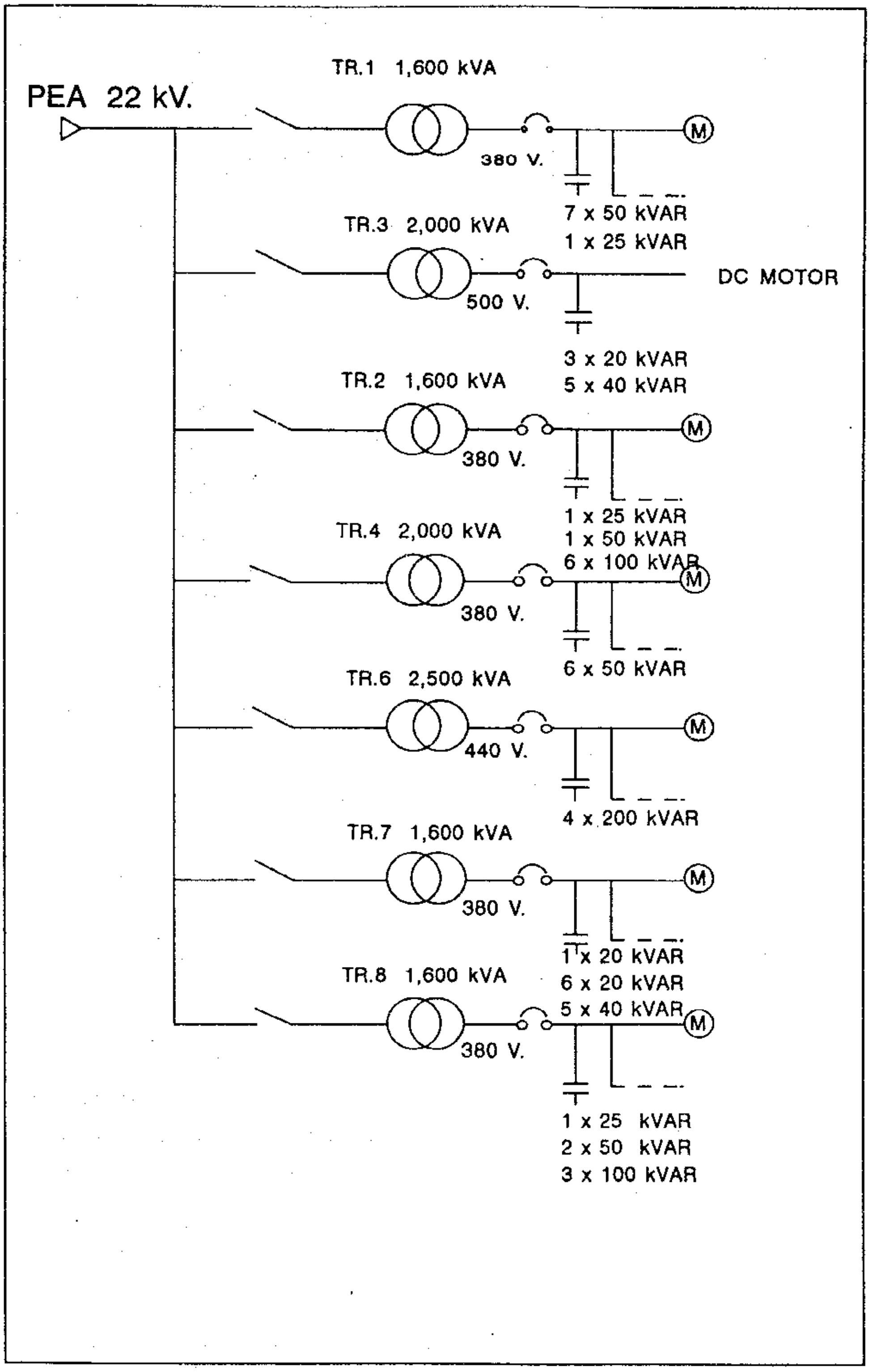
The diagram indicates capacitor installation, as shown in Figure 8.2.46 below.

At MDB of Tr.1 (PM.4) and Tr.2 (PM.5) installed continuously, and switchboard for installing the capacitor of Tr.1 and Tr.2 existing behind MDB but not in use anymore and no capacitor installed just the control set is available. It is recommended that a factory should consider to install capacitor of Tr.1 and Tr.2 of the same design size as that in the foregoing recommendation by using the existing switchboard. The installation should be made at secondary side of Tr.1 and Tr.2 which will be able to control the load for total system of each transformer.

At PM.6 that uses Tr.4, Tr.5 and Tr.6 as typical in a factory, a panal board of MDB, feeder and subload are on the same area. Thus, if the factory considers to install capacitor of the design size as recommended previously, the installation will be at panal board of PM.6 by the secondary side of these transformers. This will be a load control for a whole system of each transformer.

Tr.3 will load from DC motors. Then, the capacitors will be installed with a reactor for hamonic resonace at PM.7 which uses Tr.7 and Tr.8 in feature of panal board same as of PM.6. The installation will be the same. But at the secondary of Tr.7, there exists switchboard that is already provided with capacitor of size of 6 × 20 kVar, then we can install the additional capacitor. At the secondary of Tr.8, there exists switchboard for installing the capacitor but is not in use and no capacitor is installed. So here we can install the capacitor for using instantly.

Figure 8.2.46 Diagram Indicates Capacitor Installation



Line Losses Reduction

After providing capacitor to improve the power factor, the electric power distribution line loss is reduced.

Table 8.2.32 Saving in Line Losses

Tr. no.	Ia (A)	Ib (A)	Saving Energy (kWh/y)	Saving Cost (Baht/y)
1	1,942	1,675	1,514	2,377
2	1,950	1,448	4,581	7,191
3	425	204	373	585
4	1,673	1,475	2,666	4,186
5	490	337	653	1,026
6	1,903	1,290	3,940	6,185
7	1,109	963	1,471	2,310
8	1,273	933	3,631	5,701
Total			18,829	29,561

Remark: Ia = current before improvement
Ib = current after improvement

This table above shows line losses reduction when the power factor is improved. Total electric energy saving (not including Tr.5) is 18,176 kWh/y and cost saving is 28,535 Baht/y. The calculation is shown in Appendix B.

Total Saving after Using Capacitors

The recommendation to correct power factor and its correction will be summarized for the saving results as shown in Table 8.2.33. If a factory is able to implement, a total savings will be 210,514 kwh per year or 330,497 Baht per year though investment costs at 770,140 Baht by getting payback within 2.3 years.

Table 8.2.33 The Total Saving After Using Capacitors

Tr. no.	Capacitor use (kVar)	Tran. loss (kWh/y)	Line loss (kWh/y)	Saving Total loss (kWh/y)	Total Cost (Baht/y)	Invest-ment cost (Baht)	Payback period (year)
1	375	31,376	1,514	32,890	51,638	95,175	1.8
2	675	55,532	4,581	60,113	94,366	167,925	1.8
3	260	7,752	373	8,125	12,755	66,600	5.2
4	300	15,395	2,666	18,061	28,357	76,850	2.7
6	800	47,918	3,940	51,858	81,417	198,000	2.4
7	220	9,909	1,471	11,380	17,867	58,840	3.3
8	425	24,456	3,631	28,087	44,097	106,750	2.4
Tota	13,055	192,338	18,176	210,514	330,497	770,140	2.3

Note : Life time of capacitor is 10 years.
: Tr.5 is not included for the total saving because the payback period is about 7.5 percent too long.

(4) Separation of Tr.6 load

The secondary rating voltage of transformer No.6 is 440 volts. There are both 440-volts rated motor and 380-volts rated motor. Power voltage is also supplied to the only 380 V rated AC fan motor from the same 440/380 volt output of the 300 kVA step-down transformer. Therefore, it increases iron loss, decreasing efficiency. It is necessary to separate according to motor rating voltage as follows:

To the 440 volts motor, it is necessary to supply from transformer no.6.

To the 380 volts motor, it is necessary to supply from transformer no.5.

We can not get information of rating voltage of transformer no.6 load motors. So, we can not calculate effect of seperation of transformer no.6 load. If it is to separate transformer no.6 load, the result of effect with power factor improvement that is shown in Table 8.2.33 will change. Because transformer no.5 and no.6 load will change, no.5 load will increase, no.6 load will decrease. It is necessary to get information, and to calculate again. And if it is to separate transformer no.6 load, it is not necessary to use 300 kVA step down transformer.

(5) Improvement of Maximum Load

In paper-making process currently, one cause that affects high costs of a factory is electricity consumption during on-peak period. We could see from electricity bill shown in Table 8.2.21 that a factory has to pay electricity cost just in the on-peak period for 19,738,685 baht per year (64,717 kW × 305 baht/kW) or at 29% of the total electricity cost annually.

On measurement of electricity consumption and the use of electrical equipment and machinery, we could not perform it for the whole but only in part for major equipment. Therefore, the guideline of this recommendation is to point out the features of Parate diagram of PM.6 and of PM.7 to make the substance of load respectively. Then we can determine which paper machine should be stopped from a process during the on-peak period. The detail of measurements, Pareto Diagram and Operation Schedule of various load are shown as follows:

a. Improvement of power consumption of PM.7

Measuring results of PM.7 are shown in Figure 8.2.46 and Table 8.2.34.

Figure 8.2.47 The Results of Measuring of PM.7

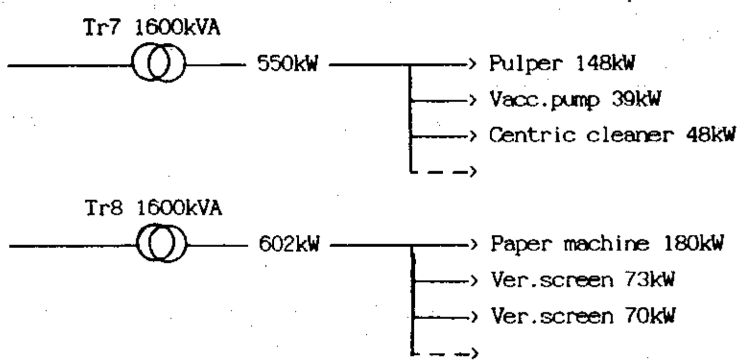


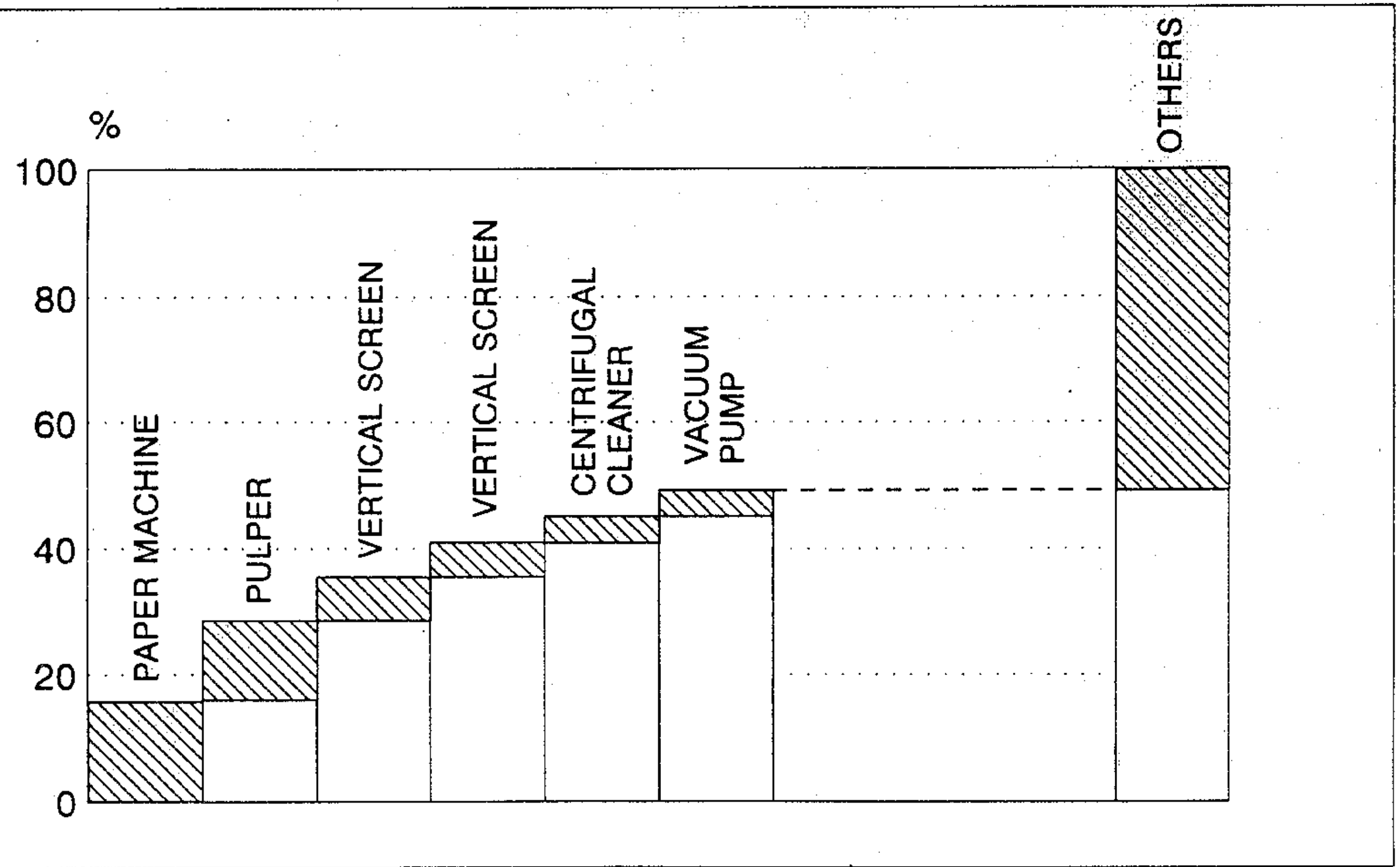
Table 8.2.34 Datas of PM.7

Total of power = 550 + 602 = 1152 kW.

Motors	kW	Sum	%
Paper machine	180	—	15.6
Pulper	148	328	28.4
Ver,screen	73	401	34.8
Ver.screen	70	471	40.8
Centric cleaner	48	519	45.0
Vácc.pump	39	558	48.4
Grand Total		1,152	100.0

These data are taken to plot the Pareto Diagram in Figure 8.2.47.

Figure 8.2.48 Pareto Diagram of P.M.7



From Pareto diagram load management can be made as follows:

Table 8.2.35 Load Management of PM.7

	P_{PA} (08:00-18:30)		P_{ON} (18:30-21:30)		P_{OFF} (21:30-08:00)	
Motors	Operating	kW	Operating	kW	Operating	kW
Paper machine	on	183	on	183	on	183
Pulper /1/ on	148	off	0	on	148	
Ver. screenon	73	on	73	on	73	
Ver. screenon	70	on	70	on	70	
Centric creaner	on	48	on	48	on	48
Vacc.pump	on	39	on	39	on	39
Total		522		339		522

Remark : /1/ a factory copes on shutdown during a on-peak period

From the above table, we consider a production process of PM.7 as shown in Figure 8.2.58 (Appendix C) in part of pulper process and refiner process having the chest for keeping the pulp. Therefore, a factory can consider that during the on-peak period, the equipment being used in part of the pulping process and the refining process should be stopped. Then, restart operating in period of partial peak and off peak. But equipment being used in paper making process is still in usual operation so that it could not affect the production. The result of recommendation as in the above table will indicate that, when a factory stops running motors during on-peak period, it will reduce electricity cost for the on-peak period. But, according to record during from Aug. 8 to Aug. 18 factory record, it is not considered to reduce electric power P_{ON} time period.

On recommendation to make an operational schedule for load of PM.7, it can be representative for PM.4 and PM.5 as well, since the process has feature almost the same, as shown in Figure 8.2.55, Figure 8.2.56 and Figure 8.2.58 of Appendix C.

b. Improvement of power consumption of PM.6

Measuring results of PM.6 are shown in Figure 8.2.49 and Table 8.2.36.

Figure 8.2.49 The Results of Measuring of PM.6

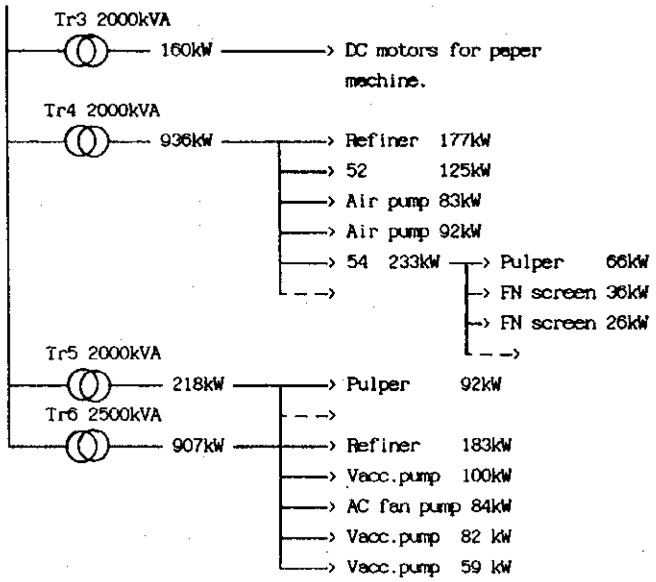


Table 8.2.36 Data of PM.6

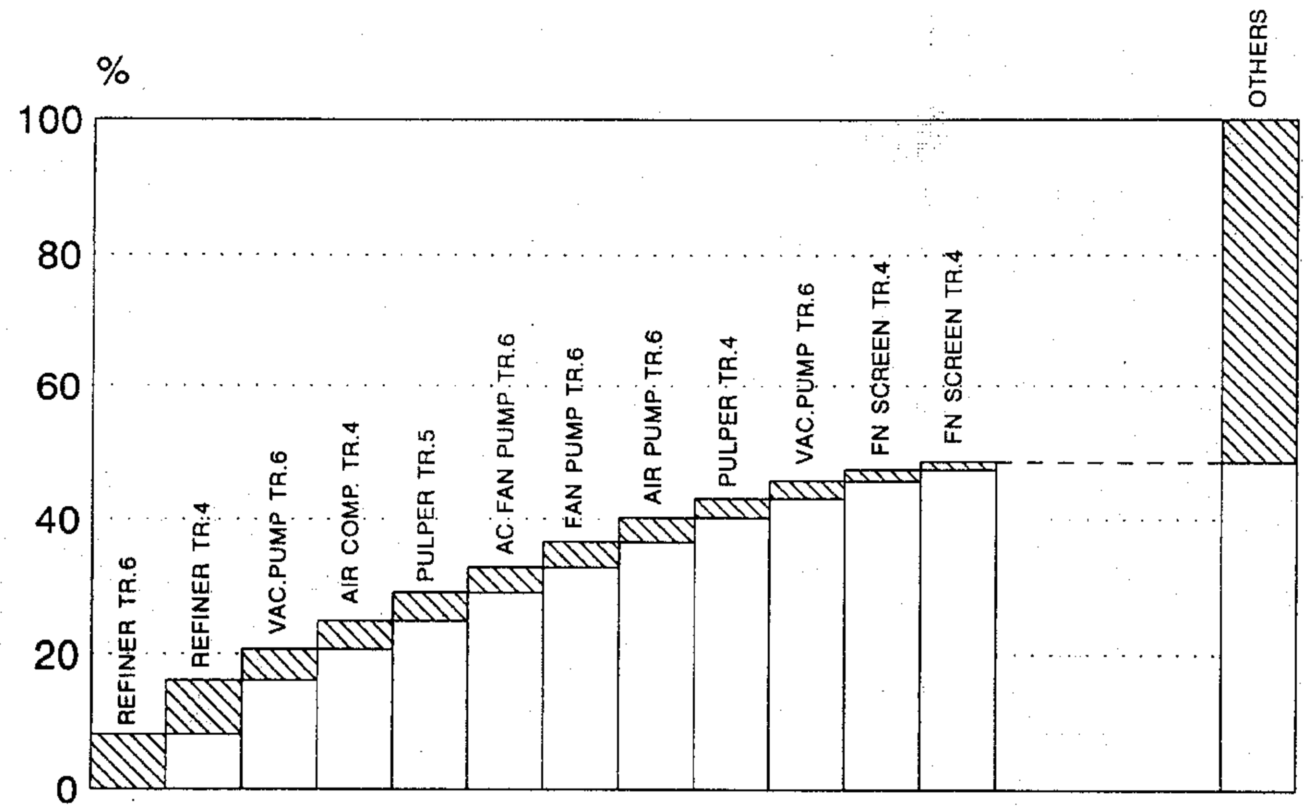
Total of power = 160 + 936 + 218 + 907 = 2221 kW.

Motors	kW	Sum	%
Refiner Tr6183	—	8.2	
Refiner Tr4177	360	16.2	
Vacc.pump Tr6	100	460	20.7
Air comp. Tr4	92	552	24.8
Pulper Tr 5	92	644	29.0
AC fan pump Tr6	84	728	32.8
Air pump Tr4	83	811	36.5
Vacc.pump Tr6	82	893	40.2
Pulper Tr4	66	959	43.2
Vacc.pump Tr6	59	1018	45.8
FN screen Tr4	36	1054	47.5
FN screen Tr4	26	1080	48.6
Grand Total	2,221	100.0	

Note : Each motor load of Tr.6 is calculated as follows:
(Rating current/Actual current) x Rating load(kW)

These data are taken to plot the Pareto Diagram in Figure 8.2.50.

Figure 8.2.50 Pareto Diagram of P.M.6



The Pareto Diagram can make a table for load management as follows:

Table 8.2.37 Load Management of PM.6

	P_{PA} (08:00-18:30)		P_{ON} (18:30-21:30)		P_{OFF} (21:30-08:00)	
Motors	Operating	kW	Operating	kW	Operating	kW
Refiner Tr6	on	183	off	—	on	183
Refiner Tr4	on	177	off	—	on	177
Vacc.pump Tr6	on	100	on	100	on	100
Air pump Tr4	on	92	on	92	on	92
Pulper Tr5	on	92	off	—	on	92
AC fan pump Tr6	on	84	on	84	on	84
Air pump Tr4	on	83	on	83	on	83
Vacc.pump Tr6	on	82	on	82	on	82
Pulper Tr4	on	66	off	—	on	66
Vacc.pump Tr6	on	59	on	59	on	59
FN screen Tr4	on	36	on	36	on	36
FN screen Tr4	on	26	on	26	on	26
Total		1,080		562		522

The electricity consumed by PM.6 is about 53 % (shown in topic (8).(b) of total electricity consumption in a factory). It is a large machine plant using most of electricity.

The production process of P.M 6 in Figure 8.2.57 (Appendix C) shows that the difference of P.M 6 from P.M 4 and P.M 5 is that the first pulper of P.M 6 has no chest to keep pulps, while its second pulper after the finishing wash process has one. The operation of P.M 6 is continuous; therefore which part of electrical equipment to be stopped should be taken into consideration. Making a table for using the motors as shown in the foregoing samples will help a factory determine such appropriate operation method as in the recommendation on reduction of electricity consumption.

The recommendation in the above table shows a production process of PM.6 in the first pulper process. There it is suggested that a chest should keep the volume of pulp for at least three hours of production. Therefore, a factory can consider that during the on-peak period, the first pulper should be stopped. Then, restart operating in period of partial peak and off peak. This result shows that the factory can stop running motors during the on-peak period also in the other process as in the above table.

(6) Analysis of Load Curve

Improving the load factor provides the following advantages:

a. Since capacity for the receiving and distribution equipment,etc. can be effectively utilized, the equipment investment costs can be saved.

b. It is possible to know operating conditions of all machines and equipment in factory and to eliminate waste by checking the load curve and load factor.

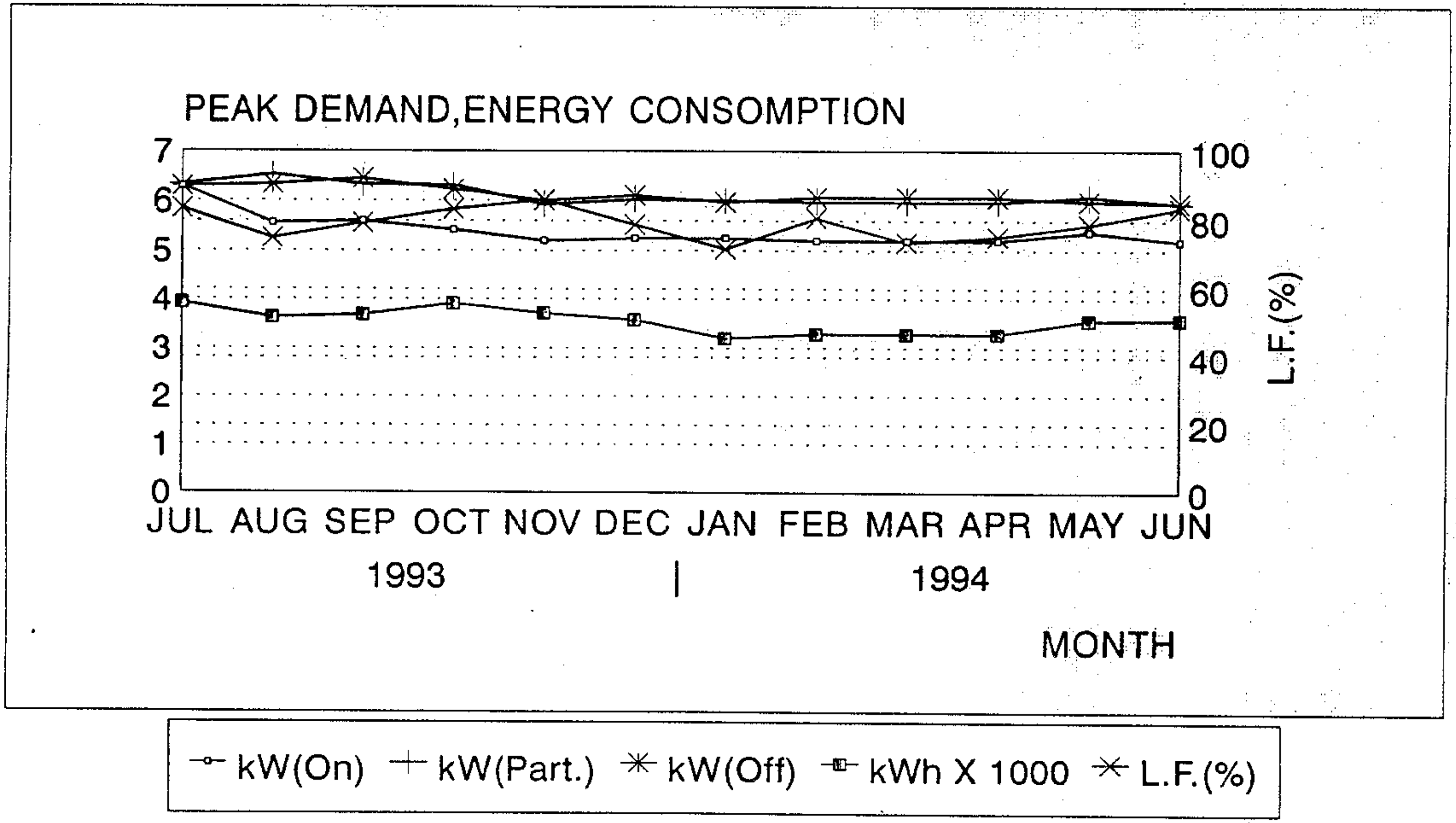
c. It is possible to reduce the demand charge by lowering the maximum power.

1) Monthly Load Curve

This load curve indicates which month registered high peak demand even with low electric consumption, that is, a low load factor as shown in July, 1993. The load curve (refer to Figure 8.2.51) plotted based on data of monthly electric consumption amount indicated on the electric bill of the factory allows the load factor to be obtained from the relationship between peak demand (in kW) and electricity consumption (in kWh). This implies the peak demand control should be improved and corrected. These months, if many, will cause higher average electricity price (baht per kWh). On the contrary, in the months in which electricity was consumed but peak demand was low, a load factor was higher (in percent), as shown in October 1993. This implies the peak demand control in a good condition and lower average electricity price. In this second case, it will be advantageous to a factory, if they can control a peak demand as low as possible without no adverse effect on the production.

Due to the reasons mentioned above, we can recommend a factory to set a target of peak demand, to determine the operational steps and arrange the schedule for machine operation. The pulper and the refiner to be used in the typical process may be operated during the peak period (6:30 pm ~ 9:30 am), but stopping of its operation should be taken into account. In addition, such equipment as attached on machines but not so necessary should be temporarily stopped until the on-peak period is over, and then started again according to their operation procedure. If a factory can manage this, it will make a peak demand lower and a load factor higher as well.

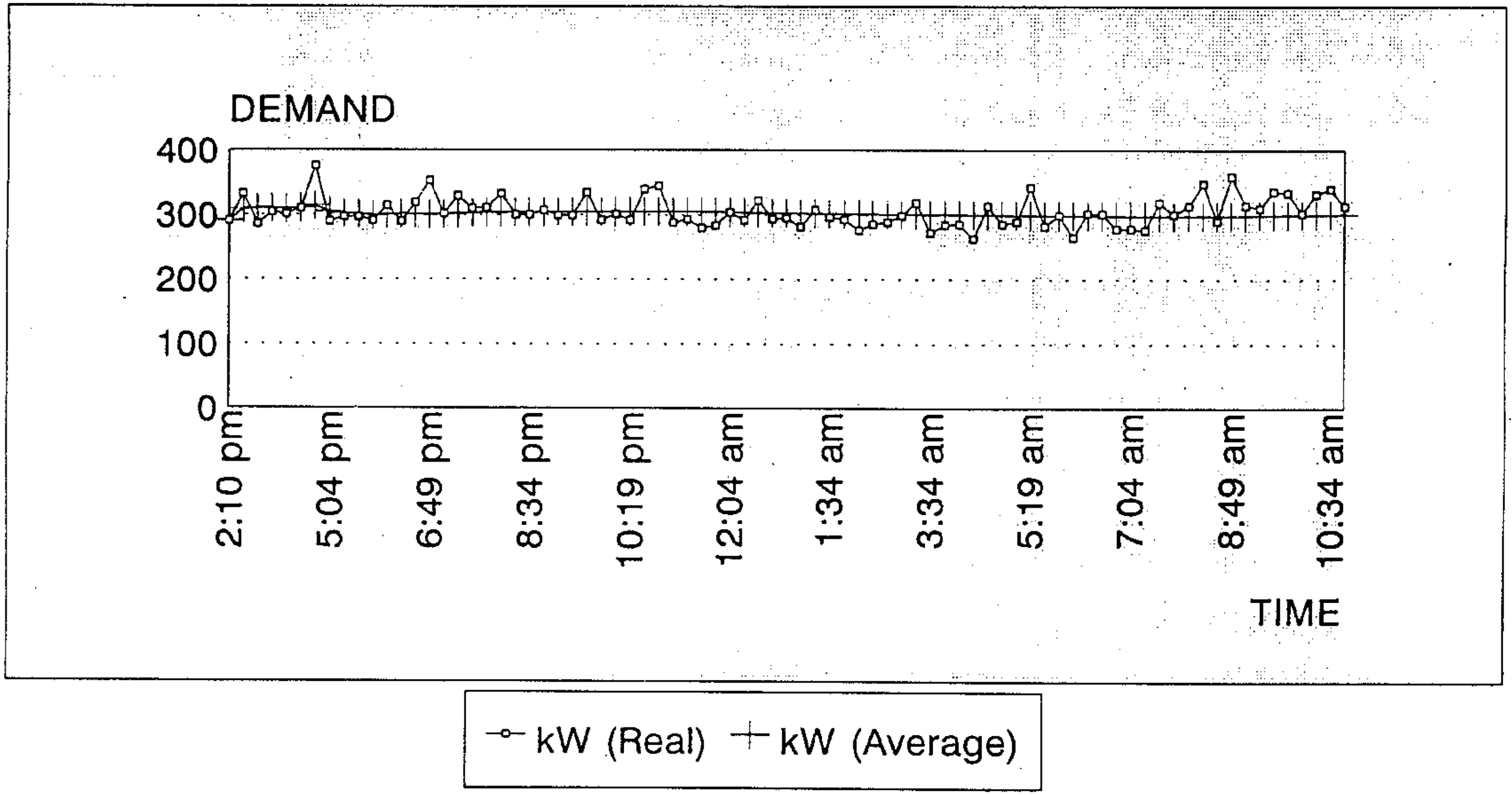
Figure 8.2.51 Monthly Load Curve



2) Daily Load Curve

Having measured at Tr.7 and Tr.8 of PM.7 and at Tr.4 of PM.6, then taking such data to plot a curve indicated in Figure 8.2.52, Figure 8.2.53 and Figure 8.2.54, we can see that the demand during the on-peak period of PM.7 is cut and unnecessary loads are put out of a process such as: Pulper (2 × 200 hp), Separator (100 hp and 50 hp), Pump (2 × 25 hp), and Water pump (30 hp). On the other hand, measurig some load of Tr. 4 of P.M 6 indicates continuous operation without cutting load out of a process during the peak period. Based on those measured data, we recommend that at PM.6 if a factory considers to cut some unnecessary load out of a process during the on peak period, such as to stop operating Pulper or Refiner in case the pulp in chest exsits sufficiently or to stop operating some equipment that is not necessary to operate during this time, it will help a factory reducing much of peak demand. That means a factory can reduce its electricity cost so much. This recommendation will also cover PM.4 and PM.5.

Figure 8.2.52 Daily Load Curve of TR.4 (P.M.6)



94/07/19 - 94/07/20

Figure 8.2.53 Daily Load Curve of TR.4 (P.M.6)

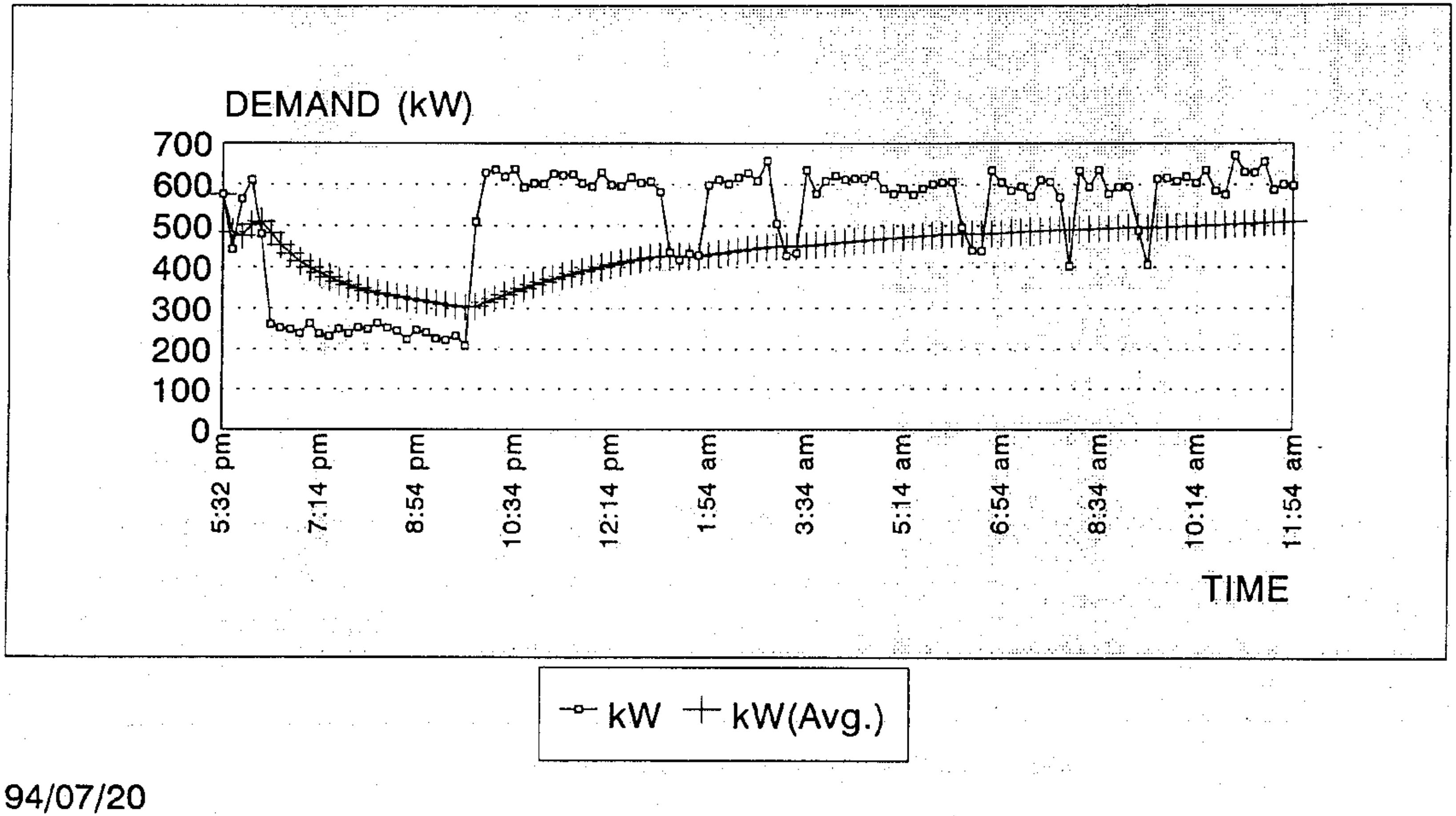
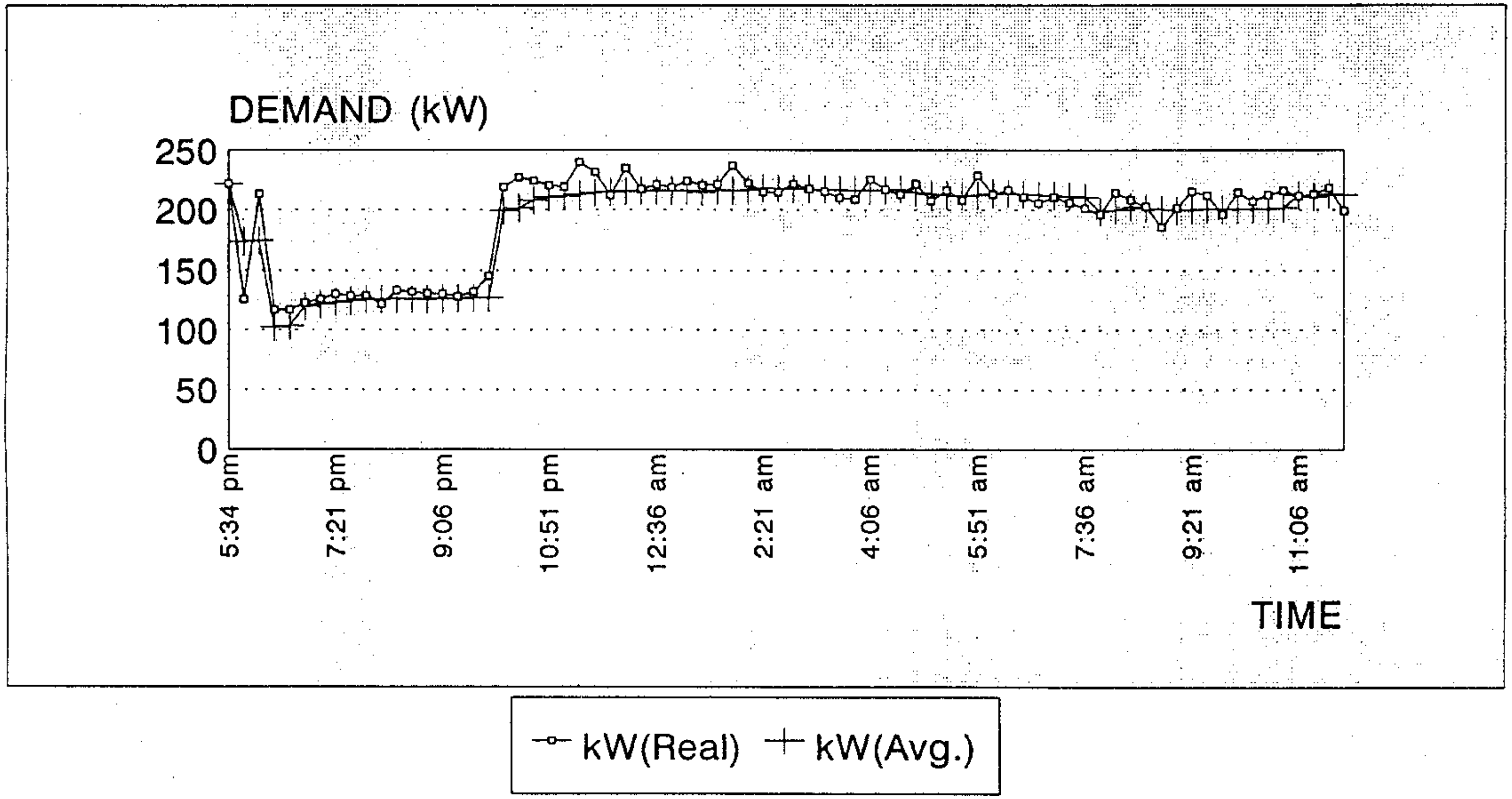


Figure 8.2.54 Daily Load Curve of TR.8 (P.M.7)



94/07/20 - 94/07/21

(7) Operation of Motors

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

Three of the motors are being operated below 55 percent of the rated current : 50.9% for the FN screen 2 (75HP) and 35.1% for pulper (200HP) in Tr. 4 and 54% for the vertical screen (175HP) in Tr. 8.

Table 8.2.38 Operation of Motors

Tr. no.	Use for:	Rating Output (HP)	Rating current (A)	Load current (B)	(B)/(A) (%)
4	FN screen 1	75	99	68	68.7
4	FN screen 2	75	108	55	50.9
4	Pulper Tr4	200	305	107	35.1
4	Air comp.	200	280	254	90.7
7	Pulper Tr5	200	305	272	89.2
7	Vacc. pump	75	108	75	69.4
7	Cleaner pump	75	103	90	87.4
8	Ver.screen 1	175	237	128	54.0
8	Ver.screen 2	125	174	125	73.6

The table shows how motors are being operated. If the load current is at a lower level than the rated one, find the cause and carry out some proper remedies such as reducing the number of motors in operation or making them smaller in capacity. The calculated motor change of FN screen 2 is shown in the following example (only one example).

MOTOR CHANGE

FORMULA

Iron loss = kW x (1/eff−1) x %Iron loss

Copper loss = kW x (1/eff−1) x %Copper loss x (L.F.)^2

MOTOR NAME FN SCREEN (2)

Measuring load	26.00	kW
	381.00	V
	55.00	A
	0.716	PF

EXISTING MOTOR			**CHANGE TO**		
Capacity	55.00	kW	Capacity	37.00	kW
Efficiency	90.50	%	Efficiency	90.50	%
Power factor	0.840		Power factor	0.870	
EXISTING LOSS			**LOSS AFTER IMPROVEMENT**		
Iron loss	1.732	kW	Iron loss	1.165	kW
Copper loss	1.017	kW	Copper loss	1.100	kW
Total loss	2.749	kW	Total loss	2.265	kW

SAVING

Loss saving	0.484	kW
Energy saving	4243.33	kWh/year
Money saving	6662	Baht/year

Remark :

L.F.	=	(kVA actual / kVA rated)
kVA actual	=	(kW load / PF load)
kVA rated	=	[kW rated / (eff x PF rated)]
% Iron loss	=	30.00 %
% Copper loss	=	70.00 %
Electricity price	=	1.570 Baht/kWh

Program by : VIRAT SONGNGAM

Printed date 12/09/94

Printed time 12:28:30

From the calculation result, a motor of FN screen2 has a suitability for changing from rating of 55 kW to that of 37 kW. This can make electricity saving for 4,243 kWh per year, amounting to 6,692 baht per year as money saving. A substantial problem is how to do with the 55 kW motor that was taken off, since keeping it is not cost effective. This will depend on consideration of a factory. If a factor keeps some spare motors, that changing will be arranged instantly, or a factor has planned to purchase some new motors. It can also provide a motor of desired rating to change alternately as needed at FN screen2.

If motor is changed, it is necessary to check again condenser capacity, which will be small capacity.

(8) Others

a. Transformer Tap Changing

The secondary voltage of the transformer no.5 (2000kVA) was found to have been kept at rather a high level of 393 volts against motor rating voltage. Tap should be changed to lower the secondary voltage down to the normal level of 383 volts for motor. Then, power loss in the transformer could be reduced and the power factor of motors and other equipment should be improved by 3 to 5 percent.
A reduction of power loss in the transformer will be :

$$2{,}000 \text{ kVA} \times (1-0.986) \times 0.2 \times \{(393/383)^2 - 1\} \times 8{,}400 \text{ h/y}$$
$$= 2{,}488 \text{ kWh/y}$$

A resultant saving of money will amount to :

$$2{,}488 \text{ kWh/y} \times 1.57 \text{ Baht/kWh} = 3{,}907 \text{ Baht/y.}$$

b. Meters on the Incoming Panal

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

I. In order to get good result of electric power consumption, it is necessary to get record of kWh, kW, PF, etc.

II. And, it is necessary to control and to improve using control chart. Control chart is a method of quality control. Control chart, kWh, kW, kWh/t, driving time and other process control have to be used:

III. In addition to using a control chart, it is necessary to analyze record periodically.

It will be possible to do management of electric power consumption.

c. No Load of Motors

Avoid operating any unload motor while it operates for unload. Electric power that motor takes will lose all including iron loss, copper loss, power loss due to friction loss, and windage loss from ventilating fan. Therefore we must stop operating that motor while there is no load, if possible.

d. Belts

In examination we found that, there were the loose belts used in many places. This causes reduced efficiency of power transmission of motor and increased loss. Motor needs power for surplus, which causes the unnecessary power loss. Hence, we should adjust the motor belts to be always at good condition.

e. Lubrication

In a process of energy conservation for lubrication of equipment within a factory, reducing friction during their operations on lubrication will cause resistance and high friction to the equipment in operation. Motors have to run heavier and consume much more electricity. Therefore, a factory must pay more for electricity cost as well, this which will be not good or benefitial to a factory.

Moreover, the finding from a survey reveals that so much lubrication is provided to several motors that they are over greased outside. From an interview we found that lubrication is made daily for some motors, which is not the correct operation. It will cause some damages to motors, if grease gluts into a stator.

Hence, we recommend that a factory should set up a schedule for lubricating the equipment by grease periodically, thus preventing the shortage of lubrication.

f. Lighting

In discussion with engineers in a factory,we knew that electricity consumption for lighting was very low and less than 1% of the total electricity consumption. However, we should not neglet at all, because we have to do in a factory whatever can be managed for saving. This means that the factory should consider the reduction on costs of a factory by such means as adding the skylight (by using transparent-clear material for roof) on a factory roof to increase the light inside a factory. It is advisable to reduce the lamps or some part of lamp-usage.

g. Conservation of Water Volume

Water volume is in proportion to electric power of pump. Therefore, it is necessary to reduce water volume used for operation.

8.2.3.8 Summary of the improvement effects

(1) Reduction of paper breaking

The frequency of paper breaking in Japanese printing & writing paper manufacturing process is 0.1 ~ 0.2 times/day. The following measures will reduce the frequency of paper breaking from six times/day to once/day.

a. Countermeasures for prevention of mixture of dust

1) The scatter of sawdust used as fuel should be prevented.

For the paper machine room and the finishing room, the window, the door and the wall should be so modified as to allow the fresh outside air to let in, thus preventing the intrusion of the polluted outside air as much as possible.

2) Prohibition of stamping down waste paper with shoes on

Shoes must always be removed before entering the paper machine and the finishing room. (The countermeasure will be to make a shoes cleaner available or to make people change their shoes)

3) Installation and control of dedusting equipment

A centri-cleaner should be installed, and also its preventive maintenance should be enforced. Gauges should be installed at both entry and exit sides, thereby allowing the equipment to function properly by means of controlling the differential pressure.

(2) Improvement of the dryer hood and ventilation

28% of evaporated steam leaks into the room due to insufficient maintenance of the hood, thus worsening the operating environment of the paper machine. Poor ventilation of the dryer part makes the moisture in the all width direction uneven, forming a factor for which overdrying of 1.6 ~ 2.0% cannot be avoided.

a. It is recommendable in terms of both product quality and the production cost to make the paper moisture approximately 6%. This will allow increasing the yield by as much as 4.2% and also reducing steam consumption rate. The side wall for the hood should be fully reinforced and also pocket ventilation should be improved.

b. The temperature inside the existing hood and on the ceiling was 48°C.
The hood should be improved so as to keep the temperature inside the hood at 55°C and thus to control the exhaust air. This will reduce exhaust air by 10% and also electric power for the exhaust fan by 10%.

(3) Arrangement of dryers

The effective use of a doctor for removing the paper dust attached on the surface of the dryer will improve the heat conductivity and increase the evaporation efficiency. Even under the current situation, the drying equipment have still surplus capacity even if 6 ~ 7 dryers are to be stopped, and this is estimated to reduce 10 ~ 15% of the total electric power for operating the dryers.

(4) Increase of press line pressure

By improving the equipment, the moisture of wet paper after pressing should be reduced by 1%. This reduction of moisture by 1% allows decreasing dryer steam by 4%, thus making the payback period for the equipment investment shorter.

(5) Reconsideration on finishing freeness

The freeness of printing & writing paper is ideally 450 ~ 500 cc (csf). For the refiner to obtain the freeness of 100 cc, electric power of 80 ~ 100 kWh/pulp ton is consumed. Since the current freeness is approximately 350 cc, approximately 90 kWh/pulp ton can be saved. (This shall also apply to paper without yield taken into consideration.)

(6) Improvement of the transformer power factor

(7) Change of the transformer tap

List of Summary of Energy Conservation Improvements for the Pulp and Paper Mill

Fuel oil price: 3040 Baht/kl = 3.24 Baht/kg
Steam price: 0.582 kl/7.5t × 3040 = 236 Baht/ton
Electric power price: 1.57 Baht/kWh
Production amount of No. 6 paper machine: 18,000 t/y

Improvement item	Installation cost (Baht)	Energy savings (Baht/y)	Payback period (year)
Heat management			
1. Heat insulation of the steam pipe (Oil: 9,024, 62 kg/y)	Baht 10,978.-	9,024.62 kg/y × 3.24 Baht/kg = 29,240 Baht/y	0.38 y
2. Paper machine (No. 6 Paper Machine)			
2.1 Reduction of paper breaking (Increase of working ratio by 1.5%) (Downtime of paper breaking: 5 min/time)	Nil	Steam: 2.65 t/t-paper × 0.015 = 0.04 t/t-paper 0.04 × 18000 t/y × 236 Baht/t = 169,920 Baht/y Electricity: 803 kWh/t-paper × 0.015 = 12 kWh/t-paper 12 × 18000 t/y × 1.57 Baht/kWh = 339,120 Baht/y Total = 169,920 + 339,120 = 509,040 Baht/y	
2.2 Improvement of ventilation and the hood equipment (No. 6 PM) 1) Increase of paper moisture (1.6%~6%) 2) Raising of dew point (48°C~55°C)	Baht 2,500,000.-	804/0.96 kWh/t-paper - 804 = 33 kWh/t-paper 803 kWh/t-paper × 0.1 = 80 kWh/t-paper Total = 33 + 80 = 113 kWh/t-p 113 × 18000 t/y × 1.57 Baht/kWh = 3,193,380 Baht/y	0.78 y
3. Dryer (No.6 PM) Effective use of dryers	Baht 500,000.-	804 kWh/t-paper × 0.1 = 80 kWh/t-paper 80 × 18000 t/y × 1.57 Baht/kWh = 2,260,800 Baht/y	0.22 y
4. Press part (No. 6 PM) Enhancement of dehydration efficiency (1%)	Baht 1,200,000.-	Steam: 2.63 t/t-paper × 0.043 = 0.11 t/t-paper 0.11 × 18000 t/y × 236 Baht/t = 467,280 Baht/y	2.59 y
5. Refiner (No. 6 PM) Increase of finishing freeness (Increase by 100 cc)	Nil	90 kWh/t-paper 90 × 18000 t/y × 1.57 Baht/kWh = 2,543,400 Baht/y	

Improvement item	Installation cost (Baht)	Energy savings (Baht/y)	Payback period (year)
Management of Electricity			
1. Improvement of transformer power factor (210,514 kWh/y to be saved)	Baht 770,140.-	330,497 Baht/y	2.33 y
2. Change of transformer tap (2,488 kWh/y to be saved)	Nil	3,907 Baht/y	
Total	B$ 4,981,118.-	9,337,544 Baht/y	0.53 y

Saving Ratio

Electric power: $((12 + 113 + 80 + 90) \times 18000 + 210514 + 2488)/44231000 = 5523000/44231000 = 0.125$

Fuel oil: $(9024 \times 1.07/1000 + (0.04 + 0.11) \times 18000 \times 0.582/7.5)/7235 = 219/7235 = 0.03$

APPENDIX A

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR.1 (P.M.4)	
Capacity of Transformer	1600.00	kVA
Efficiency (eff)	98.59	%
Rated sec. voltage	400.00	V
Rated current (Ir)	2309.40	A
Iron Losses (at 75 deg. C)	2850	W
Copper Losses (at 75 deg. C)	20650	W (at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	1008.00	kW	Active Power	1008.00	kW
Apparent Power	1227.77	kVA	Apparent Power	1059.38	kVA
Reactive Power	700.97	kVar	Reactive Power	325.92	kVar
Power Factor	0.821		Power Factor	0.9515	
Actual sec. voltage	365.00	V	Actual sec. voltage	365.00	V
Actual current (Ia)	1942.07	A	Actual current (Ib)	1675.71	A
Iron Losses	2850	W	Iron Losses	2850	W
Copper Losses	14019.11	W	Copper Losses	10437.32	W

Work hour	8760.00	h/y
Electricity price	1.57	baht/kWh
To use capacitor	375	kVar (Approximate)

FORMULA

Copper loss reduction = kVA x (1 – eff) x % CU loss x [(Ia/Ir) ^ 2 – (Ib/Ir) ^ 2]
x Work hour per year

SAVING

Energy saving	31376.44	kWh/year
Money saving	49261	Baht/year

Program by : VIRAT SONGNGAM
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Printed Time 13:12:38

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR.2 (P.M.5)	
Capacity of Transformer	1600.00	kVA
Efficiency (eff)	98.59	%
Rated sec. voltage	400.00	V
Rated current (Ir)	2309.40	A
Iron Losses (at 75 deg. C)	2850	W
Copper Losses (at 75 deg. C)	20650	W (at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	1000.00	kW	Active Power	1000.00	kW
Apparent Power	1418.44	kVA	Apparent Power	1053.30	kVA
Reactive Power	1005.97	kVar	Reactive Power	330.81	kVar
Power Factor	0.705		Power Factor	0.949	
Actual sec. voltage	420.00	V	Actual sec. voltage	420.00	V
Actual current (Ia)	1949.85	A	Actual current (Ib)	1447.91	A
Iron Losses	2850	W	Iron Losses	2850	W
Copper Losses	14131.70	W	Copper Losses	7792.45	W

Work hour	8760	h/y
Electricity price	1.57	baht/kWh
To use capacitor	675	kVar (Approximate)

FORMULA

Copper loss reduction = kVA x (1 – eff) x % CU loss x [(Ia/Ir) ^ 2 – (Ib/Ir) ^ 2]
x Work hour per year

SAVING

Energy saving	55531.81	kWh/year
Money saving	87185	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 16:27:07

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR.3 (P.M.6)		
Capacity of Transformer	2000.00	kVA	
Efficiency (eff)	98.66	%	
Rated sec. voltage	600.00	V	
Rated current (Ir)	1924.50	A	
Iron Losses (at 75 deg. C)	3250	W	
Copper Losses (at 75 deg. C)	24000	W	(at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	160.00	kW	Active Power	160.00	kW
Apparent Power	350.11	kVA	Apparent Power	167.91	kVA
Reactive Power	311.41	kVar	Reactive Power	50.92	kVar
Power Factor	0.457		Power Factor	0.953	
Actual sec. voltage	476.00	V	Actual sec. voltage	476.00	V
Actual current (Ia)	424.65	A	Actual current (Ib)	203.66	A
Iron Losses	3250	W	Iron Losses	3250	W
Copper Losses	1149.25	W	Copper Losses	264.33	W

Work hour	8760	h/y	
Electricity price	1.57	baht/kWh	
To use capacitor	260	kVar	(Approximate)

FORMULA

Copper loss reduction = kVA x (1 − eff) x % CU loss x [(Ia/Ir) ^ 2 − (Ib/Ir) ^ 2] x Work hour per year

SAVING

Energy saving	7751.89	kWh/year
Money saving	12170	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 16:21:36

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR. 4 (P.M.6)	
Capacity of Transformer	2000.00	kVA
Efficiency (eff)	98.66	%
Rated sec. voltage	400.00	V
Rated current (Ir)	2886.75	A
Iron Losses (at 75 deg. C)	3250	W
Copper Losses (at 75 deg. C)	24000	W (at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	936.00	kW	Active Power	936.00	kW
Apparent Power	1118.28	kVA	Apparent Power	986.51	kVA
Reactive Power	611.93	kVar	Reactive Power	311.62	kVar
Power Factor	0.837		Power Factor	0.9488	
Actual sec. voltage	386.00	V	Actual sec. voltage	386.00	V
Actual current (Ia)	1672.64	A	Actual current (Ib)	1475.55	A
Iron Losses	3250	W	Iron Losses	3250	W
Copper Losses	7924.39	W	Copper Losses	6166.90	W

Work hour	8760.00	h/y
Electricity price	1.57	baht/kWh
To use capacitor	300	kVar (Approximate)

FORMULA

Copper loss reduction = kVA x (1−eff) x % CU loss x [(Ia/Ir)^2 − (Ib/Ir)^2]
x Work hour per year

SAVING

Energy saving	15395.55	kWh/year
Money saving	24171	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 07/09/94
Printed Time 11:18:54

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR. 5 (P.M.6)	
Capacity of Transformer	2000.00	kVA
Efficiency (eff)	98.66	%
Rated sec. voltage	400.00	V
Rated current (Ir)	2886.75	A
Iron Losses (at 75 deg. C)	3250	W
Copper Losses (at 75 deg. C)	24000	W (at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	218.00	kW	Active Power	218.00	kW
Apparent Power	333.84	kVA	Apparent Power	229.69	kVA
Reactive Power	252.84	kVar	Reactive Power	72.35	kVar
Power Factor	0.653		Power Factor	0.9491	
Actual sec. voltage	393.00	V	Actual sec. voltage	393.00	V
Actual current (Ia)	490.44	A	Actual current (Ib)	337.44	A
Iron Losses	3250	W	Iron Losses	3250	W
Copper Losses	681.30	W	Copper Losses	322.51	W

Work hour	8760.00	h/y
Electricity price	1.57	baht/kWh
To use capacitor	180	kVar (Approximate)

FORMULA

Copper loss reduction = kVA x (1 − eff) x % CU loss x [(Ia/Ir)^2 − (Ib/Ir)^2]
x Work hour per year

SAVING

Energy saving	3143.04	kWh/year
Money saving	4935	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 07/09/94
Printed Time 11:24:23

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR.6 (P.M.6)		
Capacity of Transformer	2500.00	kVA	
Efficiency (eff)	98.66	%	
Rated sec. voltage	440.00	V	
Rated current (Ir)	3280.40	A	
Iron Losses (at 75 deg. C)	3700	W	
Copper Losses (at 75 deg. C)	28200	W	(at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	907.00	kW	Active Power	907.00	kW
Apparent Power	1417.19	kVA	Apparent Power	951.76	kVA
Reactive Power	1088.93	kVar	Reactive Power	288.45	kVar
Power Factor	0.640		Power Factor	0.953	
Actual sec. voltage	430.00	V	Actual sec. voltage	430.00	V
Actual current (Ia)	1902.82	A	Actual current (Ib)	1277.91	A
Iron Losses	3700	W	Iron Losses	3700	W
Copper Losses	9964.29	W	Copper Losses	4494.15	W

Work hour	8760.00	h/y	
Electricity price	1.57	baht/kWh	
To use capacitor	800	kVar	(Approximate)

FORMULA

Copper loss reduction = kVA x (1 − eff) x % CU loss x [(Ia/Ir) ^ 2 − (Ib/Ir) ^ 2]
x Work hour per year

SAVING

Energy saving	47918.39	kWh/year
Money saving	75232	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 17:46:15

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR.7 (P.M.7)		
Capacity of Transformer	1600.00	kVA	
Efficiency (eff)	98.59	%	
Rated sec. voltage	400.00	V	
Rated current (Ir)	2309.40	A	
Iron Losses (at 75 deg. C)	2850	W	
Copper Losses (at 75 deg. C)	20650	W	(at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	616.00	kW	Active Power	616.00	kW
Apparent Power	747.57	kVA	Apparent Power	648.63	kVA
Reactive Power	423.57	kVar	Reactive Power	203.12	kVar
Power Factor	0.824		Power Factor	0.950	
Actual sec. voltage	389.00	V	Actual sec. voltage	389.00	V
Actual current (Ia)	1109.54	A	Actual current (Ib)	962.68	A
Iron Losses	2850	W	Iron Losses	2850	W
Copper Losses	4575.93	W	Copper Losses	3444.77	W

Work hour	8760.00	h/y	
Electricity price	1.57	baht/kWh	
To use capacitor	220	kVar	(Approximate)

FORMULA

Copper loss reduction = kVA x (1 − eff) x % CU loss x [(Ia/Ir) ^ 2 − (Ib/Ir) ^ 2]
x Work hour per year

SAVING

Energy saving	9908.91	kWh/year
Money saving	15557	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 18:05:39

POWER FACTOR CORRECTION

DATA OF TRANSFORMER

Transformer name	TR.8 (P.M.7)		
Capacity of Transformer	1600.00	kVA	
Efficiency (eff)	98.59	%	
Rated sec. voltage	400.00	V	
Rated current (Ir)	2309.40	A	
Iron Losses (at 75 deg. C)	2850	W	
Copper Losses (at 75 deg. C)	20650	W	(at full load)

BEFORE IMPROVEMENT			AFTER IMPROVEMENT		
Active Power	602.00	kW	Active Power	602.00	kW
Apparent Power	862.46	kVA	Apparent Power	631.95	kVA
Reactive Power	617.61	kVar	Reactive Power	192.26	kVar
Power Factor	0.698		Power Factor	0.953	
Actual sec. voltage	391.00	V	Actual sec. voltage	391.00	V
Actual current (Ia)	1273.51	A	Actual current (Ib)	933.14	A
Iron Losses	2850	W	Iron Losses	2850	W
Copper Losses	6028.37	W	Copper Losses	3236.60	W

Work hour	8760.00	h/y	
Electricity price	1.57	baht/kWh	
To use capacitor	425	kVar	(Approximate)

FORMULA

Copper loss reduction = kVA x (1 − eff) x % CU loss x $[(Ia/Ir)^2 - (Ib/Ir)^2]$ x Work hour per year

SAVING

Energy saving	24455.87	kWh/year
Money saving	38396	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 18:09:53

APPENDIX B

LINE LOSS REDUCTION

DATA OF CONDUCTOR TR.1 (P.M.4)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	500.00	sq.mm
Quantity of conductor	8.00	line/phase
Distance of conductor (L)	13.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.0354	Ohm/km/Conductor
Current before improvement (Ia)	1942.07	A
Current after improvement (Ib)	1675.71	A
Work hour	8760	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia^2−Ib^2) x Rt x [1 + Tc (tw−20)] x L x work hour / 10^6

SAVING

Energy saving	1514.01	kWh/year
Money saving	2377	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 15:17:01

LINE LOSSES REDUCTION

DATA OF CONDUCTOR TR.2 (P.M.5)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	300.00	sq.mm
Quantity of conductor	6.00	line/phase
Distance of conductor (L)	10.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.059	Ohm/km/Conductor
Current before improvement (Ia)	1949.85	A
Current after improvement (Ib)	1447.91	A
Work hour	8760	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia ^ 2−Ib ^ 2) x Rt x [1 + Tc (tw−20)] x L x work hour / 10 ^ 6

SAVING

Energy saving	4580.49	kWh/year
Money saving	7191	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 16:06:34

LINE [illegible] REDUCTION

DATA OF CONDUCTOR TR.3 (P.M.6)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	300.00	sq.mm
Quantity of conductor	6.00	line/phase
Distance of conductor (L)	10.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.059	Ohm/km/Conductor
Current before improvement (Ia)	424.65	A
Current after improvement (Ib)	203.85	A
Work hour	8760	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia^2-Ib^2) x Rt x [1 + Tc (tw-20)] x L x work hour / 10^6

SAVING

Energy saving	372.72	kWh/year
Money saving	585	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 16:21:36

LINE LOSSES REDUCTION

DATA OF CONDUCTOR TR.4 (P.M.6)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	300.00	sq.mm
Quantity of conductor	6.00	line/phase
Distance of conductor (L)	16.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.059	Ohm/km/Conductor
Current before improvement (Ia)	1672.64	A
Current after improvement (Ib)	1475.55	A
Work hour	8760	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia^2–Ib^2) x Rt x [1 + Tc (tw–20)] x L x work hour / 10^6

SAVING

Energy saving	2666.35	kWh/year
Money saving	4186	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 16:33:27

LINE LOSS REDUCTION

DATA OF CONDUCTOR TR.5 (P.M.6)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	300.00	sq.mm
Quantity of conductor	5.00	line/phase
Distance of conductor (L)	16.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.059	Ohm/km/Conductor
Current before improvement (Ia)	490.44	A
Current after improvement (Ib)	337.44	A
Work hour	8760	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia^2–Ib^2) x Rt x [1 + Tc (tw–20)] x L x work hour / 10^6

SAVING

Energy saving	653.21	kWh/year
Money saving	1026	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 16:55:51

LINE LOSSES REDUCTION

DATA OF CONDUCTOR TR.6 (P.M.6)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	300.00	sq.mm
Quantity of conductor	8.00	line/phase
Distance of conductor (L)	10.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.059	Ohm/km/Conductor
Current before improvement (Ia)	1902.82	A
Current after improvement (Ib)	1290.32	A
Work hour	8760.00	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia^2-Ib^2) x Rt x [1 + Tc (tw-20)] x L x work hour / 10^6

SAVING

Energy saving	3939.61	kWh/year
Money saving	6185	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 17:36:30

LINE [illegible] REDUCTION

DATA OF CONDUCTOR TR.7 (P.M.7)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	300.00	sq.mm
Quantity of conductor	5.00	line/phase
Distance of conductor (L)	15.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.059	Ohm/km/Conductor
Current before improvement (Ia)	1109.54	A
Current after improvement (Ib)	962.68	A
Work hour	8760.00	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia^2–Ib^2) x Rt x [1 + Tc (tw–20)] x L x work hour / 10^6

SAVING

Energy saving	1471.19	kWh/year
Money saving	2310	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 17:52:54

LINE [illegible] REDUCTION

DATA OF CONDUCTOR TR.8 (P.M.7)

Type of conductor (THW,TW ect.)	THW	
Conductor materials	Annealed Copper	
Norminal cross area	300.00	sq.mm
Quantity of conductor	5.00	line/phase
Distance of conductor (L)	15.00	m
Temp. of conductor (tw)	30.00	deg. C
Temp. coefficient at 20 deg. C (Tc)	0.00393	
Max.resistance at 20 deg. C (Rt)	0.059	Ohm/km/Conductor
Current before improvement (Ia)	1273.51	A
Current after improvement (Ib)	933.14	A
Work hour	8760.00	h/y
Electricity price	1.57	baht/kWh

FORMULA

Line losses saving = 3 x (Ia^2–Ib^2) x Rt x [1 + Tc (tw–20)] x L x work hour / 10^6

SAVING

Energy saving	3631.00	kWh/year
Money saving	5701	Baht/year

Program by : VIRAT SONGNGAM
Printed Date 12/09/94
Printed Time 18:15:45

APPENDIX C

1. (1) Flowsheet

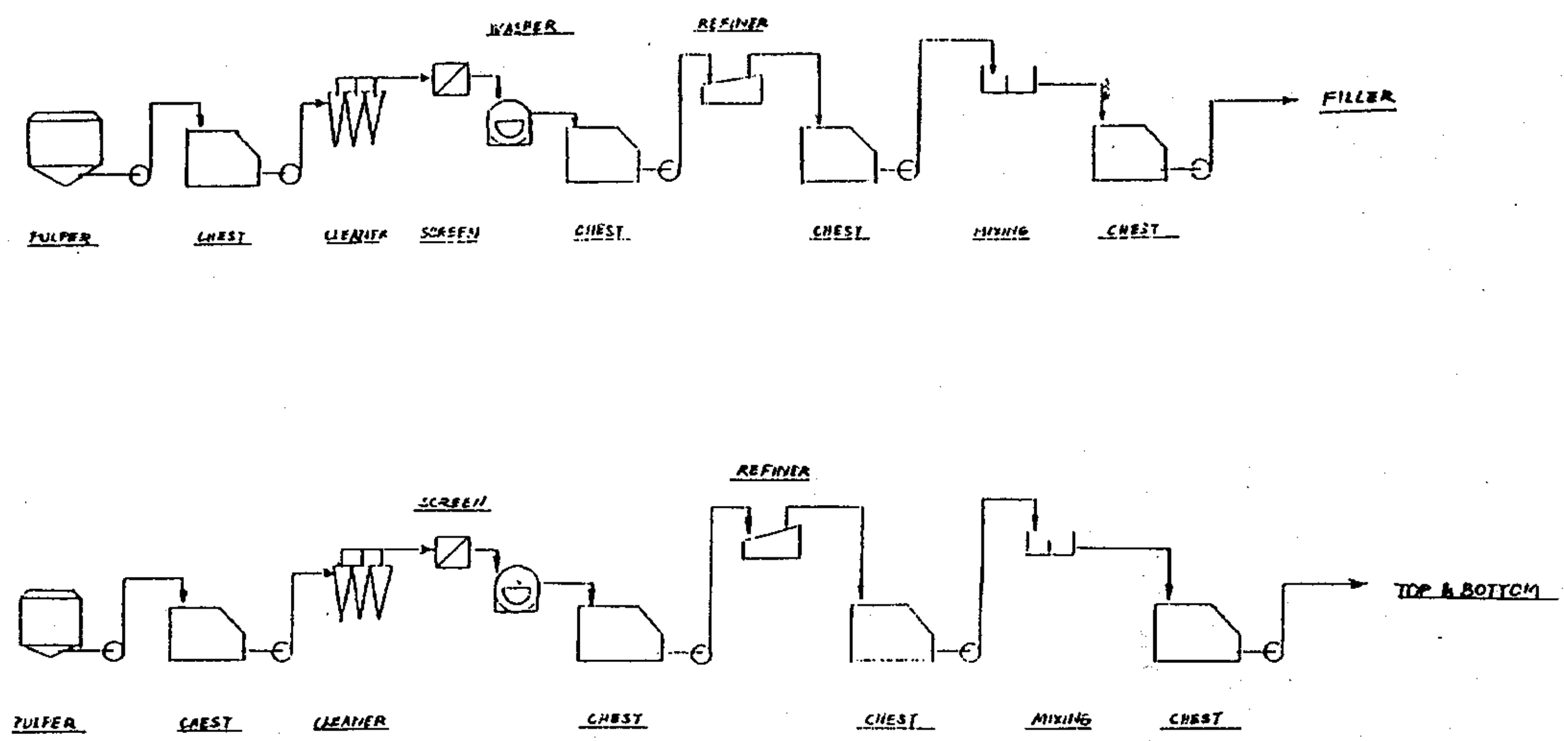
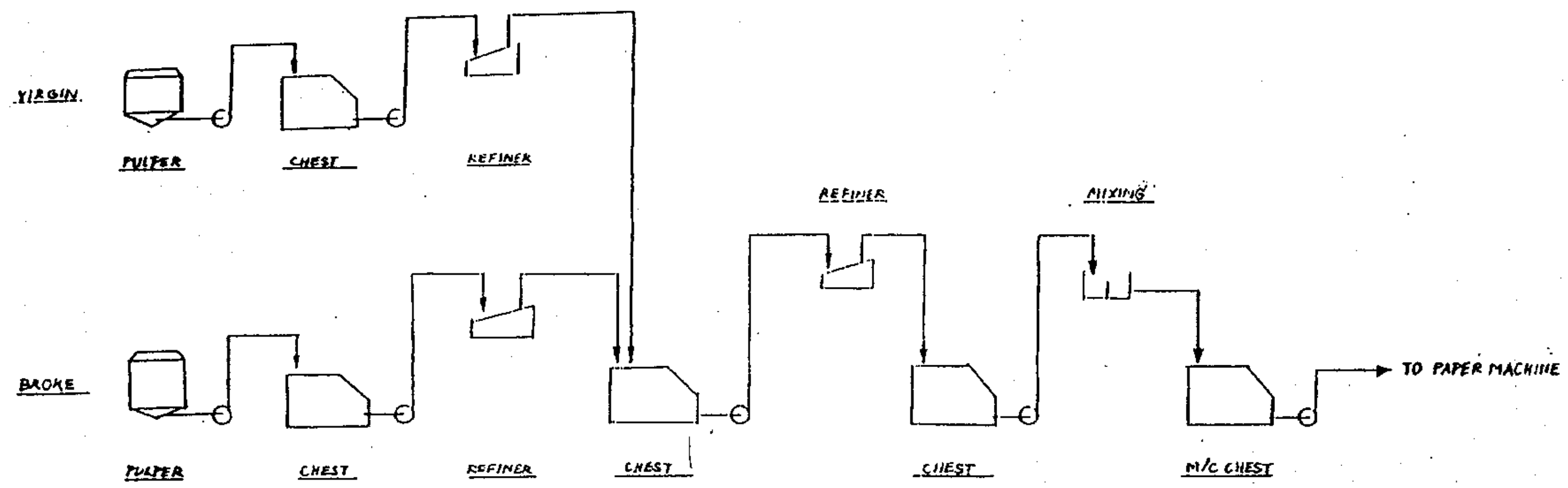


Figure 8.2.55 Process of P.M.4



P.M. 5

Figure 8.2.56 Process of P.M.5

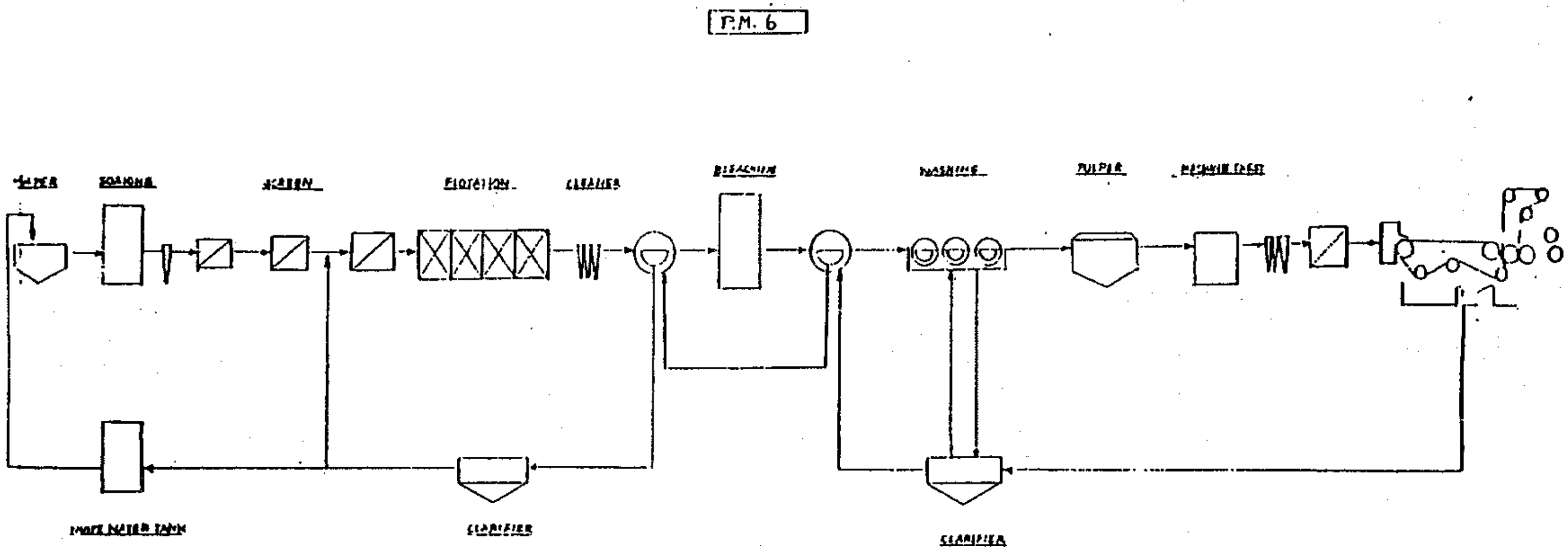


Figure 8.2.57 Process of P.M.6

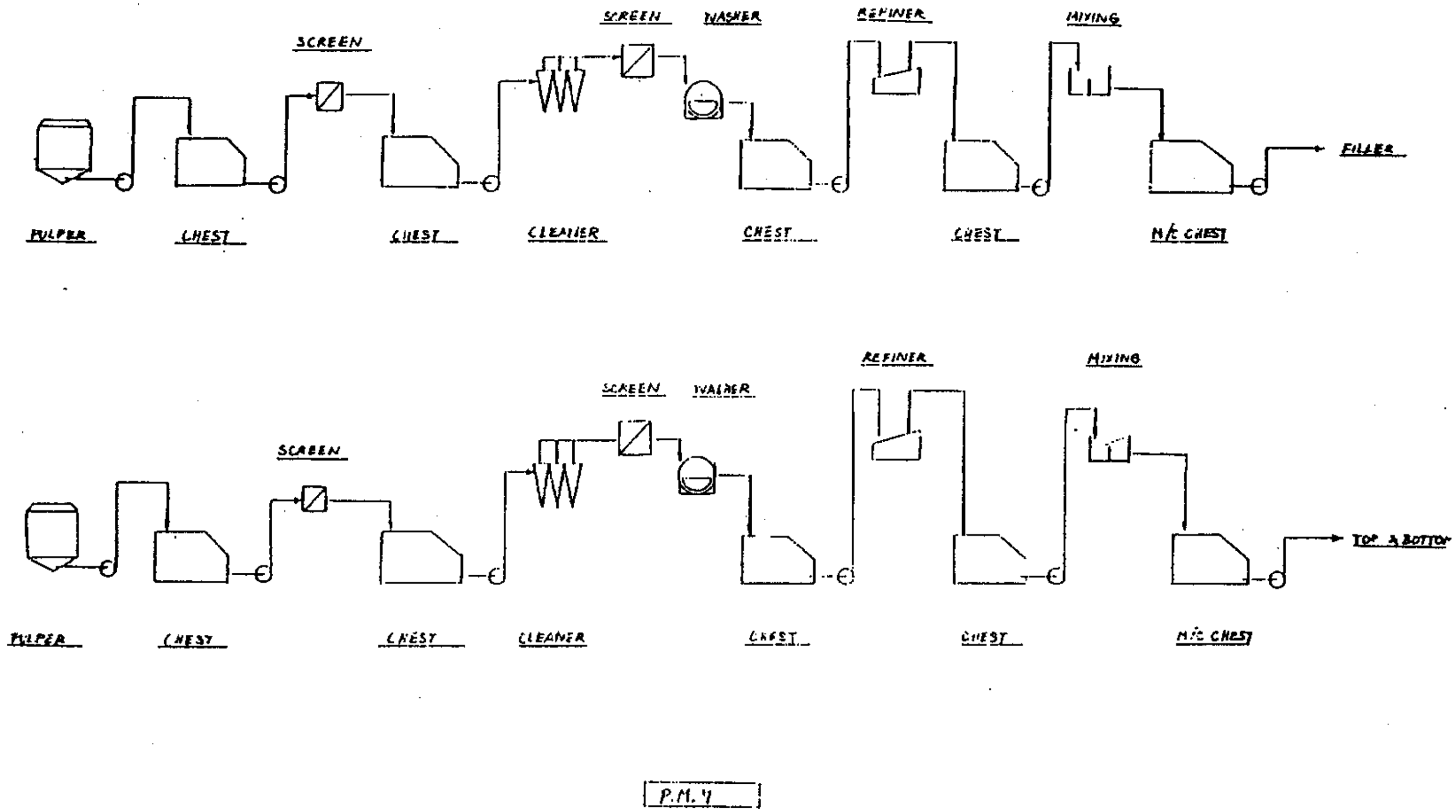


Figure 8.2.58 Process of P.M.7

9. REPORT ON TECHNOLOGY TRANSFER BY WORKSHOP METHOD

9. REPORT ON TECHNOLOGY TRANSFER BY WORKSHOP METHOD

9.1 Purpose

The purpose is to conduct technology transfer for the promotion of energy conservation including the concrete methods thereof to the counterpart through workshop method by the effective use of the equipment carried by the study team for the purpose of improving the technology required for the counterpart when the Government of Thailand enforces various regulations relevant to the Energy Conservation Promotion Act. The foregoing technology includes the technique for factory/building energy audit, method of working out plans for improving energy conservation in factories/buildings and the technique for evaluation of energy conservation promotion plans submitted by factories/buildings.

9.2 Period

From 7 March to 25 March 1994 (15 days)

9.3 Place

Conference room of the Department of Energy Development and Promotion.

9.4 Description

Workshop was conducted by way of case study described below.

(1) Explanation of specifications and operation method of the audit equipment

An explanation was made on the specifications and the operation method of the measuring equipment for energy use audit which were brought to Thailand in March 1994.

(2) Report on energy use audit of factories and buildings (Thai side)

In order to make the workshop more effective, the Japanese side requested the counterpart to report the results of factory/building energy use audit and thereby evaluated the current technical level of energy use audit in Thailand.

(3) Lecture by the Japanese experts

The Japanese experts gave lectures on factory/building energy conservation technology.

(4) Presentation of case study (Thai side)

The Thai side made a presentation on the energy conservation improvement method for the supposed factory/building. This was made based on the Thai side's experience and the knowledge of energy conservation improvement methods and the knowledge obtained through lectures given by the Japanese experts.

In connection with this, the Japanese experts provided guidance and evaluation.

The timetable and members in charge are listed below.

Date	Day of the week	Lecture subjects		Members in charge
March 7	Monday	Morning Afternoon	Opening, expalantion of the outline of workshop Specifications of the audit equipment (2)	Thai side Teruo Nakaga Norio Nakagawa
March 8	Tuesday	Morning Atternoon	Operation method of the audit equipment (1) Operation method of the audit cequipment (2)	Teruo Nakagawa Tcruo Nakagawa
March 9	Wednesday	Morning Afternoon	Operation method of the audit equipment (3) Operation method of the audit equipment (4)	Teruo Nakagawa Teruo Nakagawa
Macrh 10	Thursday	Morning Afternoon	Thai side's report on energy conservation audit (factory) Thai side's report on energy conservation audit (building)	Thai side Thai side
March 11	Friday	Morning Afternoon	Factory energy management Energy conservation measures for existing buildings	Mitsuo Iguchi Kenjiro Yamaguchi
March 14	Monday	Morning Afternoon	Heat management (1) Electricity management (1)	Yukio Nozaki Toshiro Sugimoto
March 15	Tuesday	Morning Afternoon	Energy management for buildings (1) Heat management (2)	Kenjiro Yamaguchi Yukio Noguchi

Date	Day of the week	Lecture subjects		Members in charge
March 16	Wednesday	Morning Afternoon	Electricity management (2) Energy management for buildings (2)	Toshio Sugimoto Kenjiro Yamaguchi
March 17	Thursday	Morning	Electricity management (3)	Toshio Sugimoto
March 18	Friday	Morning Afternoon	Energy management for buildings (3) Heat management (3)	Kenjiro Yamaguchi Yukio Nozaki
March 21	Monday	Morning Afternoon	Electricity management (4) Energy management for buildings (4)	Toshio Sugimoto Kenjiro Yamaguchi
March 22	Tuesday	Morning Afternoon	Data processing method by computer (1) Data processing method by computer (2)	Teruo Nakagawa Teruo Nakagawa
March 23	Wednesday	Morning Afternoon	Preparation for presentation of case study Preparation for presentation of case study	All members, Thai side All members, Thai side
March 24	Thursday	Morning Afternoon	Preparation for presentation of case study Preparation for presentation of case study	All members, Thai side All members, Thai side
March 25	Friday	Morning Afternoon	Presentation of case study Presentation of case study, review and comment Closing	Thai side Thai side, all members Thai side Teruo Nakagawa

(Lecture time)

Morning course: From 9:30 to 12:30

Afternoon course: From 13:30 to 16:30

9.5 Attendees

(1) Thai side

32 members from DEDP and ECCT

Group A

Name	Specialist
1) Mr. Pramoul Chanpong	Electrical engineer
2) Mr. Pinyo Tanthumart	Technician/Heat
3) Mr. Supachok Kusolsong	Mechanical engineer
4) Mr. Virat Songngam	Electrical engineer/Electric
5) Mr. Suthat Chobchuen	Electrical engineer/Electric
6) Ms. Somsiri Sintusak	Chemical engineer
7) Mr. Thira Manussadhama	Electrical engineer
8) Mr. Chakrapongse Bhucksasri	Electrical engineer/Electric
9) Ms. Sasithon Sinbuchongchit	Economist
10) Mr. Worapoch Moonmorathup	Technician/Electric
11) Mr. Vason Tonya	Energy training instructor

Group B

Name	Specialist
1) Mr. Danai Eg-kamol	Mechanical engineer/Heat
2) Mr. Artnarong Kuptrabutr	Electrical engineer
3) Mr. Rangsan Thongsut	Technician/Electric
4) Mr. Phruttapong Sarakasetrin	Electrical engineer/Electric
5) Mr. Atthaphon Hongsamat	Electrical engineer/Electric
6) Ms. Renu Cheokung	Energy technology
7) Mr. Thamasak Suwanteap	Technician/Electric
8) Mr. Thongchai Reongsri	Technician
9) Mr. Amornsak Rungsakol	Energy training instructor
10) Ms. Phonsom Rochanapadit	Economist
11) Mr. Songkarn Tonma	ECCT/Building/Electric

Group C

Name	Specialist
1) Mr. Thongdee Benchamongkon	Specialist/Electric
2) Ms. Amarapom Achavangkool	Scientist
3) Mr. Banphot Diskul	Technician/Electric
4) Mr. Pittava Kruakhunpet	Technician/Electric
5) Mr. Kittipong Rattanapisutikul	Industrial engineer/Heat
6) Mr. Chartree Peampravut	Technician/Heat
7) Mr. Chaiwat Trisan	Electrical engineer
8) Mr. Sopon Maneechot	Energy training instructor
9) Mr. Wiraphon Rharsapraharce	Economist
10) Mr. Montree Jittavira	ECCT/Factory/Heat

(2) Japanese side

1) Teruo Nakagawa
2) Norio Fukushima
3) Mitsuo Iguchi
4) Yukio Nozaki
5) Toshio Sugimoto
6) Kenjiro Yamaguchi

9.6 Text Materials

English texts and OHP

English texts

1) Model Factory
2) Model Building
3) Energy Management
4) Methods of Energy Management in Industry
5) Measuring Methods for Factory Energy Audit
6) Energy Conservation Measures for Existing Buildings
7) Energy Conservation in Boiler
8) Energy Conservation in the Utilization of Steam
9) Energy Conservation in Industrial Furnace
10) Energy Conservation in Electric Equipment Operation
11) Model Factory Key Sheet
12) Model Building Key Sheet

9.7 Outputs and Future Theme

(1) Giving instruction in the method of handling the latest measuring equipment for energy conservation audit, data collection and analysis method improved the level of the counterpart's technology for energy conservation audit.

(2) Making a case study on the supposed factory/building allowed the counterpart to acquire a practical auditing technology for energy conservation and the improvement method.

(3) The counterpart could obtain knowledge in the operation method, lecture subjects, instruction methods, text materials, etc. necessary for the counterpart to open workshop on its own.

(4) Regarding the handling of the measuring equipment, it is advisable for the counterpart personnel to hold a voluntary study meeting and thereby to get more familiar with the handling method.