(3) Chemicals recovery process

a) Improved vacuum evaporator efficiency

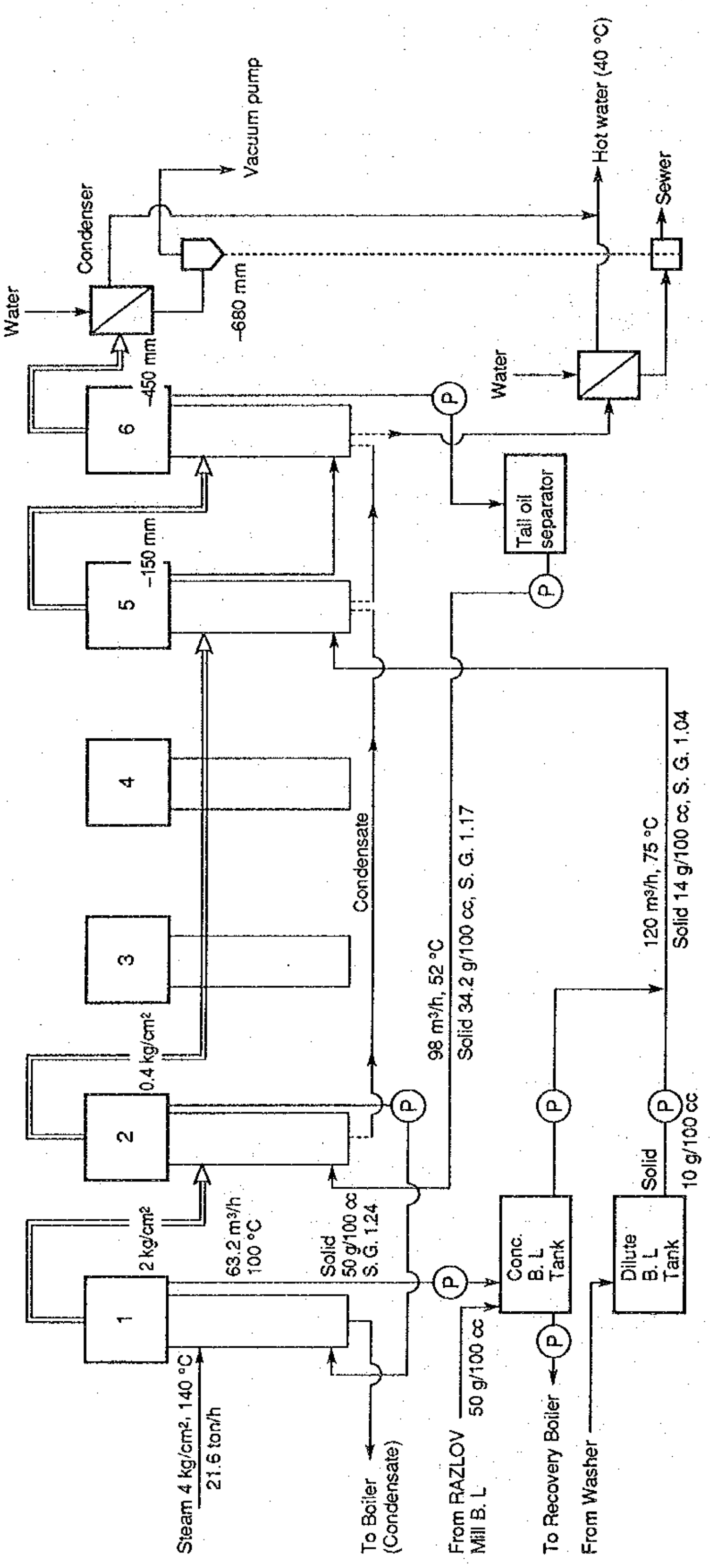
The volume of the steam used for black liquor concentration in this plant accounts for about 30% of the total steam consumption in the plant, registering the greatest percentage of all the processes.

The black liquor is concentrated in the multi-effect vacuum evaporator. The vacuum evaporator is designed in a long tube type, and can be used for 6 effect concentrator. The liquid side of two heater tubes is clogged with scale, and is currently under repair. It is now working for four effect. Though it is designed as a 6-effect device, repair is postponed and equipment performance is not effectively used.

Figure 5.3.9 illustrates how the four-effect concentrator is operated as of June 18. The evaporation ratio in this case is 2.15.

$(120\ \mathrm{m^3/h} \times 1.04 - 63.2\ \mathrm{m^3/h} \times 1.24) / 21.6\ \mathrm{t/h} = 2.15$

Figure 5.3.9 Operation of Multi-effect Concentrtor



The evaporation ratio represents the ratio of the amount of the evaporated water with respect to the amount of the steam used, and provides an index for determining the concentration efficiency. The evaporation ratio is affected by the number of effects, preheating method, scale deposition and air leakage, but is generally 2.8 to 3.4 for the four-effect concentrator, 3.5 to 4.1 for the five-effect device and 4.2 to 5.2 for the six-effect device.

To estimate annual average evaporation ratio for 1989 to 1992 in this plant, it is as low as 1.9 to 2.5, as shown in Table 5.3.8.

Table 5.3.8 Evaporation Ratio

Item	Unit	1989	1990	1991	1992
Black Liquor Feed	1000㎥/y	589.9	509.5	484.2	343.9
Specific Gravity	t／㎥	1.04	1.04	1.04	1.04
Solid Matter	g/100cc	14	14	14	14
	1000t/y	82.6	71.3	67.8	48.1
Concentrated Liquor	1000㎥/y	172.8	149.2	141.8	100.7
Specific Gravity	t／㎥	1.273	1.270	1.269	1.265
SolidMatter	g/100cc	47.8	47.8	47.8	47.8
Evaporated Water (A)	1000t/y	393.6	340.4	323.6	230.3
Steam Consumption (B)	1000t/y	204.6	138.7	134.7	119.9
Evaporation Ratio (A/B)		1.92	2.45	2.40	1.92

If the evaporation ratio can be improved from the current 1.9 to 2.5 up to the annual average of 3.5 (the lowest limit of five-effect use) by extending the six-effect operation time, then the required amount of the steam can be kept down to 2.3/3.5 = 66 % on an average. The amount of the steam used in the vacuum evaporator was about 120,000 tons or 73,000 Gcal in 1992, so the amount saved in this case is obtained as follows:

73,000 × (1 – 0.66) = 25,000 Gcal/y
25,000 × 433 = 10,825,000 Lv/y

b) Pickling

Although this plant is equipped with the most economical 6-effect concentrator, it has to operate in the four-effect mode because of the trouble caused by scale. This is considered to be due to the insufficient definition of the management standards to check the scale deposit, and to the absence of the system which ensures quick removal of such scale.

Prediction of the scale deposit should be done by the evaporation ratio and by the daily management through periodic analysis of the silicon contained in the black liquor, as well as by internal inspection when the plant is shut down.

Furthermore, operation with a small number of effects will cause the efficiency of the evaporator to be reduced. So in order to reduce the less effective time, the repair program which ensures quick heater disconnection and connection,and tube cleaning by pickling should be worked out. Efforts must be made to conform to this program, and the results should be analyzed to upgrade the programs one after another.

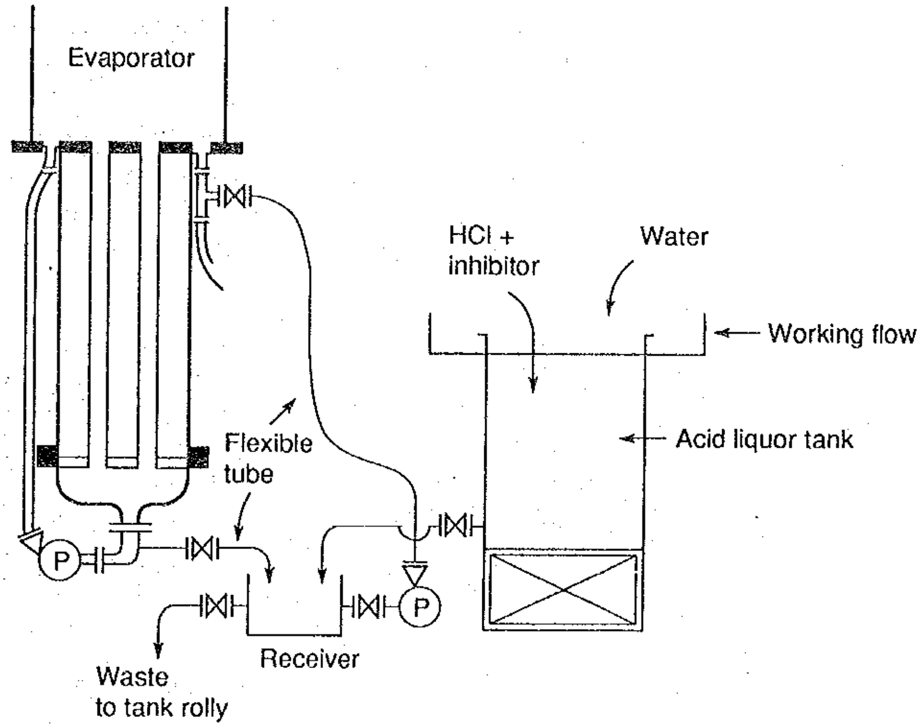
This approach also applies to the maintenance of the cooker already discussed. Scale is removed from the cooker heater, multi-effect vacuum evaporator and heat exchanger in the way characteristic of each plant. The following shows one example:

① Equipment

As shown in Figure 5.3.10, prepare the pickling tank having a capacity to allow complete dipping of the entire heater tube, and install it close to the cooker or evaporator. Piping and pump for pickling liquor circulation are equipped between tank and heat exchanger.

Disconnect the heater, then reconnect it in one to two hours in order to minimize equipment suspension time. For this purpose, prepare the hoisting device and other tools to permit quick switching of the piping system, and prepare the scaffold and other safety equipment so that many people can work together. If possible, automate the valves.

Figure 5.3.10 Pickling System



② Pickling

After switching the pipe, wash it with water and inspect the interior. Scale must be removed from the clogged tube by jet water or tube drill.

Prepare in the pickling tank a sufficient amount of the pickling liquid to cover the entire tube; in this case the pickling liquid is composed of inhibitor added to hydrochloric acid having a concentration of 2 to 3%.

Pickling is done by the pickling liquid circulating between the tank and tube. During the pickling, the concentration of calcium ion gradually increases. When this concentration has reached an equilibrium, the pickling reaction is considered to have reached the end point.

After discharging the pickling water, wash the tube with water and check the expander and weld zone for leakage. If any fault is found out, repair it. If it is beyond repair, plug the tube. Recently, the stainless tube has come to be used, and brittleness due to pickling and mechanical treatment does not occur often.

Furthermore, the plate type evaporator has come to be used frequently since it allows easy removal of scale. Normally, this pickling work takes about 8 hours.

③ Control of the scale trouble

The major component of scale is calcium silicate. Analyze the silicon in the chemicals circulating system; control must be done according to its concentration. In a certain plant, silica contained in the solids of black liquor is kept down to about 2.5%. It is controlled so that the percentage will not exceed 5.5% at most. Silica concentration is controlled by removing out of the system the lime mud of the sludge filter before the kiln. The lime mud is sold to the cement plant or is used for base of buildings.

c) Increased concentration

To improve efficiency of the recovery boiler, the concentration of the black liquor should be increased. In the evaporation process it is easy to finish at 55 g/100 cc. The effect can be calculated as follows, by referring to the record as of June 18 given in Figure 5.3.9:

Current Evaporation volume : 120 m^3/h × 1.04 – 63.2 m^3/h × 1.24 = 46.4 t/h
Evaporation ratio : 46.4 t/h ÷ 21.6 t/h = 2.15

When the same liquid is to be concentrated to 55 g/100 cc at the evaporation ratio of 4.5:

Volume of black liquor supplied : 120 m^3/h × 1.04 = 124.8 t/h
Solid : 120 m^3/h × 14 g/100 cc = 16.8 t/h
Volume of concentrated black liquor : 16.8 t/h ÷ (55 g/100 cc) = 30.5 m^3 /h
Steam consumption : (124.8 – 30.5 × 1.24) /4.5 = 19.3 t/h

Namely, with the amount of steam about 11% smaller than the current value it is possible to get the black liquor having a concentration 10% greater.

Under the present circumstances, the black liquor with a concentration of 50 g/100 cc is concentrated to 55 g/100 cc by the venturi scrubber installed at the recovery boiler duct, and is jetted into the boiler. When it can be jetted at 60 g/100 cc, the volume of gas in the chamber will be decreased by reduction of water, resulting in improved combustion efficiency.

In recent years, the black liquor with a concentration of 70% or more has come to be obtained by using the plate type evaporator discussed above, eliminating the need of the venturi scrubber and disk evaporator. Instead, the economizer is installed for further improvement of heat efficiency.

d) Recovery boiler

1) Availability factor

The recovery boiler uses black liquor as fuel and recovers the soda from it. At the same time, the generated steam is used for power generation; after that, the extracted steam is used as a heat source for each process including the vacuum evaporator. Thus, the recovery boiler not only assists energy coneservation but also makes contribution as a water pollution preventive device.

The recovery boiler of this plant has the capacity corresponding to the daily production of 230 tons of the kraft pulp. Since the current daily pulp production volume is 170 tons, it receives the black liquor of the Razlog plant, and generates 55 tons of steam of 40 bars at 440 °C per hour with the mixed combustion of heavy oil.

Table 5.3.9 shows the boiler operating conditions as of May 1993.

Table 5.3.9 Operation of Boilers

Boiler	Fuel	Capacity t/h	Generated Steam t	Operation Time h	Generated Steam t/h	Operation Rate %	Share %
7	B.L.+Oil	60	30,617	552	55.5	92.4	48.9
6	Fuel Oil	35	4,912	209	23.5	67.1	7.8
8	Fuel Oil	50	11,151	344	32.4	64.8	17.8
9	Fuel Oil	50	15,908	672	23.7	47.3	25.4
	Total		62,588		135.1		
	Black Liquor		18,990				30.3
	Fuel Oil		43,598				69.7

The temperature rise of the recovery boiler takes a long time at the time of startup, and much heavy oil is consumed. It is important to reduce the frequency of starting and stopping and to perform a long-term operation in order to save both energy and cost. To reduce the causes for operation stop, both operation and maintenance divisions must cooperate with each other. Generally, continuous operation of the recovery boiler is possible for half a year. This period is closely connected to the availability factor in other processes.

The operation time for May 1993 was 552 hours. This amounts to 23 days if continuous operation was performed. Systematic efforts should be made to ensure that continuous operation will be performed for at least 40 days.

The continuous operation period of the paper machine is restricted by the service life of the wire. The 6-month continuous operation is possible for the pulp division if preventive maintenance system is prepared. For this reason, there are cases where the pulp machine is installed so that the pulp itself can be sold to the market, and the continuous operation of the pulp process and recovery boiler can be operated even when the paper machine is shut down.

2) Boiler efficiency

The following shows the amount of black liquor used in May 1993.

Black liquor	8,705 m^3	
Specific gravity	1.284	
Concentration	51.95 g/100 cc	
Calorific heat	1,715 kcal/kg	
Heat of steam	771 kcal/kg	(according to figures of the plant)
Heat of feed water	140 kcal/kg	(according to figures of the plant)

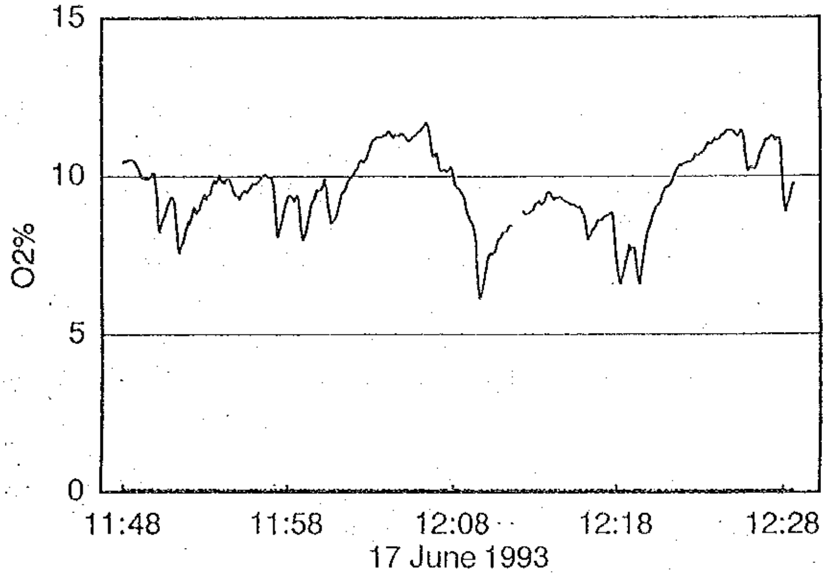
These values and those in Table 5.3.9 are used to calculate the heat efficiency as follows:

Heat input : 8,705 × 1.284 × 1,715 = 19,169 Mcal
Heat output : 18,990 × (771 − 140) = 11,983 Mcal
Efficiency : 11,983/19,168 × 100 = 62.5 %

Generally, the heat efficiency of the recovery boiler is said to be about 65%, so the above result is little lower. To increase the recovery boiler efficiency, care should be taken to ensure uniform distribution of the black liquor, adjustment of the height of the char bed and dust suspension level, and elimination of dust from the tube, as well as to decrease the frequency of operation suspension. In recent years, it has become possible to conduct infrared or ultrasonic measurement of the char bed and dust level, and the boiler efficiency can be maintained at 70%.

Figure 5.3.11 shows the results of measuring the oxygen concentration of the exhaust gas. The air ratio is 1.6 when oxygen concentration is about 8%. This is the average value for the recovery boiler.

Figure 5.3.11 O_2 Content of Recovery Boiler Exhaust Gas



It shows excellent adjustment; primary air of 45%, secondary air of 35% and tertiary air of 20%. However, smelt deposit was found on the primary air inlet. The smelt deposit will make the air and fuel mixing and the char level uneven. So it must be removed when the boiler is not used. Even during the operation, it must be cleaned on a periodic basis.

The dust is deposited on the water tube, superheater tube, economizer, damper and induction fan, to disturb heat transfer and ventilation. So it must be cleaned on a periodic basis. The soot blower of the superheater tube is likely to cause the clogging of the steam nozzle, the shift of the blow pipe and failure of the rotary mechanism. It will lead to waste of steam and reduction of heat transfer efficiency, so inspection and maintenance must not be neglected.

(4) Circulating white water

The amount of water used in the paper pulp 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 following effects:

① The loss of pulp contained in the waste water is reduced, resulting in increase of pulp yield.

② Energy loss of white water and waste water is reduced, causing the system temperature to be raised.

③ The waste water treatment equipment load can be reduced.
For the pulp from broadleaf trees, 10 °C increase in the temprature of the head box reduces the water content of the wire end by about 2 %, and accordingly about 0.2 % decrease in the water content after pressing can be expected. Waste water absorbs the process heat and has a temperature higher than that of the water supplied. If the waste water with a temperature difference of 1°C is discharged 10,000 tons per day, it means that 10 Gcal is released per day. Improvement of the circulation rate of white water to raise the pulp temperature will upgrade the efficiency of dehydration in sheet formation and dewatering in the press part, saving the steam consumption in the dryer.

The steam amount used by the B-28 paper machine in 1992 was 53,482 Gcal. Thus, the amount saved will be as follows:

53,482 × 0.01 = 535 Gcal/y
535 Gcal/y × 433 Lv/Gcal = 23,170 Lv/y

One percent reduction of the water contained in the wet web after pressing can reduce the steam consumption by 4 %.

a) Pulp temperature in major process

Table 5.3.10 shows the measurements of the process temperature from the washer to the wire part. The pulp temperature immediately after the washer is about 50 °C, but is about 26 °C after the next coarse/fine screening process (Johnson screen) and about 23 °C at the outlet of the concentrator after the centriscreen; the temperature is extremely low. This is because white water circulation is insufficient, and much new water is used. As can be seen from the fact that temperature raises 5 °C after refining, to make an effective use of calorific heat converted from the electric power is one of the major points in working out the energy saving measures.

Fresh water temperature was 17 to 20 °C and waste water temperature at the terminal treatment inlet was 28 °C.

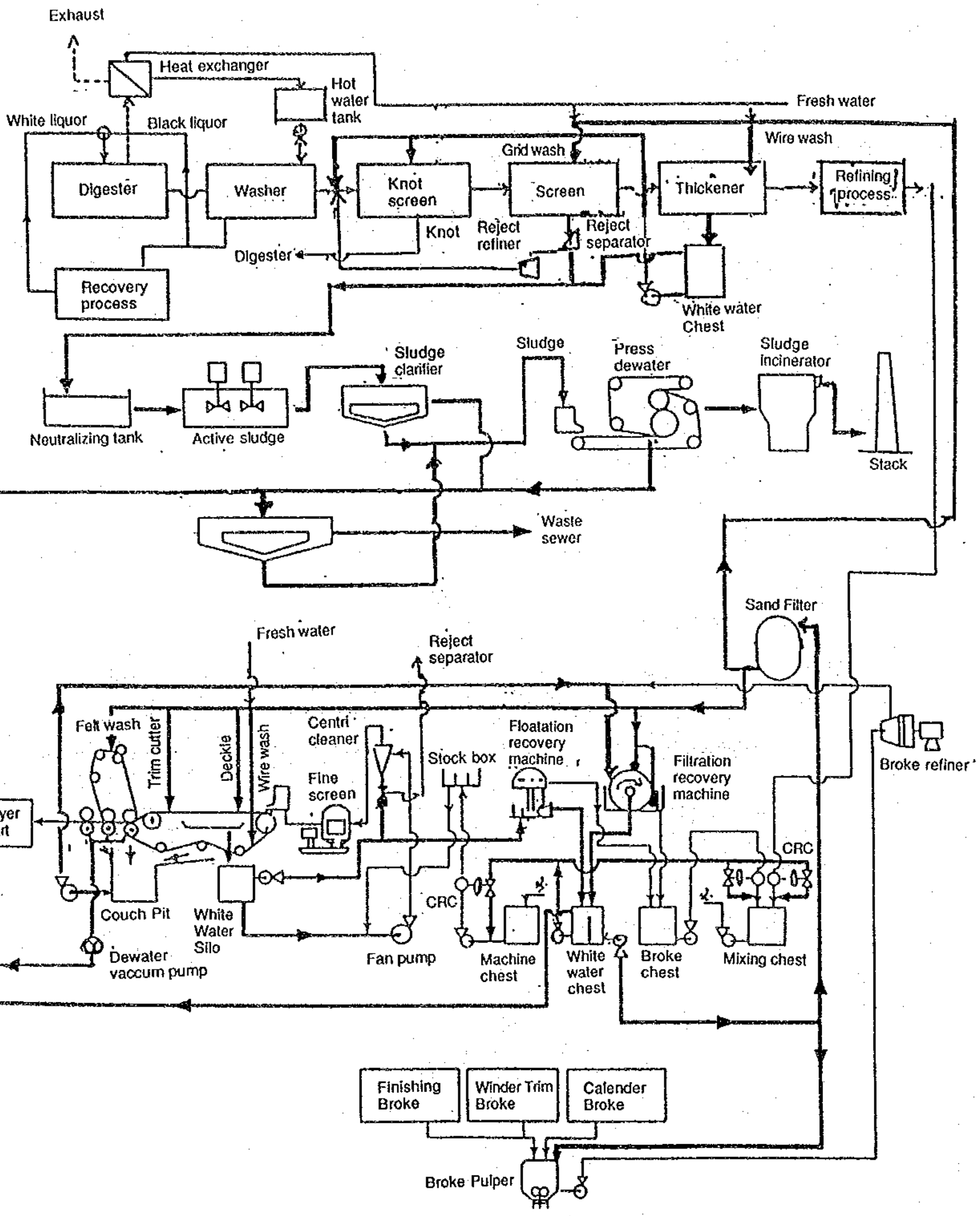
Table 5.3.10 Process Temperature

Process	MeasuringPoint	Temperture (℃)
Washing	Washer Inlet	72
	Washer Outlet	52
	Washer Pulp	49
Screening	Johnson Inlet	26
	Centriscreen Inlet	24
	Concentrator Outlet	23
Refining	Disk RefinerInlet	25
	Disk Refiner Outlet	28
Finished Stuff	Stuff Box	28
	Centricleaner Outlet	26
	Wet Broke Concentrator Inlet	27
Wire Part	Save All	26
	Wire Washing Water	20
Laboratory		17

b) Effective use of white water

It should be so designed that new water cannot be easily used for the washer to wash the mesh of the centriscreen and concentrator cylinder. The white water circulating in the wire part and the filtrate of fiber recovery equipment at couch and wet broke should be fed forward sequentially to eliminate waste water in the paper making process. One example of the white water recovery system is shown in Figure 5.3.12.

Figure 5.3.12 White Water Recovery System



The wire washing water at the wire part and the trimming high pressure water will affect paper quality and production efficiency, so it is necessary to use clean water with fine fiber completely removed. To recover clean water, some companies use sand filters, but operators working at the processes in many companies improve the equipment as required, thereby making an effective use of the white water.

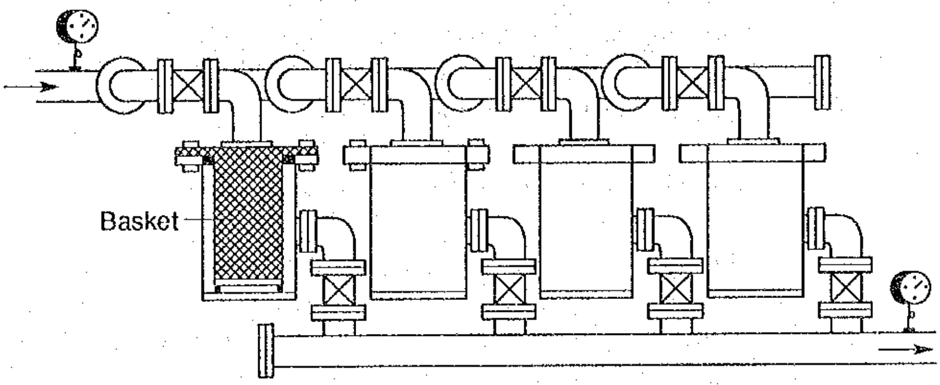
The following steps are taken to ensure such activities:

① In order to have the meaning of the effective use of white water to be fully understood by operators as well by engineers and to have them join in the activity, the plant manager should set up a policy to launch a campaign to arouse the interest of the employees for saving of new water.

② The machine design division, engineers at the job site and operators should form an improvement team, to work out the equipment/operation improvement program on the try-and-error basis.
The following shows examples of systematic activities:

New water was used for the back shower of the wet broke recovery filter (valveless filter) cylinder, and a new team was formed to replace it with filter filtrate. The idea proposed by the operator group was very elementary, and the machine design division made the filter equipment as shown in Figure 5.3.13, using the 10-inch old pipe. The operator group voluntarily selected the suitable mesh and came out with an ingenious idea of using two meshes one on top of another. In this way, improvement was continued, arousing their interest in the equipment and gaining deeper understanding of operation control. It should be borne in mind that the effective use of the device is possible only when operators are willing. Much labor is required to switch the cylinder at normal times or by pressure differences, or to clean the clogged cylinder. The operator group is currently seeking to find out the method of cleaning without having to open the cover.

Fig. 5.3.13 Clean Water Recovery Filter



c) New water consumption

Water is taken from three wells and a dedicated dam; about 85,000 tons per day is consumed in summer and about 60,000 tons per day in winter. About 70,000 tons per day of water is consumed on an annual average. This figure is excessive for the integrated pulp and paper plant having the size of this plant, and some improvement measures should be taken.

Table 5.3.6 shows that water consumption per pulp or paper unit in this plant, except for the kraft pulp process, is excessive and is about 20 percent excessive in all the processes. The target should be set to about 60,000 tons per day on an annual average for the time being.

(5) Paper making process

In the pulp and paper plant the paper making process requires much energy consumption. Especially in the plant with the Fourdrinier multiple cylinder paper machine, this process is counted among the greatest consumers of heat and electric power.

According to Table 5.3.6, more steam is consumed in both B-28 and B-14 than in Japan. For the use of electric power, there is not much difference as a whole, but differences are found in the methods of use according to different process. As discussed in the neutral sulfite semi-chemical, cooking degree is kept low in the pulp process in Japan and pulp yield is set to 70 to 80 %. Emphasis is placed on refining immediately after cooking, and refining before the paper machine is restricted to freeness adjustment. In this plant, cooking degree is increased and pulp yield is set to about 65 %. Since refining is facilitated as cooking has progressed, electric power consumption is reduced.
The paper making machine B-28 has 75 dryer cylinders (of which one is used for cooling) having a length of 4.9 meters and a diameter of 1.5 meters, and uses 100 % of coniferous trees as materials, registering a daily production amounting to about 200 tons of paper medium for heavy duty. The semi-closed type hood is used and the dryer capacity is sufficient; production increase appears to be possible.

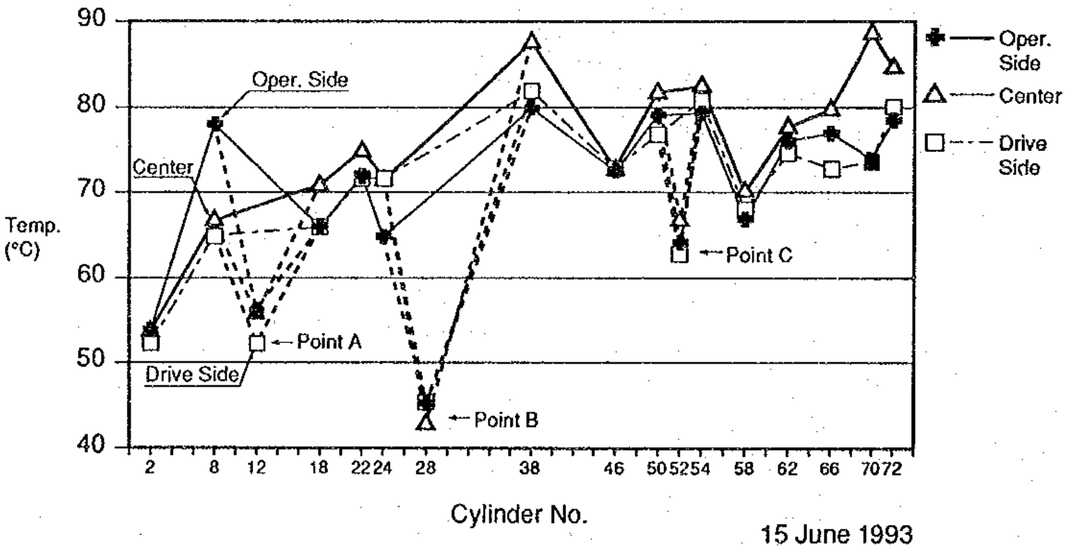
a) Dryer cylinder temperature

To measure the surface temperature of the running cylinder selected at random from among the lower group of cylinders, we divided the surface into three parts; the operation side, center and drive side, and used a radiation thermometer. Table 5.3.11 and Figure 5.3.14 show the result of this measurement.

Table 5.3.11 Dryer Cylinder Surface Temperature

Cylinder No.	Operation Side ℃	Center Side ℃	Driving ℃	Average ℃	Note
2	53	54	52	53.0	
8	78	67	65	70.0	
12	56	50	52	52.7	Steam Leak
18	66	71	66	67.7	
22	72	75	72	73.0	
24	65	72	72	69.7	
28	(45)	(43)	(46)		Valve closed
38	80	86	82	82.7	
46	73	74	73	73.3	
50	75	82	78	78.3	
52	64	63	63	63.3	
54	80	83	82	81.7	
58	67	70	68	68.3	
62	76	78	75	76.3	
66	77	80	73	76.7	
68	74	89	74	79.0	
70	79	85	80	81.3	
	70.9	73.7	70.4	71.6	

Figure 5.3.14 Dryer Cylinder Surface Temperature



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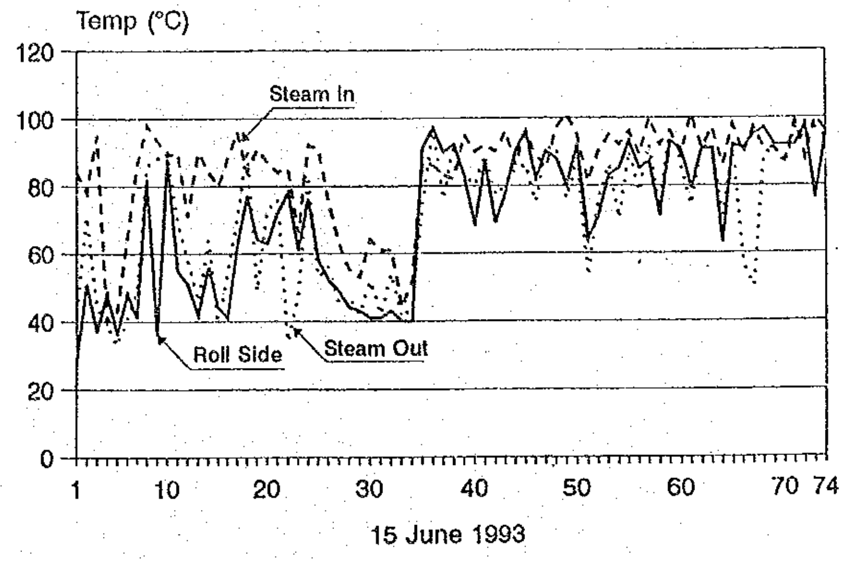
The cylinder surface temperature is abnormally lower than what is generally expected. Particular low values are found at points A, B and C in the Figure 5.3.14.

Next, temperatures were measured on the steam inlet pipe, outlet pipe and cylinder end plate for all cylinders. The results are shown in Table 5.3.12 and Figure 5.3.15. Much steam leakage is observed at point A. Steam does not seem to be entering cylinders No. 27 to 34 at point B. It appears that steam is supplied at point C, but the condensate discharge pipe inside the cylinder is damaged and the condensate seems to be filled inside without being discharged.

Table 5.3.12 Surface Temperature of Steam Pipe & Cylinder End Plate

№.	Steam Inlet ℃	Pipe Outlet ℃	Cylinder End ℃		№.	Steam Inlet ℃	Pipe Outlet ℃	Cylinder End ℃	
1	84	43	28		38	82	92	92	
2	78	71	51		39	95	83	83	
3	95	44	37		40	90	80	68	
4	40	39	48	Steam Stop	41	92	89	87	
5	43	38	36	Steam Stop	42	90	77	69	
6	–	–	48	Pipe Cutoff	43	96	80	78	
7	86	49	41		44	86	85	90	
8	90	86	82		45	96	86	96	
9	–	–	36	Pipe Cutoff	46	89	75	82	
10	89	90	88	Steam Leak	47	85	91	90	
11	90	69	55	Steam Leak	48	97	91	88	
12	71	58	51	Steam Leak	49	101	76	80	
13	90	46	42		50	95	88	92	
14	84	64	56		51	81	53	64	Pipe broken
15	80	39	44	Steam Leak	52	90	76	71	
16	–	–	41	Pipe Cutoff	53	95	86	83	
17	96	70	62		54	92	70	85	
18	84	91	77		55	96	90	93	
19	91	49	64	Pipe broken	56	89	78	85	
20	87	73	63		57	100	92	87	
21	84	76	72		58	92	74	71	
22	85	94	78		59	96	97	93	
23	66	47	61	Steam Leak	60	89	86	91	
24	92	83	76		61	101	74	79	
25	91	53	58		62	91	91	91	
26	75	56	52		63	97	92	91	
27	63	45	49	Steam Stop	64	86	71	68	Pipe broken
28	55	47	44	Steam Stop	65	98	91	92	
29	53	42	43	Steam Stop	66	89	57	91	
30	64	52	41	Steam Stop	67	97	50	95	
31	61	42	41	Steam Stop	68	91	89	97	
32	61	54	43	Steam Stop	69	91	91	92	
33	44	41	40	Steam Stop	70	87	86	92	
34	52	44	40	Steam Stop	71	99	97	92	
35	87	75	91	Steam Stop	72	88	93	98	
36	86	96	97		73	100	97	76	
37	83	76	90		74	96	94	95	

Figure 5.3.15 Surface Temperature of Steam Pipe and Cylinder End Plate



Figures 5.3.16 and 5.3.17 show the infrared thermal video pictures of the surfaces of cylinders No. 32 and No. 66 taken by the thermo video of Avio System.

The average temperature on the surface of the cylinder No. 32 is 40.4 °C, which indicates that almost no steam is supplied.

The average temperature on the surface of the cylinder No. 66 is 78.5 °C, but as shown in Figure 5.3.18, surface temperature after drying should be 100 °C.

Figure 5.3.16 Thermal Video Picture of Cylinder No.32

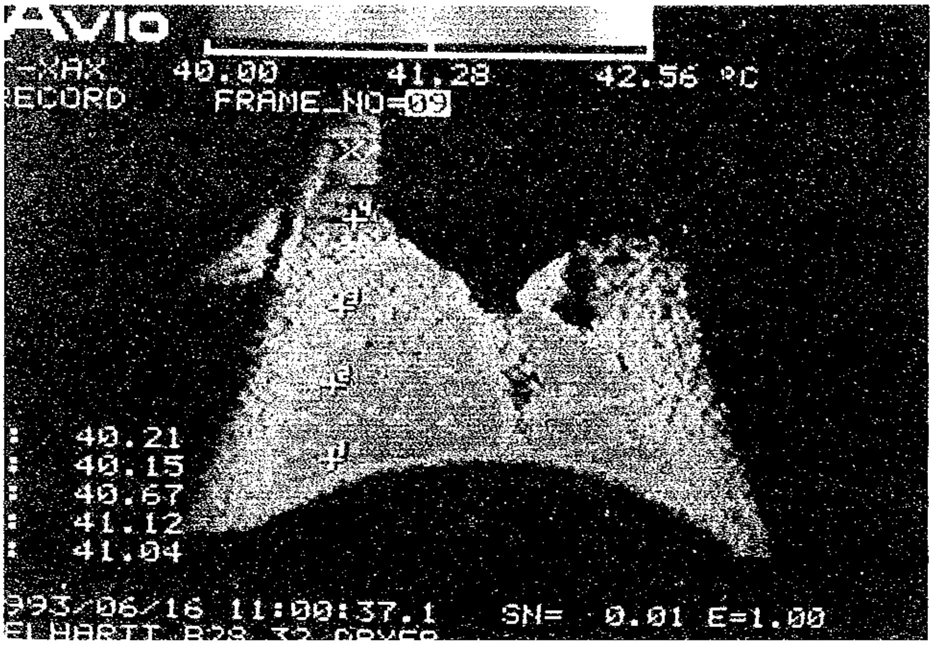


Figure 5.3.17 Thermal Video Picture of Cylinder No.66

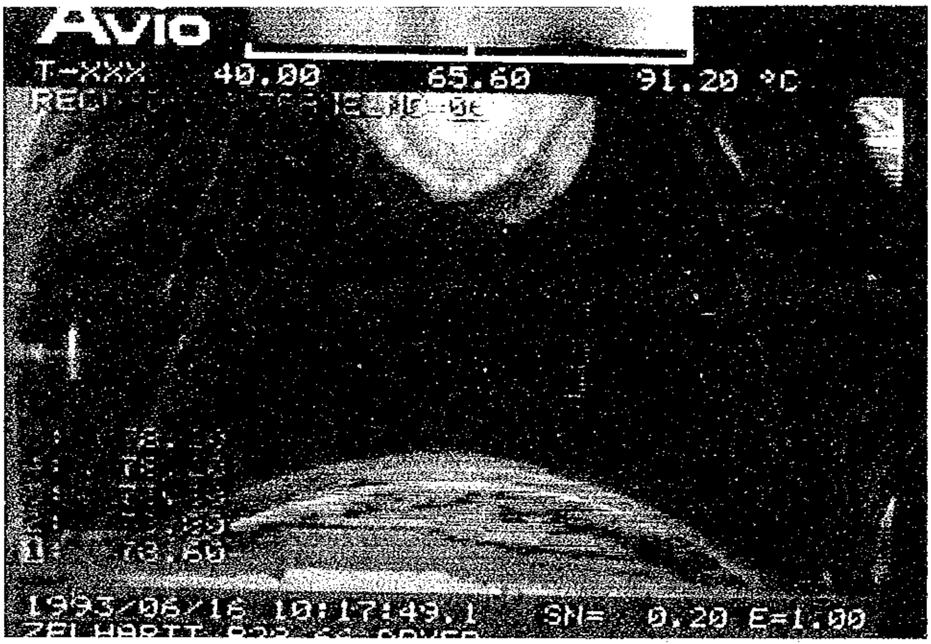
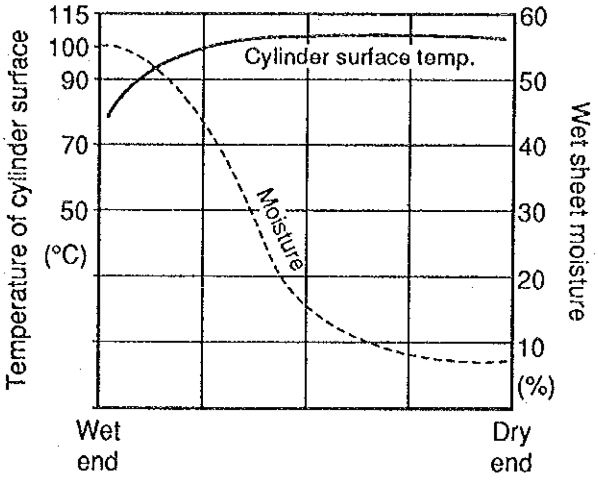


Figure 5.3.18 Wet Sheet Moisture and Cylinder Surface Temperature



In the paper machine B-14 the average temperature of cylinder No.6 was 90.9 °C. The temperature of cylinder No. 20 at the center of the dryer was 80.6 to 90.8 °C even at lower positions, and is over 100 °C at higher positions. The average temperature of the dry end paper was 91.6 °C

Results of the temperature measurements for paper machine B-28 shown above and visual observation have revealed the following:

① The steam pipes of cylinders Nos. 6, 9 and 16 are disconnected and not used.

② Much steam leaks from the joints of cylinders Nos. 10, 11, 12, 15, 23, 66 and 67.

③ The temperature on the disk surface cylinders Nos. 19, 51 and 64 is below 70°C, and the temperature of the condensate discharge pipe is considerably lowered. It shows that the condensate remains there without being discharged.

④ Cylinders Nos. 4, 5, 27, 28, 29, 30, 31, 32, 33 and 34 is not sufficiently provided with steam.

Thus, 23 cylinders are not contributing to drying process; only 51 of the 74 cylinders are related to drying. This seems to be because equipment management is neglected due to the sufficient margin of dryer capacity, resulting in steam leakage and condensate discharge failure inside the cylinder. This will cause steam to be wasted and the cylinder movement to be deteriorated due to staying condensate, possibly leading to increased power load.

Furthermore, the insufficient maintenance of cylinder will affect the product quality. The paper width at the wet end after pressing is 4,330 mm, and the shrinkage rate is 3.1 %. The heavy duty paper manufactured by B-28 is required to have a great ductility especially in the cross direction, as quality characteristics against bag breakdown; elongation of over 5.0 % is considered to be adequate. This elongation is formed by the shrinkage within the dryer. The shrinkage is increased when the wet sheet having the water content of 20 to 40 % is subjected to quick drying. Drying is promoted with increasing temperature differences between cylinder surface and wet paper. Operation should be performed by adjusting the volume of steam so that the heat curve will be gained, as shown in Figure 5.3.18.

When the paper of the same quality level is to be manufactured in Japan, cylinders Nos. 1 and 2 are not provided with canvases; shrinkage is promoted while attempts are made to prevent wet sheet from being sticked to the cylinders. Moreover, canvasses after No. 3 are applied in somewhat loose manner to assist shrinkage.

Low elongation of the kraft paper in the cross direction in this plant is considered to have occurred because cylinders in the front stage of the dryer are not sufficiently heated, the canvasses are too tight and pressure on the upper cylinders is excessive.

It should be pointed out in passing that, shrinkage in the cross direction is great at both ends, while it is small at the center. This is caused by insufficient ventilation at the center. To solve this problem, the pocket ventilation roll should be attached to promote ventilation at the center.

b) Drying capacity of B-28

Drying capacity and water evaporation volume are studied under the following conditions:

① Preconditions:

Basis weight : 75 g/m^2
Paper making speed : 360 m/min
On-reel trim : 4,330 mm
Wet paper water content : 65 %
Paper water content : 6.2 %
Paper production : 75 g/m^2 × 360 m/min × 4.33 m × 60 min = 7,015 kg/h

② Drying capacity

The total drying area of the dryer cylinder of B-28 is 1,708 m^2.

Diameter 1.5 m × π × length 4.9 m × 74 cylinders = 1,708 m^2

According to the data of TAPPI used to calculate the daily production capacity of the heavy duty kraft paper making machine, the production capacity per square meter of the drying area is 155 to 165 kg/(m².d). So the daily drying capacity of the dryer cylinder of B-28 is 273 tons, allowing the paper making speed of up to 580 meters per minute.

$$160\ \mathrm{kg/(m^2 \cdot d)} \times 1{,}708\ \mathrm{m^2} = 273\ \mathrm{t/d}$$

③ Unit Evaporation of dryer

Unit evaporation for drying capacity

$$\left\{\frac{65}{100-65}-\frac{6.2}{100-6.2}\right\}\times\frac{273\times1000}{24\times1708}= 11.9\ \mathrm{kg/(m^2 \cdot h)}$$

Unit evaporation for current production

$$\left\{\frac{65}{100-65}-\frac{6.2}{100-6.2}\right\}\times\frac{7015}{1708}=7.4\ \mathrm{kg/(m^2 \cdot h)}$$

The survey this time has shown that 23 of 74 cylinders are not making any contribution to drying.

Unit evaporation for 51 effective cylinders

$$\left\{\frac{65}{100-65}-\frac{6.2}{100-6.2}\right\}\times\frac{7015}{1708\times51/74}=10.7\ \mathrm{kg/(m^2 \cdot h)}$$

The current evaporation is only 62 % of the full capacity, and there is still margin even with 51 cylinders. The number of cylinders required for the current production volume will be about 46.

$$74 \times 7.4/11.9 = 46$$

For the time being, it is recommended that only about 55 cylinders be used for drying, and the cylinders located on the latter part be left idle so that paper will move sliding on them. This will save cylinder drive power by about 25 %.

Assuming that 20 % of the B-28 power is used for the paper making machine and the electric power for 1992 is used as a standard, the electric power illustrated below can be saved.

23,385 MWh/y × 0.2 × 0.25 = 1,169,300 kWh/y

1,169,300 kWh/y × 0.7 Lv/kWh = 818,500 Lv/y

c) Dryer ventilation

1) Fresh air

Wet sheet drying is promoted by dryer ventilation. The dryer hood was initially designed as an enclosed hood, and has been modified into a semi-closed type hood. On the operation side, the hood skirt covers the upper stage cylinder up to the center, and there is no curtain wall from below. On the drive side, the hood skirt extends to the gear box. Because of this gear box, the opening angle is much smaller than that on the operation side. The work floor bottom is provided with partition walls on both sides. And there is a canvas travel inspection entrance, but the opening area and outer air inflow conditions can be considered to be the same between both sides.

The building wall consists of the concrete wall or glass window. Since the doors are closed, the outer air does not enter so much.

B-28 is not provided with a pocket ventilation device, so the ventilation volume and air conditions are different on the operation and drive sides. To have a correct understanding on this situation, the wound paper on the reel was divided into five equal parts, and moisture contents were measured sequentially from the operation side. The results are given in Table 5.3.13.

Table 5.3.13 Moisture Contents of Dry End Paper on Reel

	Operation Side 1	2	3	4	Drive Side 5	Average
Moisture%	4.81	6.20	7.00	7.21	5.80	6.20

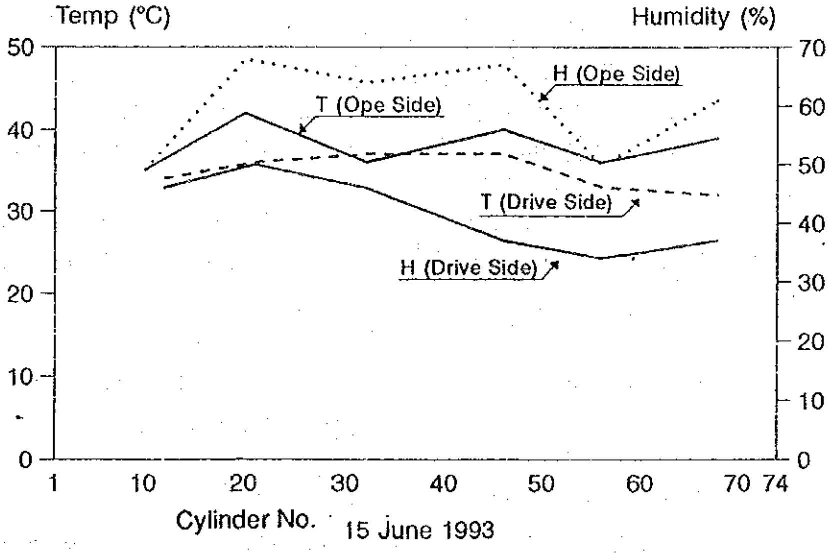
Since the operation side is well ventilated, the moisture is the least. The poorly ventilated center contains much moisture.

The temperature and humidity of the fresh air flowing into the dryer was measured immediately below the skirt of the dryer hood. The results are given in Tables 5.3.14 and 5.3.19.

Table 5.3.14 Temperature & Humidity of Fresh Air

Cylinder No.	Fresh Air				Ambient Air			
	Operation Side		Drive Side		Operation Side		Drive Side	
	Temp. ℃	R.H. %	Temp. ℃	R.H. %	Temp. ℃	R.H. %	Temp. ℃	R.H. %
10~12	35	49	34	46	30	50		
20~22	42	60	36	50			35	38
30~32	36	64	37	46	30	68		
44~46	40	67	37	37				
54~56	36	50	33	34			31	40
66~68	39	61	32	37				
72					30	45	30	40
Average	38.0	58.7	34.8	41.7	30.0	54.3	32.0	39.3

Figure 5.3.19 Temprature & Humidity of Fresh Air



The following illustrates the conditions for fresh air which enters the dryer, if the ratio of the ventilation on the operation and drive sides is assumed to be 60 to 40 using the general values where there is no adjustment action such as pocket ventilation:

Temperature	36.7 °C
Relative humidity	51.9 %
Absolute humidity	0.02 kg/kg-Dry Air
Specific volume	0.92 m³/kg-Dry Ai

2) Exhaust

The evaporated vapor is forcibly discharged by the exhaust fan from six duct installed on the hood top. The temperature in the hood should normally be controlled to a dew point of 40 to 50 °C, even though there is a difference in summer and winter.

Results of measuring the exhaust are shown in Table 5.3.15.

Table 5.3.15 Exhaust from B-28 Machine Hood

Duct №	Unit	1	2	3	4	5	6	Total
Duct Diameter	m.	0.70	1.28	1.28	1.28	1.28	1.28	
Temperature	℃	29.3	43.7	40.2	43.6	46.9	44.7	41.4
Velocity	m／s	0.75	15.31	9.68	21.98	14.19	7.77	
Exhaust Flow	㎥／h	1,039	70,923	44,842	101,822	65,735	35,994	320,356
Exhaust Flow	N㎥/h	938	61,137	39,087	87,800	56,098	30,930	275,989

The exhaust is not controlled because duct No. 1 has a low temperature, and temperature and exhaust volume of ducts Nos. 2 to 6 are not regular.

From the results shown in Table 5.3.15, the amount of evaporated moisture in the exhaust is calculated. The exhaust condition of the hood is as follows:

Temperature	41.4 °C
Relative humidity	100 %
Absolute humidity	0.053 kg/kg-Dry Air
Specific volume	0.96 m^3/kg-Dry Air

Exhaust air

320,356 m^3/h ÷ 0.96 m^3/kg-Dry Air = 333,700 kg-Dry Air/h

Moisture discharged from hood

333,700 kg-Dry Air/h × 0.053 kg/kg-Dry Air = 17,700 kg/h

Moisture in fresh air

333,700 kg-Dry Air/h × 0.020 kg/kg-Dry Air = 6,700 kg/h

Evaporation

17,700 – 6,700 = 11,000 kg/h

Evaporation obtained in (5) b. "Unit evaporation of dryer"

7.4 kg/ ($m^2 \cdot h$) × 1,708 m^2 = 12,600 kg/h

There is a slight difference between the two. It is considered to be due to leakage from the hood and errors of humidity measurement.

3) Ventilation control

After the dryer cylinder is maintained to the normal condition, from the viewpoint of ensuring energy conservation and product quality, the ventilation should be controlled as follows:

① The duct should be provided with the damper.
② Thermometers should be installed on the hood top and each duct inlet.
③ The damper opening angle should be controlled in order to keep dew point for each season, and the unnecessary fan should be stopped.
④ Though some equipment investment is required, introduction of the controller which controls rotation of the exhaust fan according to temperature will permit the optimum steam supply and fan power saving.

d) Drainage system

The drainage system is shown in Figure 5.3.20. The corresponding cylinders are divided in three groups; 11 cylinders in group 1, 22 cylinders in group 2 and 41 cylinders in group 3. In the initial phase it seems to have been designed in the blow-through method, but the pressure is currently reduced at the steam inlet; the current method of use is similar to the blow down method. Since the production volume is small, the balance at the time of initial design seems to have become unable to be maintained in an attempt to dry intensively in the latter part of the dryer.

Figure 5.3.20 B-28 Drainage System

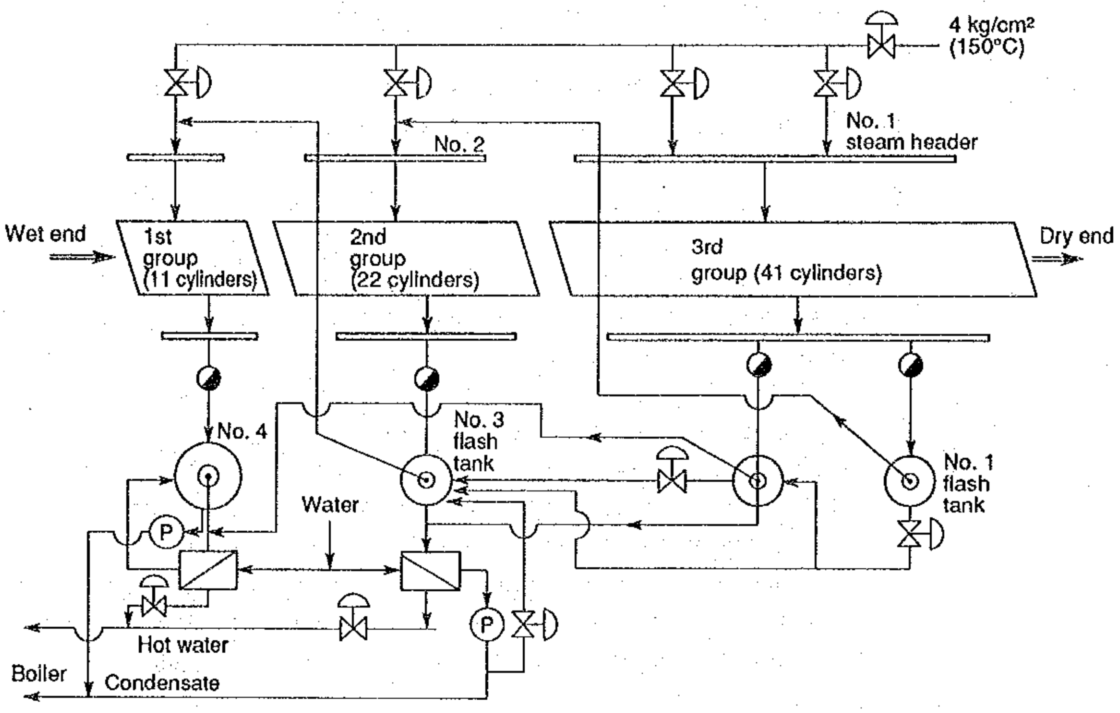
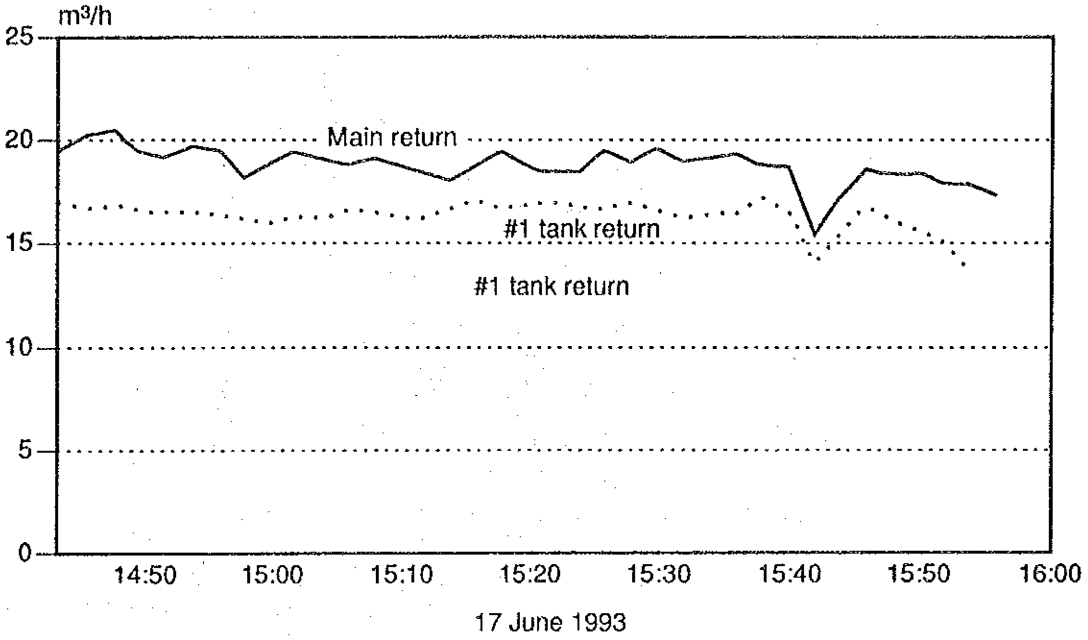


Figure 5.3.21 shows the results of measuring the condensate flow rate. The return of the condensate to the boiler amounts to about 19 tons per hour, and the return from the flash tank is about 16 tons per hour. The condensate from group 3 accounts for 84 % of the total, indicating an uneven use of the steam.

Figure 5.3.21 Steam Condensate Flow



As described in (5) a., increase in crosswise elongation of the heavy duty paper requires quick drying at the front stage of the dryer, so the current steam distribution is definitely abnormal. Through repeated experiment in the plant, reduce the number of cylinders and change the grouping of cylinders (reference: 8 cylinders for group 1, 15 cylinders for group 2 and 32 cylinders for group 3). Use the blow-through method, then steam and electric power will be saved.

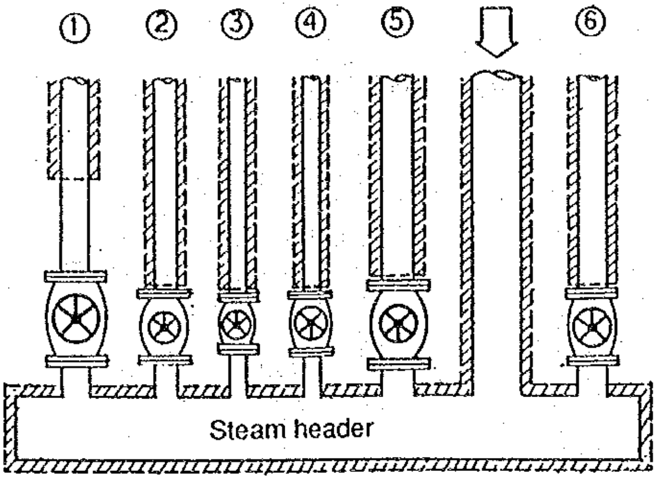
Much condensate was leaking from the pipe and pump around the drainage system, and heat insulators were damaged. It is necessary to remove unnecessary pipes and repair heat insulators immediately.

(6) Steam system

a) Intensified heat insulation

The heat insulation of the outdoor steam piping was satisfactory, and few steam leakages were found. However, valves and flanges were not heat-insulated.
For example, the outdoor steam collector installed close to the entrance of the power generation room is as shown in Figure 5.3.22.

Figure 5.3.22 Outdoor Steam Collector



▨ Shaded portion indicates the section where heat-insulation has already been provided.

Heat-insulating status for steam header, valve and pipe

Table 5.3.16 shows the heat release from the surface of the valves and installed pipes:

Table 5.3.16 Heat Radiation Surface Area of Valves

No.	Size inch	Equivalent length Valve m	Pipe m	Total m	Heat Radiation Present kcal/h	after Insulated kcal/h	Decrease kcal/h
①	16	2.04	1.00	3.04	7,680	400	7,280
②	10	1.90	0.25	2.15	3,740	200	3,540
③	8	1.84	0.25	2.09	2.990	160	2,830
④	8	1.84	0.25	2.09	2,990	160	2,830
⑤	16	2.04	0.25	2.29	5,790	300	5,490
⑥	12	1.90	0.25	2.15	4,360	230	4,130
Total					27,550	1,450	26,100

Preconditions: Steam temperature : 158 °C
Average outside air temperature: 10 °C
Heat insulation : Glass wool 60 mm

The heat release is calculated from the program worked out by the Energy Conservation Center, Japan (See Guideline).

Heat insulation saves the following amount:

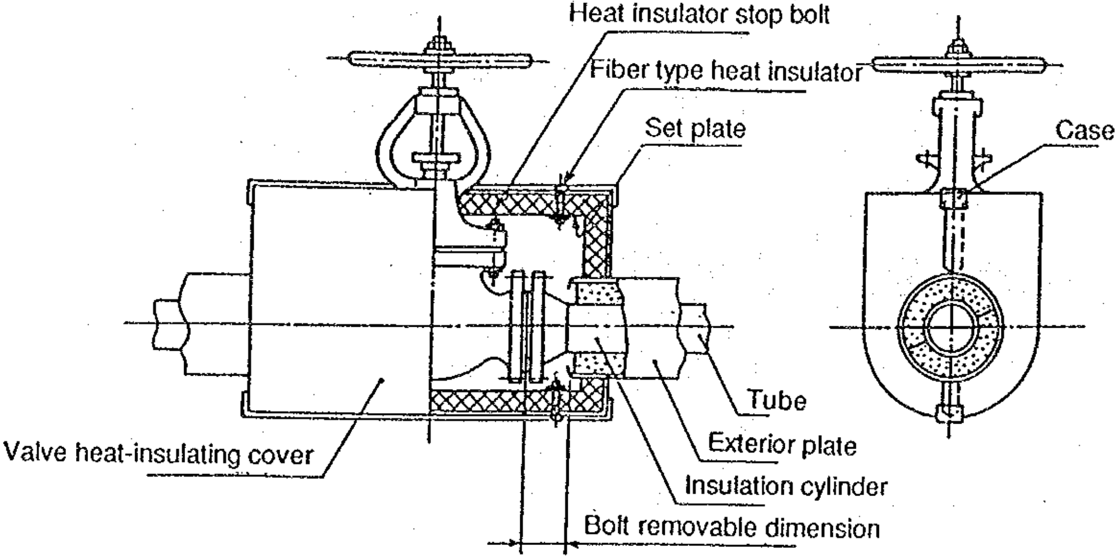
26.1 Mcal/h × 8,760 h/y = 228.6 Gcal/y
228.6 Gcal/y × 433 Lv/Gcal = 98,980 Lv/y

As simple valve heat insulation, cover the valve in a box covered with aluminum which can be split into two parts and can be removed easily. Fill the box with glass wool, and fix the box in position. This heat insulation can be provided by employees of the plant.

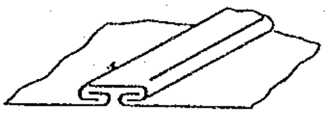
The total work area is about 15 m^2, and the work cost is estimated at about 1,500 Lv, which can be recovered in a short time.

Figure 5.3.23 Insulation of Valve & Flange

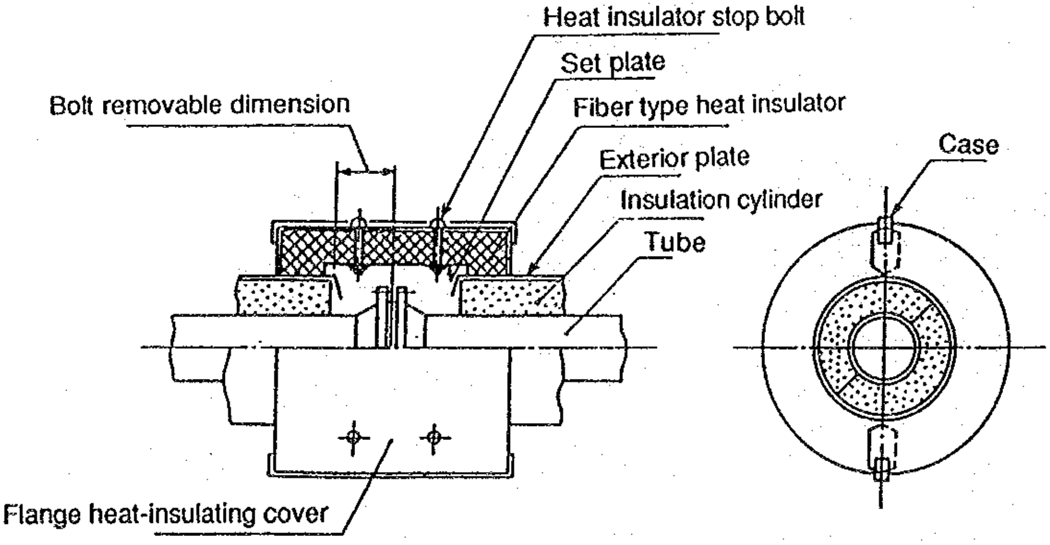
Heat Insulation of Valve



Details of case



Heat Insulation of Flange



b) Prevention of steam purge

Several times during the inspection period, high pressure steam was heard to be released into the atmosphere. This seems to have been caused by reduction in steam consumption on the process side and increase in the boiler pressure.
Since the boiler has a great heat capacity, a close contact should be had between the process and boiler sides, to enable earlier actions to be taken to prevent steam from releasing into the atmosphere. If there is much load change, a steam accumulator should be installed to provide smooth load distribution.

(7) Generated, received power and distribution facilities

a) Overview of the facilities

Figure 5.3.6 shows the electric power one line diagram. As a private power generation equipment, the plant is provided with four generators driven by steam turbine, which are generator No. 1 with a capacity of 4,000 kW, generator No. 2 with a capacity of 4,000 kW, generator No. 3 with a capacity of 6,000 kW, and generator No. 4 with a capacity of 12,000 kW, generating a total of 26,000 kW. Nos.1 and 3 were operating during the survey period. Two 6-kV cables were led from the electric utility, and power is received by one cable at all times.

The bus line of the power station is divided into four bus lines for each four generators, and they can be connected.

6-kV power was supplied to the five plants -- material plant, pulp plant, chemicals plant, B-14 paper machine and B-28 paper machine. The bus line in each plant is divided, and the power supply to each plant is stabilized by being supplied through different power station bus lines. Almost all the plant loads correspond to motor loads.

b) Results of measurement and study

1) Generated and received power of the factory

Figure 5.3.24 and Table 5.3.17 show the results of measurement.

Figure 5.3.24 Generated and Received Power

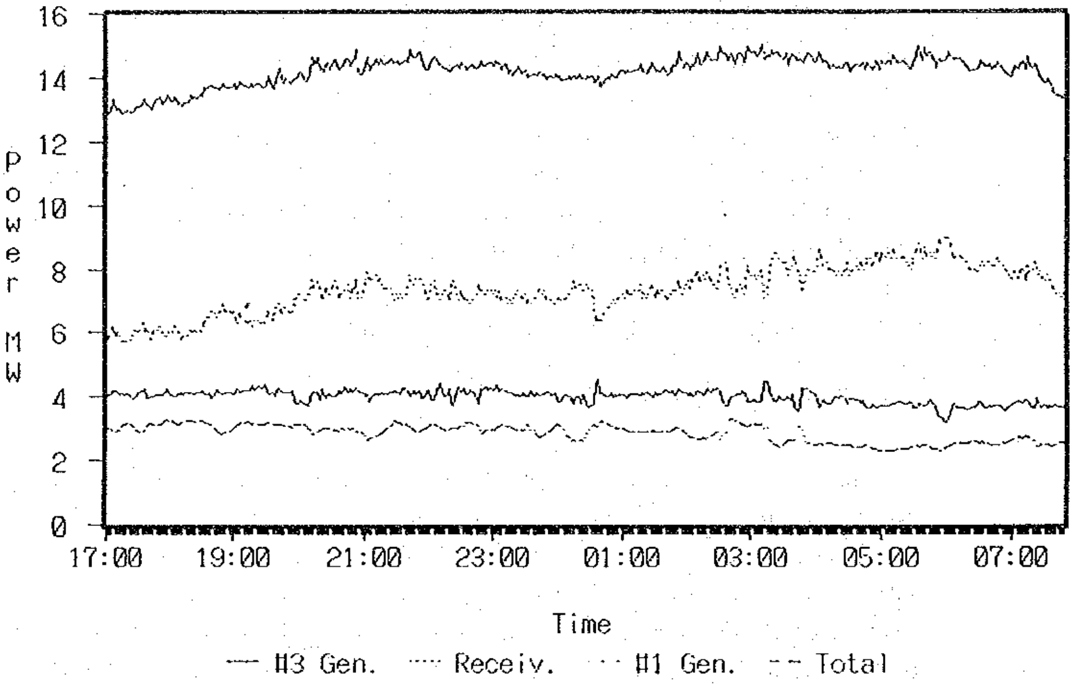


Table 5.3.17 Generated and Received Power

Measurement items	Rated capacity (kW)	Maximum power (kW)	Mean power (kW)	Minimum power (kW)	Reactive power (kVar)	Mean power factor (%)
No. 1 generator	4,000	3,550	2,790	2,290	2,860	69.8
No. 3 generator	6,000	4,830	4,000	3,190	4,250	68.5
Purchased power		9,430	7,350	5,700	3,260	91.4
Total		15,040	14,140	12,880	10,370	80.7

Note: Date of measurement: June 16 (16:00) to June 17 (10:00)

The steam passing through the turbine is approximately determined by the steam used in the plant. So the generators are base loads, and the variation of the electric power used in the plant absorbed by the purchased power. The load factor is about 80 %, and the power factor of the generator is reduced to load the reactive power, so that the purchased power factor is kept above 92 % of the contract. According to this method, however, the armature current of the generator will increase, causing the copper loss to be raised. Unused capacitors may be available in the plant, so if these capacitors are used to improve the load power factor, it is possible to reduce the range of reduction in the generator power factor.

For reference, the following shows the copper loss at the time of measurement:

Generator specifications :

Generator No. 1 : Capacity 5,000 kVA, voltage 6.3 kV, current 458 A, power factor 80 %, efficiency 96 %

Generator No. 3 : Capacity 7,500 kVA, voltage 6.3 kV, current 688 A, power factor 80%, efficiency 96.4 %

Average current during the measurement period :

392 A for No. 1 generator, 574 A for No. 3 generator

Copper loss : Assuming that the copper loss at the rated time is half the total loss, then:

Generator No. 1 : $5,000 \times 0.8 \times (1 - 0.96) \times 1/2 \times (392/458)^2 = 59$ kW

Generator No. 3 : $7,500 \times 0.8 \times (1 - 0.964) \times 1/2 \times (574/688)^2 = 75$ kW

The capacitor should be installed at the position as close as possible to the load terminal.

To take an example from the positions measured this time, power receiving terminal at Nos. 22 and 46 lines of B-28 showing poor power factor should be used.

2) B-28 power transmitted from power station to 6-kV substation for B-28 paper making machine through bus line, and power received at B-28 Substation (Nos. 6, 22 and 46 lines)
Tables 5.3.18 and 19 show the results of measurement:

Table 5.3.18 Power from Power Station to B-28 Substation

Line No.	Mean Voltage (kV)	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Time of measurement
B-28 No. 6	6.13	2,410	2,380	2,300	96.5	12:10-15:10
B-28 No. 22	5.95	2,490	2,210	1,980	57.6	12:00-15:10
B-28 No. 46	5.90	860	680	660	75.5	12:00-15:10
Total		15,040	5,270	12,880	76.9	80.7

Note : Date of measurement: June 15

Table 5.3.19 Power Received at B-28 Substation

Line No.	Mean Voltage (kV)	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Time of measurement
B-28 No. 6	5.94	2,460	2,430	2,410	98.3	11:15-11:40
B-28 No. 22	5.78	2,430	2,290	2,210	66.4	11:00-11:30
B-28 No. 46	5.50	501	460	437	71.5	11:30-12:00

Note: Date of measurement: June 17

The power factor of the distribution line No. 6 is satisfactory. Since measurement was made at different times, there may be some variations; the average voltage on the power station side is 6.13 kV, and that on the B-28 side is 5.94 kV, showing a voltage drop of 0.19 kV.

The power factor of the distribution line No. 22 is low. This is because the load on the paper making machine is as small as below 50 %, and the power factor is as low as 40 to 50 %.

Voltage is a little low; the average voltage on the power station side is 5.95 kV, and that on the B-28 side is 5.78 kV, showing a voltage drop of 0.17 kV. Though it may depend on the operating conditions, it is recommended to use the capacitor to improve power factor.

The power factor of the distribution line No. 46 is low. This is considered to be because most of the loads on transformers Nos.36 and 38 are used under the light load conditions for the roof blower and others.

Voltage is considerably low; the average voltage on the power station side is 5.90 kV, and that on the B-28 side is 5.50 kV, showing a voltage drop of 0.4 kV. The voltage drop should be kept below 5 %. It is recommended to use the capacitor to improve voltage drop.

3) Power distributed from B-28 substation (No. 6 line)

Table 5.3.20 shows the results of measurement:

Table 5.3.20 Power Distributed from B-28 Substation (No. 6 Line)

Measurment items	Rated capacity (kW)	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Time of measurement
#7 Compressor	800	1,151	876	823	90.6	11:35-12:05
#11 Disk Refiner	500	274	269	265	99.0	14:15-14:45
#13 Disk Refiner	500	237	232	229	96.4	14:15-14:45
#19 Mixer Pump	250	169	168	166	71.5	15:05-15:35
#23 Vacuum Pump	250	235	230	227	85.7	15:04-15:34
			(A)			
#33 Disk Refiner			32			
#35 Disk Refiner			20			
#39 Disk Refiner			10			

Note: Date of measurement: June 17

The measured power of turbo compressor NO.7 (800 kW) exceeds the rated value, but the ammeter indication is 90 A, and is not contradictory to the measurements. The problem may lie with the CT ratio, so it should be checked.

The disk refiner and mixing pump are operated under considerably small load conditions. If the light load conditions are to continue, idle small motor should be used to replace it.
The vacuum pump is almost fully loaded.

4) Power distributed from B-28 substation (6 kV No.22 line)

Table 5.3.21 shows the results of measurement:

Table 5.3.21 Power Distributed from B-28 Substation (No. 22 Line)

Measurment items	Rated capacity (kW, kVA)	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Time of measurement
Paper Machine #14	730	140	138	130	48.6	12:10-12:41
Paper Machine #16	730	327	325	323	51.0	14:05-14:35
Paper Machine #18	730	86	85	85	45.2	12:30-13:00
Paper Machine #20	730	360	343	338	52.5	14:10-14:40
Paper Machine #22	730	210	208	200	51.7	12:35-13:05
Transformer #24	1,000	368	326	324	77.2	14:45-15:15
Transformer #26	1,000	82	78	76	42.7	14:50-15:20
Transformer #28	1,000	360	248	130	100.0	15:30-16:00
			(A)			
Transformer #8			10			11:30-12:00
Transformer #12			42			11:30-12:00

Note: Date of measurement: June 17

The 1,000 kVA transformer is operating under the low load condition. It is necessary to integrate the transformers. Since their test records are not available, the iron loss and loss ratio of the 1,000-kVA transformer are assumed to be the same as those of the general transformers, and are 3.5 kW and 4, respectively. The following studies the feasibility of integrating three transformers measured this time.

Average apparent power:

No. 24 transformer	422 kVA
No. 26 transformer	184 kVA
No. 28 transformer	245 kVA
Total	$((326 + 78 + 248)^2 + (268 + 166 + 0)^2)^{0.5} = 783$ kVA
Nos. 26 and 28 total	$((78 + 248)^2 + (166 + 0)^2)^{0.5} = 366$ kVA

Current transformer loss

No. 24 transformer	$L_1 = 3.5 + 3.5 \times 4 \times (422/1{,}000)^2 = 5.99$ kW
No. 26 transformer	$L_2 = 3.5 + 3.5 \times 4 \times (184/1{,}000)^2 = 3.97$ kW
No. 28 transformer	$L_3 = 3.5 + 3.5 \times 4 \times (245/1{,}000)^2 = 4.34$ kW
Total	$L_4 = 5.99 + 3.97 + 4.34 = 14.30$ kW

Loss when integrated to one 1,000-kVA transformer:

$$L_1' = 3.5 + 3.5 \times 4 \times (783/1{,}000)^2 = 12.08 \text{ kW}$$

Total loss when Nos. 26 and 28 transformers are integrated to one:

$$L_1'' = 5.99 + 3.5 + 3.5 \times 4 \times (366/1{,}000)^2 = 11.37 \text{ kW}$$

Reduced loss	(14.30 – 11.37) = 2.93 kW
Annual reduced loss	2.93 × 8,760 = 25,670 kWh

Measurement should be continued further to predict the subsequent load conditions, and it is necessary to determine how to integrate the five transformers, including two units which could not be measured in this study.

5) Power distributed from B-28 substation (6 kV No.46 line)

Table 5.3.22 shows the results of measurement:

Table 5.3.22 Power Distributed from B-28 Substation (6 kV No.46 line)

Measurment items	Rated capacity (kVA)	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Time of measurement
Transformer #36	1,000	165	141	136	64.9	15:40-16:00
Transformer #38	1,000	92	88	87	69.2	15:45-16:00
			(A)			
Transformer #42			20			

Note: Date of measurement: June 17

- Major load on transformer No. 36

Roof-top induced blower	No. 1 (28 kW), No. 2 (28 kW), No.6 (5.5 kW)
Roof-top forced blower	No. 3 (13 kW), No. 5 (22 kW), No.6 (22 kW) No. 9 (30 kW), No. 10 (30 kW)
Induced blower (for indoor use, 40 kW)	
Total blower load	218.5 kW

- Major load on transformer No. 38

Roof-top induced blower	No. 3 (28 kW), No. 4 (28 kW), No. 5 (10 kW)
Roof-top forced blower	No. 2 (13 kW), No. 4 (13 kW), No. 7 (22 kW), No. 8 (22 kW) No. 11 (30 kW), No. 12 (30 kW), No. 13 (30 kW)
Total blower load	226 kW

Similar to the case of 4), the 1,000-kVA transformer is operating under the low load condition, so it is necessary to integrate the transformers. Since their test records are not available, the iron loss and loss ratio of the 1,000-kVA transformer are assumed to be the same as those of the general transformers, and are 3.5 kW and 4, respectively. The following studies the feasibility of integrating two transformers measured this time.

Average apparent power:

No. 36 transformer	217 kVA
No. 38 transformer	128 kVA
Total	$((141 + 88)^2 + (165 + 92)^2)^{0.5} = 344$ kVA

Current transformer loss

No. 36 transformer	$L_1 = 3.5 + 3.5 \times 4 \times (217/1{,}000)^2 = 4.16$ kW
No. 38 transformer	$L_2 = 3.5 + 3.5 \times 4 \times (128/1{,}000)^2 = 3.73$ kW
Total	$L_3 = 4.16 + 3.73 = 7.89$ kW

Loss when integrated to one 1,000-kVA transformer:

$L_1' = 3.5 + 3.5 \times 4 \times (344/1{,}000)^2 = 5.16$ kW

Reduced loss	$(7.89 - 5.16) = 2.73$ kW
Annual reduced loss	$5.16 \times 8{,}760 = 45{,}200$ kWh

Measurement should be continued further to predict the subsequent load conditions, and it is necessary to determine how to integrate the three transformers, including one unit which could not be measured in this study.

6) Compressor

Table 5.3.23 shows the results of measurement:

Table 5.3.23 Compressor Load

Measurment items	Rated capacity (kW)	Maximum power (kW)	Mean power (kW)	Minimun power (kW)	Mean power factor (%)	Time of measurement
6 kV Compressor #7	250	234	234	232	96.7	11:00-12:00
6 kV Compressor #9	250	223	222	221	93.5	11:00-12:00
380 kV Compressor #5	75	60	59	58	88.6	11:45-13:15
380 kV Compressor #7	75	60	59	59	86.7	11:45-13:15

Note : Date of measurement: June 16

- 6-kV compressor: pressure 8 bars, flow rate 40 m^3/min., current 28.7 A
- 380-V compressor: pressure 8 bars, flow rate 10 m^3/min., current 140 A

Two 6-kV compressors with rated capacity of 250 kW and two 380-kV compressors with rated capacity of 75 kW are operated for all plants, with a total of 574 kW. The availability factor of the 6-kV compressors was 91 % and that of the 380-V compressors was 78 %, showing favorable values. Observing the pressure, however, the delivery pressure in the compressor room was 6 bars, while operating pressure in the B-28 plant was 4 bars, exhibiting a difference of 2 bars. The permissible pressure loss at this pressure is said to be 0.3 to 0.8 bars, so the pressure loss in this plant is excessive. If pressure loss is reduced to 0.5 bars, loss of 1.5 bars will be reduced, resulting in the saving of power by about 7 %. Since the compressor power is about 570 kW, annual power saving will be as follows:

570 × 0.07 × 8,760 = 350,000 kWh

To reduce the pressure loss, the air leakage should be checked first. According to the air leakage measurement described in the guideline, leakage can be easily measured. It is recommended to refer to this guideline. Secondly, the problem may lie in excessive pipe length (about 600 meters). Distributed compressor layout plan should also be studied.

(8) Total effect

Table 5.3.20 shows the above mentioned improvements which permit quantitative prediction of the effects of taking improvement actions.

Table 5.3.24 Summary

Item	Expected Saving							Investment Payback	
	Steam			Power			Total	Year	
	Gcal/y	1000Lv/y	%	kwh/y	1000Lv/y	%	1000Lv/y	1000Lv	y
Cooking									
Indirect Cooking	6100.0	2641.3	2.2				2641.3	4000	1.5
Evaporation									
Evaporation Ratio Up	25000.0	10825.0	8.9				10825.0	200	0.02
Paper Machine									
Cylinder Number Decrease				1169300	818.5	1.3	818.5	0	0.0
Steam Pipe									
Insulation of Valves	228.6	99.0	0.1				99.0	1.5	0.02
Transfomer									
Integration #26, #28				25700	18.0	0.0	18.0	0	0.0
Integration #36, #38				45200	31.6	0.1	31.6	0	0.0
Compressor									
Pressure Decrease				350000	245.0	0.4	245.0	0	
Total	31328.6	13565.3	11.2	1590200	1113.1	1.8	14678.4	4201.5	0.3

5.4 Results of the Study at a Textile Factory

5.4 Results of the Study at a Textile Factory

5.4.1 Overview of the plant

(1) Factory name
Nitex-50

(2) Type of industry
Textile products

(3) Major product name and production capacity
Woollen and worsted fabric : 2,500 km/y
Woollen and worsted yarn : 1,500 t/y

(4) Number of employees
520

(5) Factory address
gara Iskar, Sofia

(6) History
Started as a private company in 1938, Nitex-50 was then nationalized, and is now producing the wool yarn, winter clothing and blanket. Ninety-five percent of the products are exported mainly to the North America and mid-South America. Of the six companies in Bulgaria, Nitex-50 is 4th factory in size. It features a compact, well-organized factory. New production equipment have been introduced, and the number of employees on the payroll has been reduced to one fourth of 2,000 for the peak time. The products are competitive for export in both quality and price. Affected by the economic slump, the production of the last fiscal year has been decreased to one fourth to one third of the peak time level. There are indications for recovery, and the company is planning to convert the operation from the two-shift system to the three-shift system. The Nitex-50 has a subsidiary company which degreases the raw wool within the factory, and the use of the waste water treatment facilities is shared by these two companies.

(7) Study period
June 28, 1993 to July 2

(8) Members of study group
Mitsuo Iguchi : Head of the study group, energy management
Teruo Nakagawa : Assistant Head of the study group, measurement
Akira Koizumi : Thermal technology
Shoji Nakai : Thermal technology
Takashige Taniguchi : Textile process
Tetsuo Ohshima : Thermal technology
Kazuo Usui : Electric engineering

(9) Persons interviewed

Mr. Nikolai Lazarov : President
Mr. Savcho Savchev : Deputy Director
Mr. Emanuil Stoyanov : Energy Manager

(10) Trend of production

Table 5.4.1 Trend of Production

Name of Product	Unit	1987	1988	1989	1990	1991	1992
Fabric	km	2333	2022	2352	2042	1096	525
Worsted	km	695	609	906	832	504	310
Woollen	km	1191	1051	1098	955	341	215
Knitted goods	km	416	354	348	255	0	0
Blanket	km	31	8	0	0	251	267
Yarn	t	1588	1595	1513	1277	742	470
Worsted	t	908	955	906	697	310	157
Woollen	t	680	640	607	580	432	313

(11) Trend of sales amount

Table 5.4.2 Trend of Sales Amount

Name of Product	Unit	1987	1988	1989	1990	1991	1992
Fabric	km	2294	2003	2332	2042	982	574
Worsted	km	700	608	728	704	422	372
Woollen	km	1189	1018	1257	1074	327	202
Knitted goods	km	390	373	347	256	0	0
Blanket	km	15	4	0	0	231	259
Yarn	t	426	545	413	349	57	21
Worsted	t	364	457	361	316	57	21
Woollen	t	62	88	52	33	0	0

(12) Trend of energy consumption

Table 5.4.3 Trend of Energy Consumption

Energy	Unit	1987	1988	1989	1990	1991	1992
Steam	Gcal	38905	36702	30449	36654	29962	28039
Electric Power	MWh	7439	7243	7383	6651	4305	3225
City Water	km^3	150	150	214	188	158	197

(13) Trend of unit energy consumption

Table 5.4.4 Trend of Unit Energy Consumption

Energy	Unit	1987	1988	1989	1990	1991	1992
Steam	Gcal/km-Fab.	16.7	18.2	12.9	18.0	27.3	53.4
Electric Power	MWh/km-Fab.	3.19	3.58	3.14	3.26	3.93	6.14

(14) Trend of monthly production and energy consumption

Table 5.4.5 Monthly Production & Energy Consumption

Year	Month	Production			Energy			
		Yarn	Weaving	Finishing	Steam	Hot Water	Total	El. Power
		ton	km	km	Gcal	Gcal	Gcal	MWh
1992	1	58.4	125.4	96.3	5583.6	704.0	6287.6	379.5
	2	55.0	90.4	103.3	4471.6	525.1	4996.7	384.9
	3	47.9	96.5	73.3	4796.9	443.6	5240.5	319.8
	4	43.8	78.9	48.9	2309.5	186.8	2496.3	276.1
	5	42.3	57.2	54.3	1025.8	0	1025.8	180.5
	6	49.9	90.0	65.9	1431.3	0	1431.3	327.0
	7	29.1	70.9	102.6	556.7	0	556.7	309.3
	8	0	0	−0.5	32.8	0	32.8	65.2
	9	17.7	33.4	67.3	249.9	0	249.9	100.5
	10	34.2	61.3	51.5	1205.3	0	1205.3	244.2
	11	41.1	63.9	55.4	1234.8	256.2	1491.1	241.2
	12	53.1	62.3	73.7	5140.9	653.3	5794.2	397.2
1993	1	45.1	66.9	38.3	3353.1	354.2	3707.3	242.4
	2	30.5	56.4	43.1	3319.5	368.1	3687.6	259.5
	3	37.3	72.1	57.4	2804.0	442.2	3246.2	267.6
	4	31.1	54.8	68.3	2815.8	209.5	3025.3	325.5
	5	33.6	52.1	45.9	805.3	0	805.3	192.0

Figure 5.4.1 Monthly Heat (Steam + Hot Water) Consumption

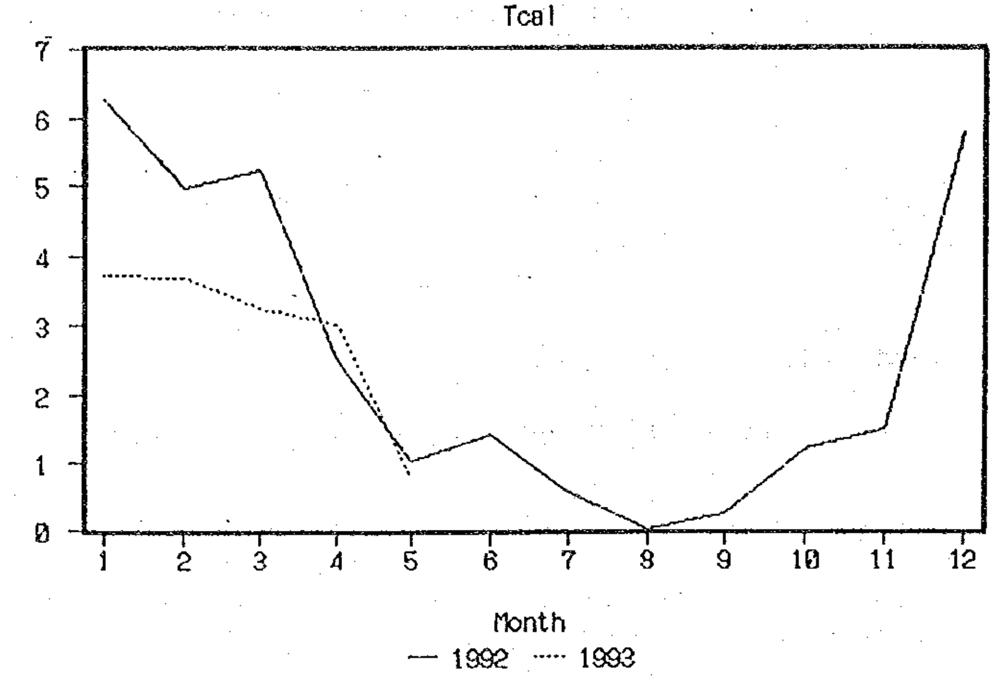
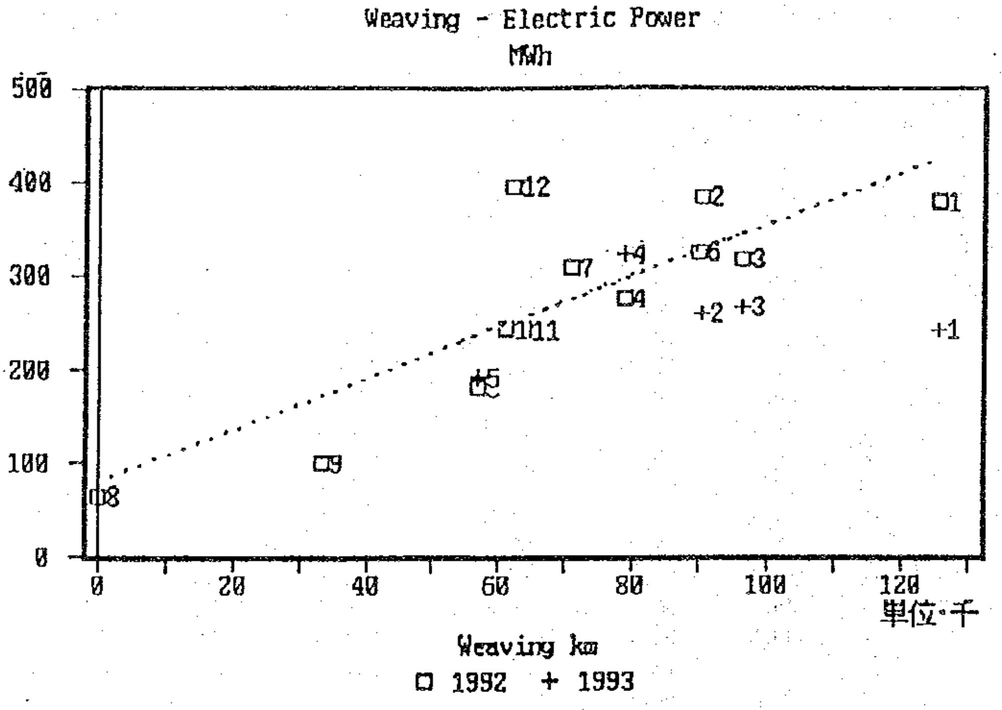


Figure 5.4.2 Weaving km vs. Electric Power Consumption MWh



Correlation $R^2 = 0.65$ $Y = 2.759X + 81.65$

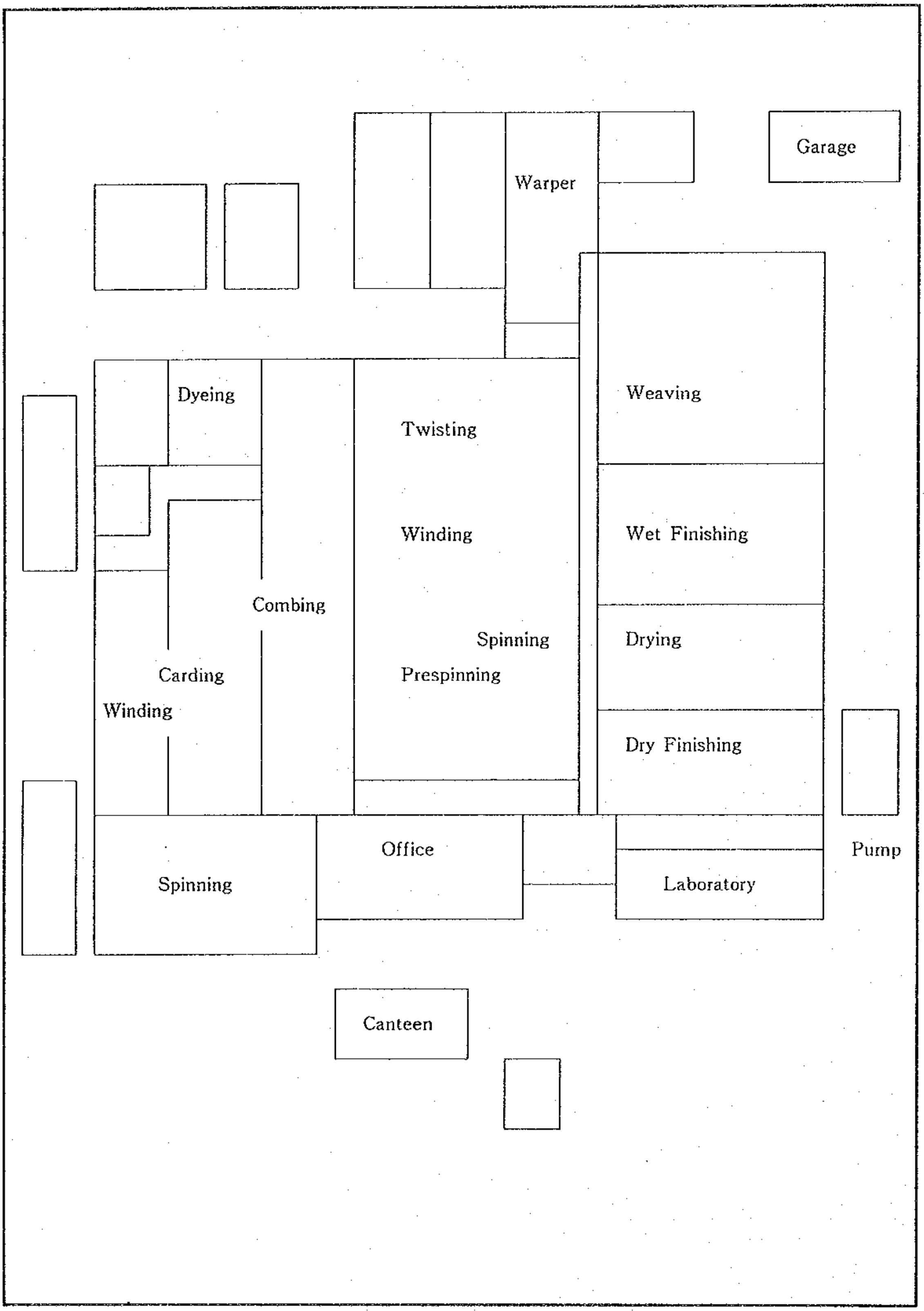
(15) Energy cost

Steam	Period	1992. 1-4	1992. 5-12	1993. 1-4	1993. 5-
	Lv/Mcal	0.343	0.463	0.509	0.610

Electric power	Time	Peak	Day	Night	
	Lv/kWh	1.395	0.754	0.374	Oct-Mar
	Lv/kWh	1.217	0.655	0.322	Apr-Sep

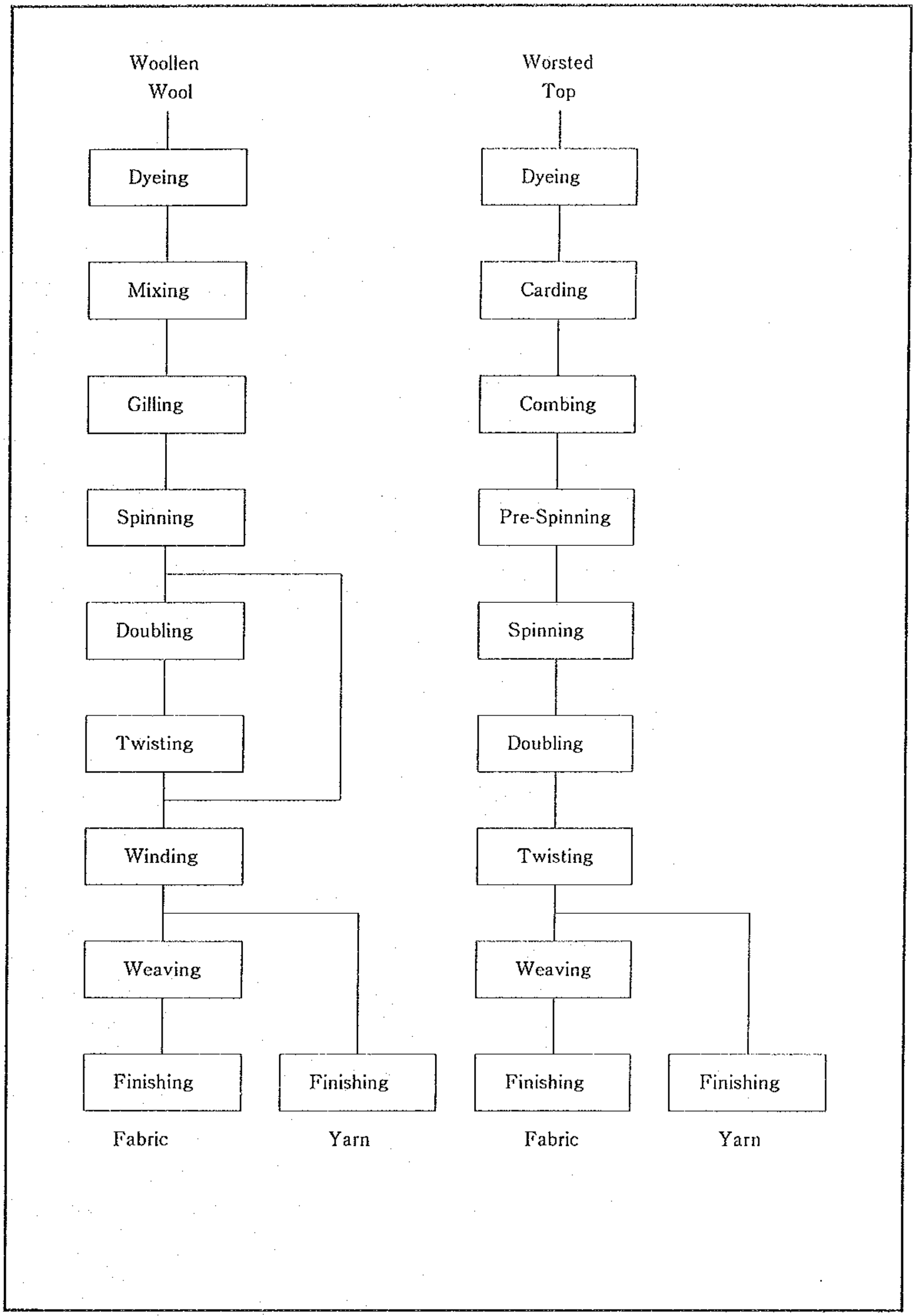
(16) Factory layout

Figure 5.4.3 Factory Layout



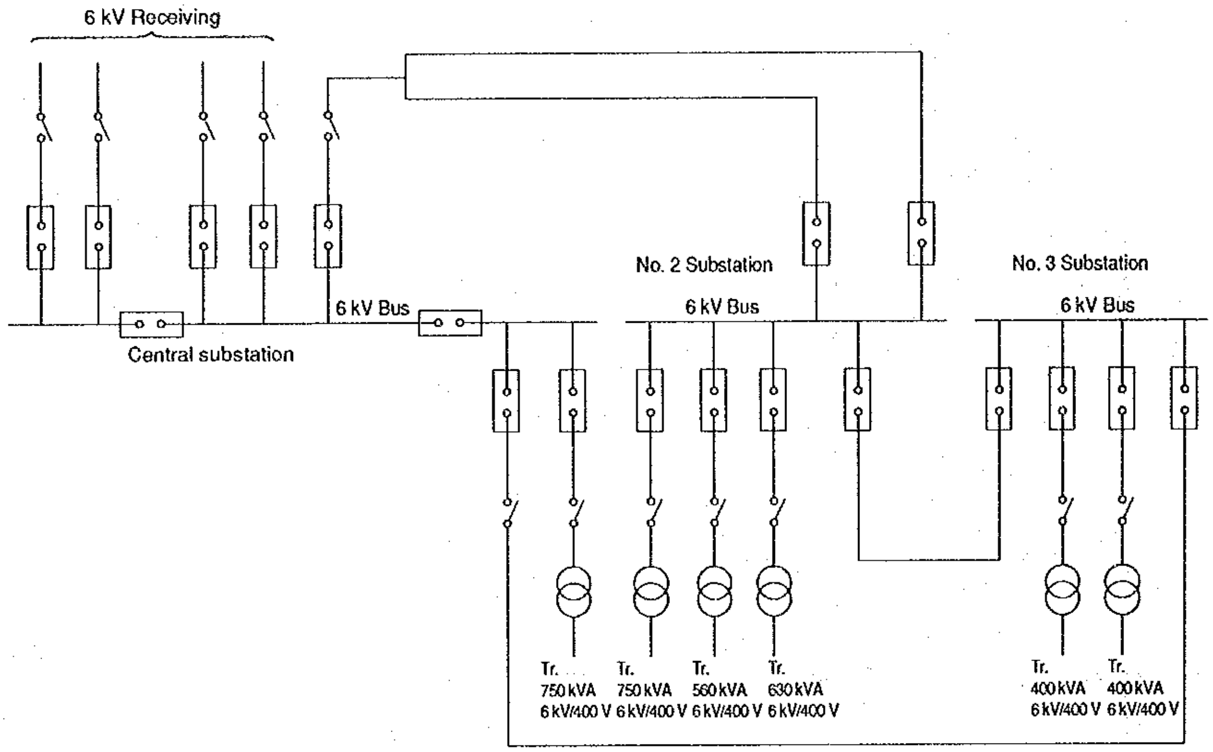
(17) Production process

Figure 5.4.4 Production Process



(18) Electric power one line diagram

Figure 5.4.5 Electric Power One Line Diagram



(19) Outline of principal equipment

Table 5.4.6 Outline of Principal Equipment

Name	Number	Specifiction	
Worsted Yarn Process	1	Top Dyeing	1
		Back Washer	1
		Sliving	1
		Prespinning	1
		Ring Spinning	1
		Autoconer	24
		RT Winder	1
		Double Twister	10
		Twister	1
Woollen Yarn Process	1	Open Vat Dyeing	1
		Dryer	1
		Roller Card	5
		Vacuum Cleaner	1
		Ring Spinning	6
		Twister	4
		Autoconer	2
Weaving Process	1	Autoclave	1
		Que Winder	1
		Warper	5
		SOMET Looms	8
		Looms	1
Wet Finishing Process	1	Crabing	3
		Wide Washer	2
		Milling	9
		Cord Washer	5
		Dyeing	4
Dry Finishing Process	1	Dryer	2
		Raising	1
		Press	1
		Decatizer	2
		Shearing	3

5.4.2 Situation of energy management

The energy cost of Nitex-50 accounts for about 16 percent of the total cost, exhibiting the highest percentage second to the material cost. Of the energy cost, the total cost of the steam, hot water and condensate is 80 percent. The consumption does not show much correspondence with the production cost, as shown in Figure 5.4.1, and depends almost completely on the seasonal factors which are room heating demands in winter times.

All 47 thermodynamic steam traps were replaced by mechanical steam traps in this factory in the beginning of this year. As can be seen from Figure 5.4.1, the factory succeeded in reducing the total consumption of the steam and hot water by about 40 percent over the preceding year level. In addition, the company is trying to make hot water by the recovery of the condensate heat.

As described in the above discussion, the management of the Nitex-50 factory are much interested in energy consumption, and are making efforts to seek ways for cutting the energy use. However, these efforts still depend on the particular activities by part of the people; systematic energy conservation campaign involving all the employees are not yet implemented.

Energy consumption efficiency differs according to the performances of the equipment and machinery and operation methods, which depend greatly on the skills and actions of the personnel in charge of operation and maintenance.

Adequate maintenance and servicing must be taken to ensure design performance of the equipment, and small-scale modification should be made to provide improved performances. It is necessary not only to try to conform to operation standards but also to make improvement efforts to find out better operation methods.

This is related to all the members engaged in the work. To ensure effective promotion of the energy conservation, it is essential to establish an organization to ensure that all the people of the factory make concerted efforts to achieve the target, as well as to take measures for the equipment improvement.

(1) Setting the target for energy conservation

To initiate energy conservation, the top management of the company must define the energy conservation as one of major management targets, demonstrating serious attitude and enthusiasm for energy conservation to the employees. This will convince the employees that making efforts for energy conservation will conform to the policy of the company, and will motivate them for positive efforts.

When policy is shown by the top management, mere abstract instruction for energy conservation is not sufficient; concrete target values and the deadline for achieving the goal must be shown to the workers. In response to these instructions, each section of the factory should set up the concrete targets for individual items which can be taken charge of within the scope of the responsibility, so that the overall target can be achieved. Only after the target has been set, concrete action plans to achieve the target can be worked out, including study of various approaches, preparation of the programs and assignment of the works.

However, setting the target requires correct information on the current energy consumption in the factory. In the Nitex-50 factory, watt-hour meters are installed for respective substations, but the plant is not equipped to provide correct information on the consumption for each process. It is provided with purchased steam flow meter, but not with flow meters for each process. Without correct information on how much energy is consumed in each process, it is impossible to compare it with design conditions to make evaluation or to set up the quantitative target value. Even if energy conservation measures are taken, the effects cannot be confirmed. The top priority should be given to procuring measuring instruments.

(2) Systematic actions

The Nitex-50 factory is staffed with the employees in charge of energy, but systematic energy conservation campaign involving all the employees are not yet initiated.

To implement the energy conservation campaign with concerted efforts of all the members, it will be effective to establish a committee comprising representatives of the management division, production division and auxiliary division, so that interaction can be provided between the processes particularly among the production-related divisions. This committee should work out the energy conservation program, determine the budget, approve the technical energy conservation measures, evaluate the results, and introduce various cases. This will ensure uniform understanding to be shared among different divisions, permitting the efforts to be made on a priority basis. This will also make it possible to check if a particular action has a total effect including the effect given to the preceding and succeeding processes. It will also permit advice to be given from different angles.

It is also necessary to hold various events in order to keep the employees interested in the energy conservation, or appoint coordinators to make arrangements among different related divisions, in order to ensure smooth implementation of the energy conservation activity.

The employees working in the first line are placed in daily contact with energy consuming equipment, and they get the feel of the problems with their own skin. An effective use of energy cannot be achieved if the equipment are not used effectively and work standards are not observed, no matter how excellent they are. So it is effective to keep the employees in the first line interested in the energy conservation campaign so that they will take an active part in the activity.

(3) Data-based management

In energy conservation activity, as in the quality control, steady improvement can be gained by repeating the PDCA circle where an improvement plan is worked out (PLAN) and implemented (DO), the results are evaluated (CHECK), the work process is modified fixed (ACTION) in accordance with the evaluated results; then an improvement plan on a higher level is worked out. Thus the control level is gradually increased, repeating the same cycle.

The problems accompanying energy consumption to be studied in working out the improvement plan and suggestions for improvements can be made clear only through an objective analysis of the data (facts) occurring in the factory. The effects of the energy conservation efforts can be confirmed by means of statistical techniques such as unit consumption rate control chart, histogram and correlation analysis on the basis of the actual data. If there is abnormal data, much information can be gained by checking the cause for such fault.

In the Nitex-50 factory, the production volume and monthly energy consumption data are prepared effectively. If the data are prepared for each process, process engineers will take greater interest in energy to work out energy use rationalization measures.

The purchased steam measuring instrument is designed in an orifice system, and the indication differs according to the density of the flow. So correct values cannot be provided unless it has a device to measure the steam pressure and temperature and to provide automatic compensation; this was said to be currently under study. It is recommended that the instrument be replaced. The orifice type is extensively used, but indications are often not accurate in the low flow rate range (30% or less of the full scale). Since the calorific value of the saturated steam changes with the pressure, the received steam pressure should be automatically recorded.

(4) Education and training of employees

It is necessary to give sufficient information in order to promote voluntary activities of the employees. To motivate efforts for energy conservation, the employees should be informed of the trend of energy prices, the weight of the energy cost in the production cost, possible causes for energy losses, preventive measures, and cases of successful energy conservation efforts in other factories.

It is also necessary to promote education and training of the employees by giving instructions through competent staff members, by giving training courses, and by providing them with manuals; thereby increasing their level.

This Nitex-50 factory is said to have a system of providing education to the operators through the factory staff members immediately before they are subjected to higher qualification test, and the staff members are awarded with bonuses when the education has been proven effective. This system is making a significant contribution to improving the education level.

(5) Equipment management

If the equipment is not maintained in proper conditions, a great energy loss will occur. In the Nitex-50 factory, the production equipment were subjected to effective maintenance and repair. However, some of the auxiliary equipment were not provided with sufficient maintenance, and found out in damaged conditions; for example, the damaged dampers of the ventilation equipment, damaged filters, steam leakage from the collector, faulty heat insulation of the steam pipe, and broken building windows. They will lead to the waste of energy; this requires establishment of the planned equipment maintenance system.

Furthermore, the equipment installed in the past, such as the waste heat recovery equipment of the dryer, were not used. They should be removed since the remaining pipe may interrupt with the draft.

Drawings such as the factory layout plan are essential for the maintenance of the equipment. Revised drawings must be prepared immediately after any modification work has been made, and they must be put in order so that they can be easily used by any one.

5.4.3 Problems in the use of energy and countermeasures

(1) Dryer for Wool Fabric Finishing Shop

A dryer is usually used in the second half of a wool fabric finishing process. It has much effect on quality and production efficiency, and uses much steam. Drying temperature, fresh air taking in and characteristics of drying materials, are to be considered based on the results of this study.

a. Heat Balance

1) Measuring Result

The measurement was conducted from 12:50 to 16:00 on June 29. When a machine was stopped to change fabrics to be processed, data obtained from the machine became unstable. Therefore, the data obtained between 15:45 and 15:55, when the equipment was not stopped, was used.

- Wool fabric tested

Product name	: Karmen
Raw material	: Wool 100 %
Width of fabric	: 150 cm
Length tested	: 42 m
Moisture content	: Measurement of moisture content of fabrics before and after drying was done, using fabrics of the same kind on the day subsequent to the test.The moisture content was calculated using the equation below:

$$Z = \frac{Gw}{Gs} \times 100$$

Z : Rate of moisture content to bone dry weight (%)
Gs : Bone dry weight of wool fabric
Gw : Moisture contained in wool fabric

Table 5.4.7 shows the result of the measurement of moisture in the fabric samples, unit wet weight of the samples, and charges.

- Other measurement items

Table 5.4.8 shows other measurement items, measuring results and measuring equipment.

Figure 5.4.6 illustrates the measuring points.

Steam flow for drying, which is the basis of heat input, was obtained by measuring condensate flow. Electric power for hot air circulating fans was measured, and the resultant value was added to the heat input.

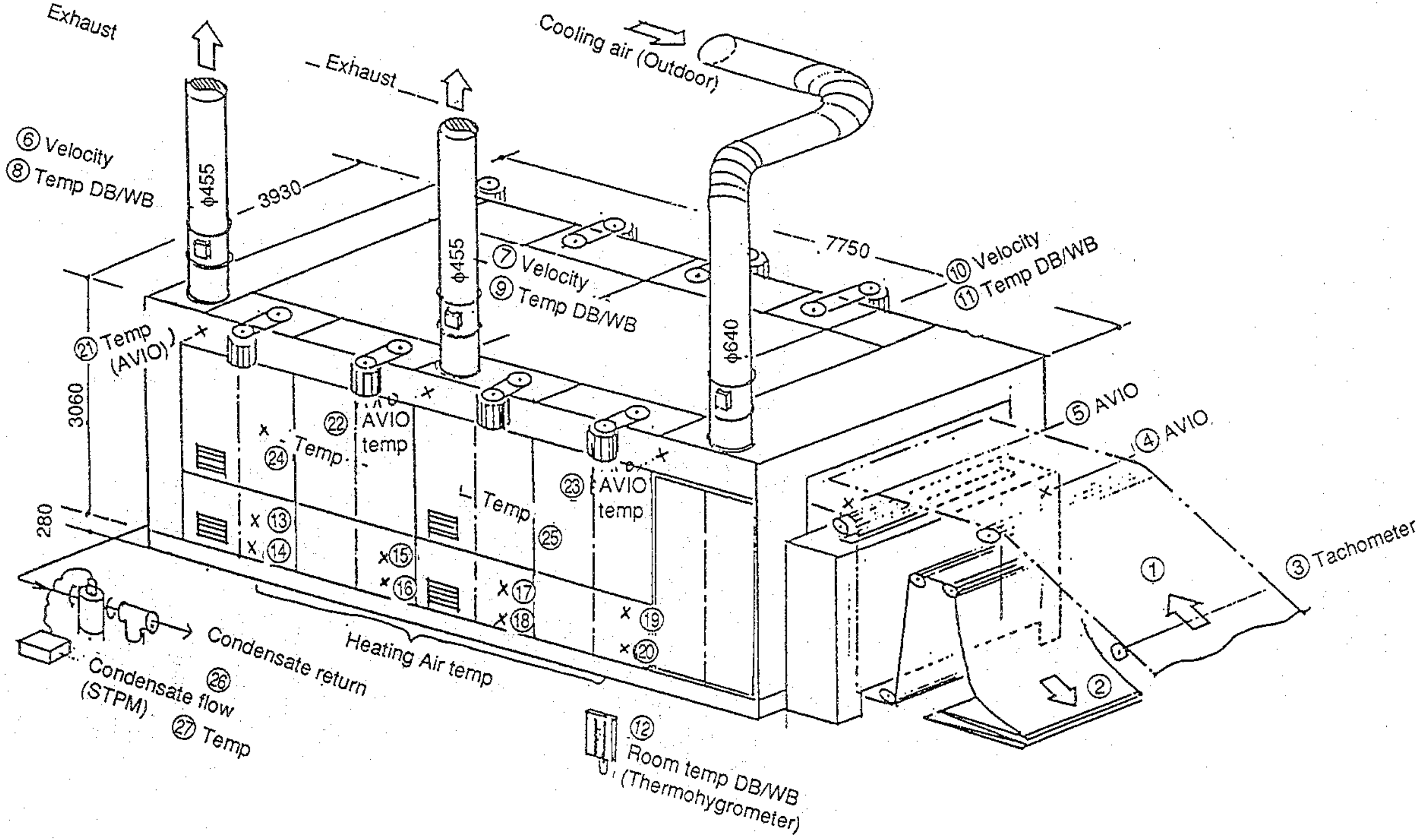
Table 5.4.7 Water Content of Sample

Item	Unit	before Drying	after Drying	Note
Sample Size	cm	150 ×38.5	153 ×49.0	
Wet Weight	g	180	165	
Bone DryWeigh	g	115	155	
Water Content	%	56.5	6.5	Water/Dry Material
Unit Wet Weight	g／m²	311.7	220.1	
Unit Wet Weight	g／m	467.5	336.7	Width 150 cm
Charge (Wet)	kg／h	594.7	404.5	Evaporated 190.2 kg／h
(Dry)	kg／h	379.9	379.9	

Table 5.4.8 Measuring Result

Item		Unit	Measuring Result	Note
Fabric				
Feed Speed		m／min	21.2	Tachometer
Inlet Temp.		℃	24.3	AVIO
Outlet Temp.		℃	62.0	AVIO
Exhaust Air				
Velocity	No. 1	m／s	2.62	Anemometer
	No. 2	m／s	2.22	Anemometer
Temp.	No. 1	℃	127	Thermocouple
	No. 2	℃	134	Thermocouple
Cooling Air				
Velocity		m／s	7.67	Anemometer
Temperature		℃	25.5／19.2	Thermocouple
Dryer Surface				
Temperature		℃	Average 43	AVIO、 Thermocouple
Steam Condensate				
Flow		kg/h	622	STPM
Pressure		kgf/cm²	8	STPM
Room Temperature		℃	28.7／21.3	Dry Bulb／WetBulb
FanPower		kW	17.2	

Figure 5.4.6 Measuring Point of Dryer



2) Heat Demand for Drying

Table 5.4.9 shows the heat demand for drying (quantity of heat applied to wool fabric + quantity of heat applied to moisture in wool fabric).

Amount of moisture vaporized from wool fabric: 380 × (0.565 - 0.065) = 190.2 kg/h
Amount of moisture remaining in wool fabric : 380 × 0.064 = 24.3 kg/h

Table 5.4.9 Heat Demand for Drying

Item	Quantity kg/h	Specific Heat kcal/(kg・℃)	Evaporat'n Heat kcal/kg	Initial Temp. ℃	Final Temp. ℃	Required Heat kcal/h
Dry Wool	379.9	0.325		24.3	62.0	4,660
Remaining Water	24.5	1.0		24.3	62.0	920
Vaporized Water	190.2		648.6	24.3	130.5	118,770

3) Heat Radiation from Dryer Surface

Heat loss from surface was calculated from the temperature of dryer surface, and Table 5.4.10 shows the result of the calculation.

Table 5.4.10 Heat Radiation from Dryer Surface

Surface	Area ㎡	Temp. ℃	Heat Radiation Coeff. kcal/(㎡・h・℃)	Heat Radiation kcal/h
Top	30.5	51.2	9.9	6,790
Side Wall	71.5	41.5	7.4	6,770
Bottom	11.8	36.0	6.2	530
Total	113.8			14,100

Note: Room Temp. 28.7 °C
Emissivity of Surface = 0.9
Refer to the guideline for the calculation method.

4) Heat Balance Chart

Table 5.4.11 shows the heat balance chart tabulated based on the results above.

Table 5.4.11 Heat Balance Chart

Item	kcal/h	%	Note
Heat Input			
Heat of Steam	411,700	97.0	622kg/h × 661.9 kcal/kg
Power of Fan	12,570	3.0	17.2 kWh × 860 kcal/kWh × 0.85
Total	42,270	100.0	
Heat Output			
Fabric	4,660	1.1	Table 5.4.9
Water in Fabric	920	0.2	Table 5.4.9
Subtotal	5,580	1.3	
Evaporated Water	118,770	28.0	Table 5.4.9
Exhaust Air	43,740	10.3	(1906-190) × 0.24 × (130.5-24.3)
Loss from Surface	14,100	3.3	Table 5.4.10
Heat of Condensate	109,790	25.9	622kg/h × 176.5 kcal/kg
Other Loss	132,300	31.2	
Total	424,270	100.0	

85 % of 17.2 kw, the measured power for the dryer hot air circulating fans, was added as heat equivalent of work to the heat input.

In the heat balance chart, the other loss occupies a large proportion. This may be because the hot air leaked into the room, and because the fabrics used for the analysis were sampled the next day of the performance test.

- Efficiency of heat utilization

If the quantity of heat of the fabrics after drying and that of moisture contained therein, and the heat of moisture vaporization are taken as effective heat, then the efficiency of heat utilization is calculated as follows:

Efficiency of heat utilization = (5,580 + 118,770) / 424,270 × 100 = 29.3 %

If the latent heat of steam is put as heat input, the efficiency of heat utilization is calculated as follows:

Efficiency of heat utilization = (5,580 + 118,770) / 314,490 = 39.5 %

- Unit consumption

The unit consumption rate per unit quantity of dry fabric is as follows:

Steam unit consumption rate : 622 / 404.5 = 1.54 kg - Steam/kg-Fabric
622 /1,270 = 0.49 kg - Steam/m-Fabric
Heat unit consumption rate : 411,700 / 404.5 = 1,018 kcal/kg-Fabric
411,700 / 1,270 = 324 kcal/m-Fabric

The insulation of the dryer is well maintained, but the loss of heat remarkably increases with the maintenance door open. It is preferable to keep the dryer surface temperature at 50°C or below, at which the dryer body can be touchable by hand.

b. Problems in Facility and Operation and the countermeasures

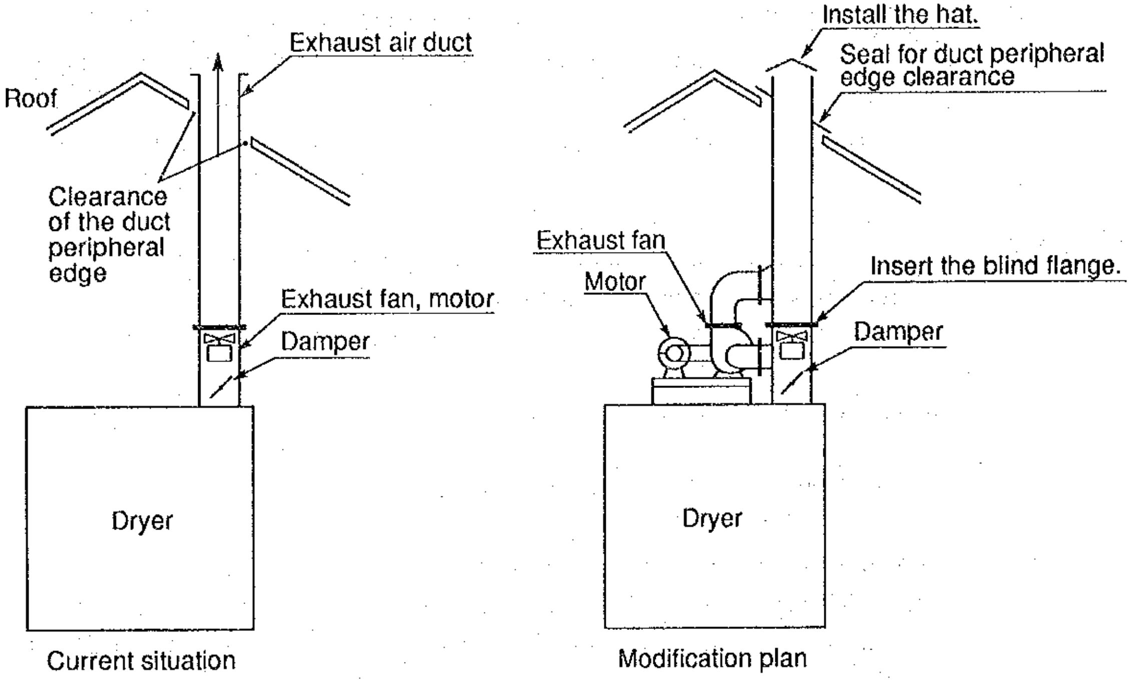
1) Normalization of Air Exhaust and Taking In

For the situation of the dryer operation, both of the two exhaust fans were out of operation because of the burning of the motors, and one of the circulating fans was at a standstill as well. As a result, the air exhaust capability was insufficient though the natural draft was provided by the ducts; hot air was discharged into the room through the fresh air inlet and the wool fabric inlet/outlet. On the other hand, when synthetic fiber blending fabrics were heat set, the partition door to the dry fabric air-cooling system is opened to make up fresh air supply. This makes it difficult to stabilize the operation.

For some type of fabrics, the maintenance door was irregularly opened to control the draft, and part of high temperature air was discharged into the room.

At present, the motors are installed within the exhaust ducts, and subjected to high temperature of 160°C at the heat setting of synthetic fiber blending fabrics, probably it may be burnt in a week. Even if motors of insulation class H are used, they should be installed outside the ducts; the allowable maximum temperature of the motor is 125°C for the stator wiring and 55°C for the bearing. Motors are generally installed as shown in Figure 5.4.7. In this case, both the motors and the fans are kept at room temperature, which will remarkably lengthen their service lives.

Figure 5.4.7 Installation of Exhaust Fan



Moreover, the ducts which were previously used for testing heat recovery of exhaust air should be removed to avoid extra air taking in.

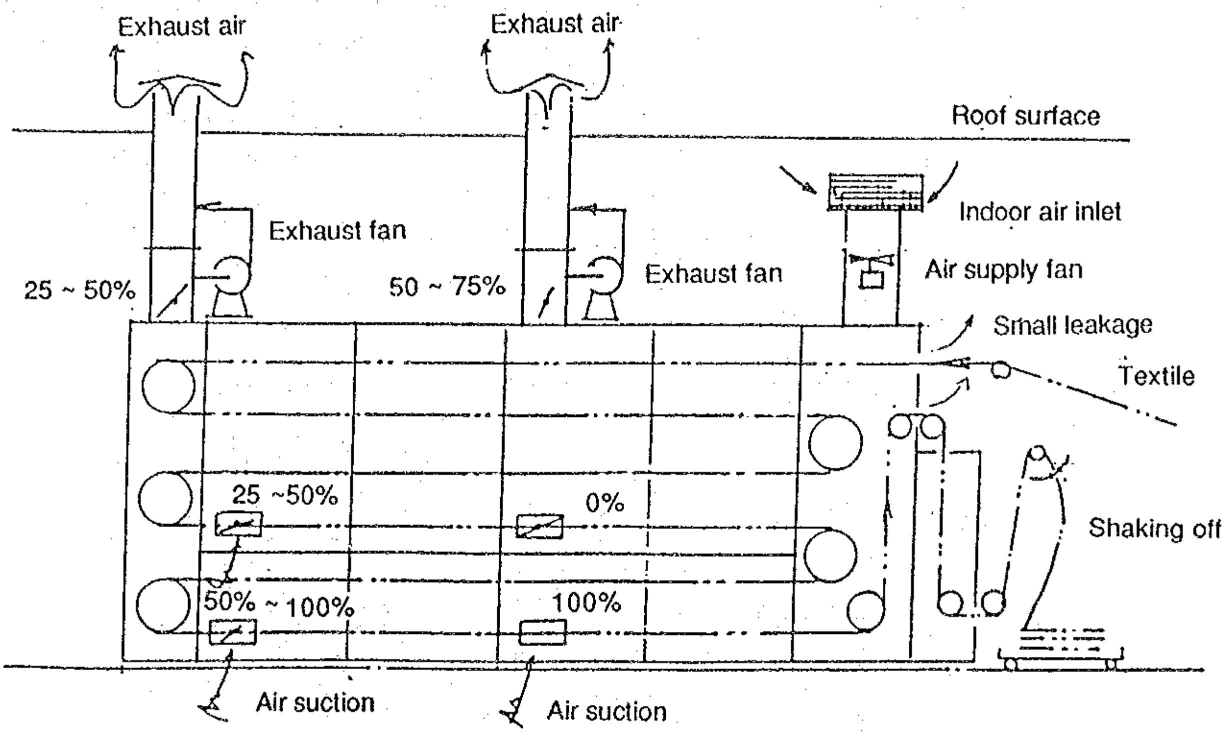
When the measures above have been taken and the forced exhaust function has been normalized, the door in the cooling air chamber should be closed and fresh air should be taken in through the regular inlet on the side of the equipment. It is currently observed that the grids are dirty; the filters are dirty and broken; and the heaters are dirty. These items should be periodically cleaned and replaced as necessary.

During the exhaust fan operation, the dampers of the ducts should be controlled to avoid excessive amount of exhaust. For reference, the amount of exhaust should be controlled so that hot air will slightly leak out of the opening of the fabric inlet. The state slightly varies depending on the type of fabrics.

Therefore, it is advisable that the dryer feed speed and the damper control are standardized according to the type and weight of fabrics. Figure 5.4.8 shows the damper control of dryer exhaust air and cooling air taking in for reference.

To facilitate the control of exhaust, it is desirable to employ the revolution number control (VVVF) system which is remote-controllable. The system is effective especially in heat setting when the exhaust temperature is high.

Figure 5.4.8 Damper Control of Dryer Exhaust Air & Cooling Air Taking in



2) Drying Temperature and Quality

The drying temperature is 127 - 134 °C, and close to the allowable maximum heating temperature for maintaining the quality of wool 100 % fabric. When a wool fabric is excessively dry, an ambient temperature exceeding 130 °C will damage its physical properties. Table 5.4.12 shows the damage to wool fabric by heating.

Table 5.4.12 Change in Nature of Wool by Heating

Temperature	Change in Nature of Wool
125 ~ 130℃	Begins to decompose
170 ℃	Decomposes with much foul odor
220 ℃	Partially burns
260 ℃	Becomes brittle
240 ~ 300℃	Carbonized with a weight loss of 25%
349 ℃	Ignition point

Figure 5.4.9 illustrates the general characteristics of the drying, showing the change in temperature and moisture content of the material being dried. The temperature of the surface of the material being dried is in the middle of the heating atmospheric temperature and the wet-bulb temperature of the atmospheric air during the constant rate drying. When the drying proceeds to the descending rate drying, the material temperature gradually gets close to the heating atmospheric temperature; when the equilibrium moisture content is finally reached, the material temperature is almost equal to the heating atmospheric temperature. The saturation temperature of the currently used 8 - 10 kgf/cm^2 steam is as too high as 170 - 180 °C, and the steam needs to be depressurized.

Figure 5.4.9 Material Temperature vs Water Content

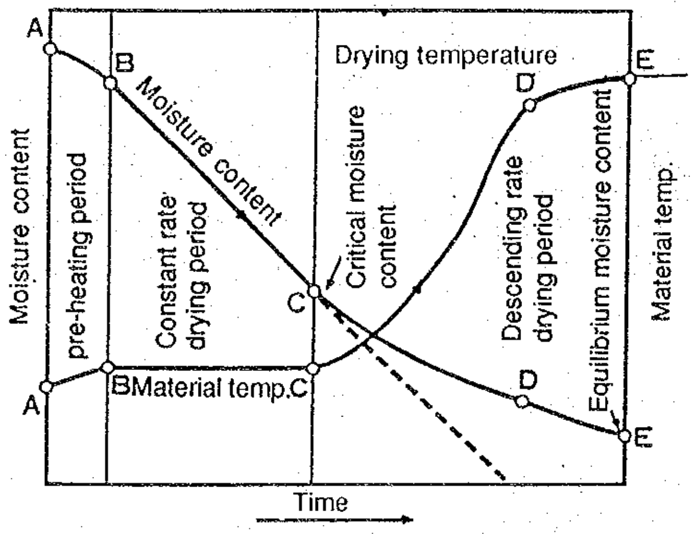
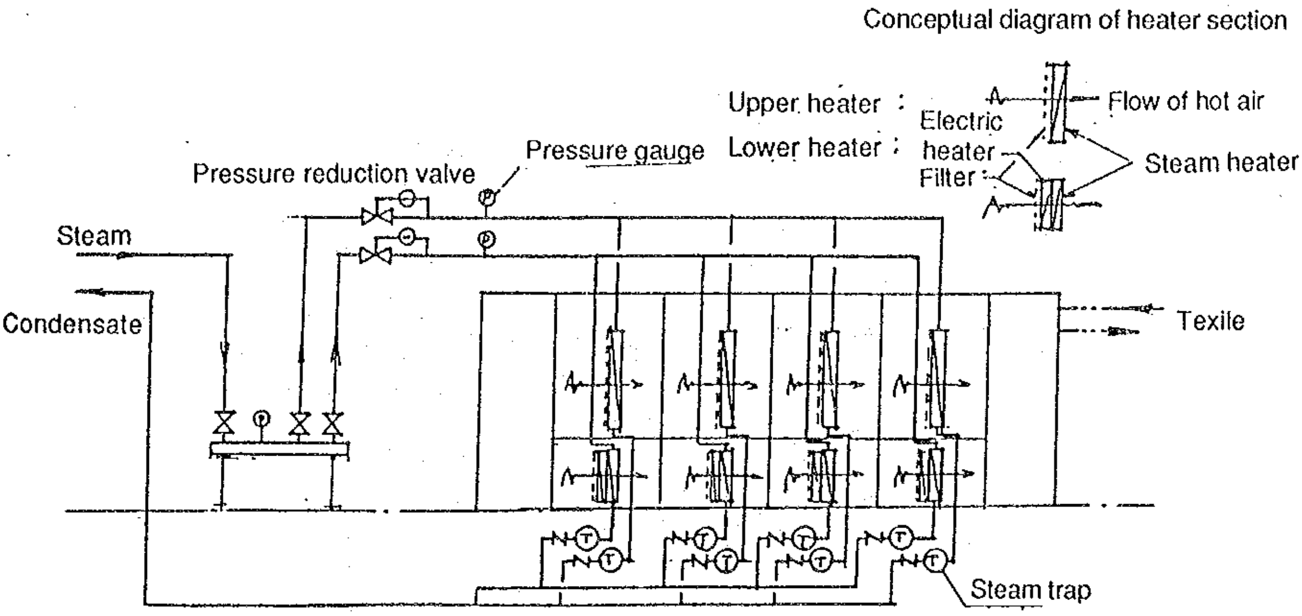


Figure 5.4.10 illustrates a typical example of piping of steam and condensate of dryer. The steam line is divided into two parts, upper and lower, and a steam trap is installed for each heater. It is believed that the thorough routine control of steam heaters and filters will provide a sufficient drying effect at a steam pressure of 4 - 5 kgf/cm^2 (G).

Fgure 5.4.10 Piping of Steam & Condensate of Dryer



Excessively high heating temperature will increase the exhaust loss and raise the dryer surface temperature, leading to the increase of heat radiation.

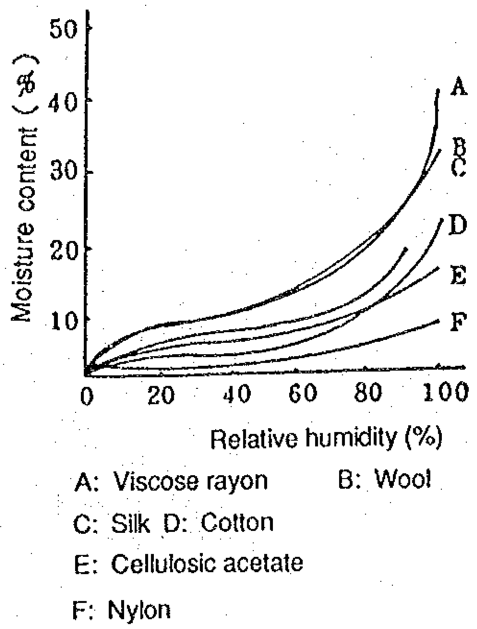
3) Drying Load Decrease

Though samples of Karmen and NIKI are different from each other in fiber composition and finishing method, the moisture content of the former is 56.5 % at data sampling, and 2.4 times that of the latter; NIKI carries in moisture 23.3 %.

The reduction of moisture carried into the dryer is the first important means for energy conservation, and one of the major routine control items.

On the contrary, the moisture content of the dry fabrics was 6.4 % at sampling. Figure 5.4.11 shows the relation between the equilibrium moisture content of wool and the atmospheric humidity. When a wool fabric with a moisture content of 6.4 % is left in an atmosphere of a temperature of 25 °C and a relative humidity of 60 %, the moisture content increases to 14.7 % and equilibrated. Excessively drying not only causes the loss of energy but also degrades the quality of products. In general, the standard moisture content is 10 % for pure wool and 6 - 7 % for wool fabric with polyester blended (35 %).

Figure 5.4.11 Equilibrium Moisture Content vs Humidity



The effect of energy conservation was calculated on trial with the current dryer operation conditions unchanged, inlet moisture content decreased, and outlet moisture content decreased. Table 5.4.13 shows the result of the calculation.

Table 5.4.13 Effect of Drying Load Decrease

Items	Unit	Current	After modification	Decrease amount	Reduction rate
Inlet moisture content	%	56.5 %	45.0 %	11.5	
Outlet moisture content	%	6.4	10 %	-3.6	
Evaporated water content	kg/h	190.2	133.0	57.2	
Evaporation heat	kcal/h	118,770	83,020	35,750	
Steam	kg/h	622	549	73	11.7 %

In 1992, the production of Worsted was 310,000 m and the unit price of heat was 0.61 Lv/Mcal. Thus the advantage in decreasing the drying load is as follows:

310,000 m/y × 324 kcal/m × 0.117 × 0.61 Lv/Mcal/1,000 = 7,170 Lv/y

4) Change of Source for Cooling Air

Polyester blended wool fabrics are heat set at a relatively high temperature of 160 °C, and air-cooled at the pull out unit. Fresh air is taken in for cooling air from the roof, and air used for cooling is discharged into the room.

One of the existing problems is that the outdoor air temperature largely fluctuates from season to season and from time to time in a day. In the coldest season, the cooling effect is excessive, and there is a fear of the condensation on the dried fabric. Also, the moisture content is unstable. In the winter season, taking in outdoor air increases the room heating load.

In case the source for cooling air is changed over to indoor air, as shown in Figure 5.4.8, the heating load is reduced as follows:

Table 5.4.14 shows the average outdoor temperature in Sofia. In this case, the "winter season" means the five months from November to March, and the average temperature is 2 °C.

Table 5.4.14 Average Outdoor Temperature in Sofia

Month	1	2	3	4	5	6	7	8	9	10	11	12	Avg
Temperature ℃	0.1	1.5	3.6	9.9	14.8	18.3	20.3	20.6	15.6	10.2	5.2	1.9	10.2

Note : 1951 ~ 1960
Source: "Science Almanac" (Tokyo Astronomical Observatory)

Temperature difference : 25 - 2 = 23 °C
Air flow : 8,500 kg/h
Reduced heating load : 0.24 × 8,500 × (25 - 2) = 46,900 kcal/h
Reduction ratio of heating load : 46,900 / 3,658,200 × 100 = 1.3 %
(Refer to Table 5.4.24.)

If exhaust fans and dampers are incorporated in the existing air inlets, they can be used to discharge high temperature air staying on the ceiling above the dryer, improving the work environment.

5) Concentrated Operation

The finishing shop has a tendency toward multikind small lot production, and the dryer is liable to be intermittently operated. However, the exhaust ducts open to outdoor continuously discharge high temperature air in the dryer even when an operation stopped. This causes the loss and decreases the temperature in the dryer. In addition, when a drying operation is interrupted, the power and the heat from the dryer surface lead to a loss.

Accordingly, the production plans should be adjusted so that an operation can be continued as long as possible. It is desirable to establish an operation standard which requires that steam be shut off, the exhaust fans be stopped, the circulating fans be partly stopped in case an operation is interrupted for some inevitable reason. The requirement of closing the dampers of duct especially in the winter season should be included in the operation standard.

6) Instruments for Control

The existing direct reading mercury rod thermometer is unsuitable for measuring the atmospheric temperature in dryer. The large dial or digital thermometer is suitable for such routine control.

It is advisable to put mark to indicate standard values for conditions of each operation on the instruments for routine control, such as thermometers and pressure gages. This sophisticates routine control.

(2) Wool Fabric Finishing Shop

a. Wet Finishing

1) Stabilization of Operation Conditions

Table 5.4.15 shows the operation conditions for the major processing machines. These machines were provided with an automatic system in the beginning, but some of them are now unusable.

While state-of-the-art processing machines are being introduced, the existing machines are, in general, not provided with sufficient general control instruments in place, such as thermometers and pressure gages. Therefore, the processing operation depends on the experience of operators, and thus the actual processing conditions tend to be largely dispersed compared with target set values.

Table 5.4.15 Operation Condition of Finishing

Kind	Process	Temperature ℃	Heating Time min	Cooling Time min
Worsted	Crabing	85~90	30~50	25
	Washing	45~50	60	45
Woollen	Washing	40~50		
	Dyeing	90	45~60	

For the stabilization of the operation conditions, it is advisable to take the following measures:

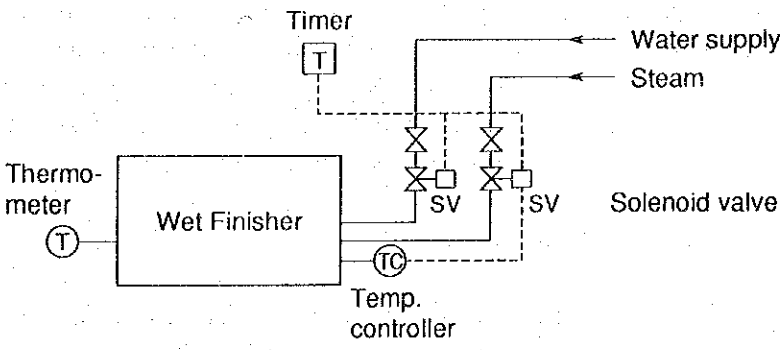
- Indicate control standards.

  Operation conditions, including temperature and time, for each kind of product, should be indicated at a prominent point on respective machines to eliminate difference between individual persons. This is highly effective in saving the use of steam and water, and improving product quality.

- Automate the operation system.

  Some parts of the shop are equipped with sophisticated processing facilities controllable by programs; however, the other parts are not furnished with automatic system. Even a simple system as shown in Figure 5.4.12 enables the automation and the equalization of the operation. A lower pressure is better for higher controllability and longer service life.

Figure 5.4.12 Simple Control System



2) Control of Radiation Heat Loss

Crabbing and dyeing are usually performed at a temperature of 90 °C or above. In such high temperature processing, a cover is usually used to prevent heat from being radiated from the surface of high temperature chemical in contact with air. In the present facility, the dyeing machines are operated with their covers open. The quantity of heat radiated from open chemical surface is approx. 10,000 kcal/($m^2 \cdot$ h) at 90 °C. This value can be reduced to half by using a cover to eliminate the contact with ambient air. The use of a cover is also an effective measure against condensing in the winter season.

In the present facilities, a lot of machines are provided with no thermal insulation on their surface. In case the surface temperature of a chemical bath exceeds 50 °C, it is advisable to suspend a vinyl sheet to provide an air layer around the bath. A case, where the quantity of heat radiated was reduced 70 % by taking this measure, has been reported.

3) High Density Operation of Facility

The consumption of steam and water per unit amount of processing increases with the decrease of the amount of processing per batch. It will be most effective in the improvement of energy unit consumption rate to reduce the number of operation batches as much as possible to increase the working density per hour of every processing machine.

b. Dry Finishing

1) Steam Pressure Control

In a glazing machine (calender), the supplied steam pressure largely influences the quality of products. Though the operation standard specifies the processing temperature of 135 - 140 °C, the current situation is that sometimes it may be 160 - 170 °C according to the supplied steam pressure.

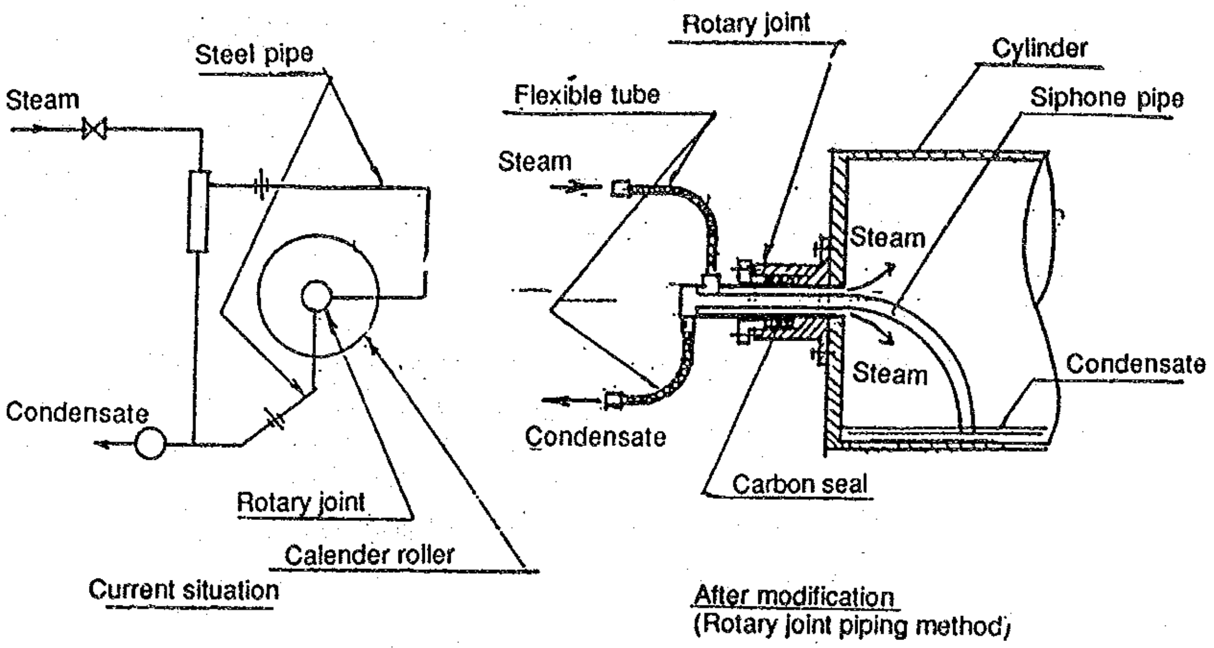
As mentioned later, for stabilized operation, it is basically necessary to use pressure reducing valves. We suggest that each blazing machine is provided with a steam pressure reducing valve, and the steam pressure is controlled. The steam pressure control is provided, for example, by indicating steam pressure specified for each kind of product on the side of the respective machines.

2) Prevention of Steam Leakage

It has been reported that steam leakage occurred in carbon seals of the rotary joints integrated with the blazing machine cylinders and replacement of the seals could not stop the leakage.

It is considered that the steam leakage was caused by the use of rigid bodies to connect the steam supply piping and the condensate piping. The use of flexible tubes for connecting these pipes with rotary joints, as shown in Figure 5.4.13, reduces the thermal stress and vibrations applied to the carbon seals. The reduction of the steam pressure is also effective to reduce the steam leakage.

Figure 5.4.13 Connection of Steam Pipe with Rotary Joint



(3) Spinning and Weaving Shops

a. End Breakage

1) Temperature and Humidity and End Breakage

The following are general factors in the occurrence of end breakage in spinning and weaving shops:

- Oiling
- State of machine maintenance
- Temperature and humidity control

These factors act singly or mixedly, and the frequency of end breakage largely varies depending on them. The routine control of temperature and, in particular, humidity among these factors, is important for stable operation.

Table 5.4.16 shows the result of the survey on the temperature and humidity and end breakage; Table 5.4.17 shows the recommended humidity for wool spinning and weaving shops. The humidity is slightly low in the present factory. Table 5.4.18 shows the comparison of the frequency of end breakage and the pneumafil waste rate of the present factory and those of a typical factory in Japan. It turns out from the table that the frequency of end breakage of the present factory is approx. ten times that of average Japanese factories.

Table 5.4.16 Temperature & Humidity vs Yarn Break

Process	Item	Measuring date	Machine type	Temperature (°C)	Relative humidity (%)
Spinning					
	Reference value			22	75
	Measured value	1992.11	Woollen old machine	21~25	37~55
			Woollen new machine	23~28	40~55
			Worsted small number yarn count	22~28	42~62
		1993.6.30	Worsted small number yarn count	26~26.5	53~55
Weaving	Reference value			18~20	65
	Measured value	1992.11		20~29	65
				20~29	38~62
		1993.6.30		28	37

Process	Machine type	Number of broken ends (per 1000m)	Pneumafil waste rate (%)
Spinning	Old machine	0.52	
	New machine	0.42	
	Small number yarn	0.35	6~8

Table 5.4.17 Recommended Humidity

Process	Worsted Yarn	Woollen Yarn
Carding	65～70%	60～75%
Combing & Gilling	60～70	
Drawing	50～60	65～70
Prespinning	50～60	65～70
Spinning	50～55	55～60
Twisting	50～60	55～60
Preparation	50～55	55～65
Weaving	50～60	55～65

Note: Temperature 24-29 °C

Source : Text World

Table 5.4.18 Comparison of Yarn Break with Japan

Item	Unit	NITEX-50	Japan (a certain factory)
Product	Wool (%)	100	100
	Yarn Number	25	70
End Breakage	Piece (s)/(1000 Spindle · h)	210[1]	15~20
Pneumafil Waste	%	6~8	1.5~2.0
Personnels with unit	unit (s)/person	1	6

Note: Calculated based on the number of broken ends per 1000 m of small number yarn count with 10 m/min taken as spinning speed.

2) End Breakage and Pneumafil Waste Rate

At the time of the study, it turned out that the frequency of end breakage of the wool spinning machines excessively differed from machine to machine. This may be because some problem lies in some factors other than temperature and humidity control.

It will aid in finding the causes to daily measure and record the quantity of pneumafil waste produced in each machine for every shift and analyze the record. The quantity and rate of pneumafil waste are significant indexes for routine control. And there are many factories in Japan to graph and display these data on a wall to attract employees' interest.

3) Temperature and Humidity Control

In the present factory, the engineer in charge requests the laboratry to measure the humidity, and judges from the result of the measurement whether to operate air conditioners. For more accurate temperature/humidity control, however, the engineer in charge should measure the temperature and humidity by own shop as routine task to grasp changes in them. For this purpose, the following measures should be taken:

- Install a simple wall type thermometer/hygrometer in every major shop, such as spinning and weaving.
- Record temperature and humidity at a regular time in the morning and afternoon, plot the record on a graph and display the graph on a wall.
- The reference values shown in Table 5.4.16 are hard to achieve in seasons other than winter. It is necessary to set reference values achievable for summer and middle seasons.
- In a production process with a large heat load, such as spinning machines, it is desirable to continuously operate air conditioners as a rule to stabilize the temperature and humidity. Though air conditioners increase the power consumption, their effect on the reduction of end breakage and pneumafil waste will more than compensate it. In addition, it is more effective to control the air flow in the air conditioners according to the season and the number of units in operation.

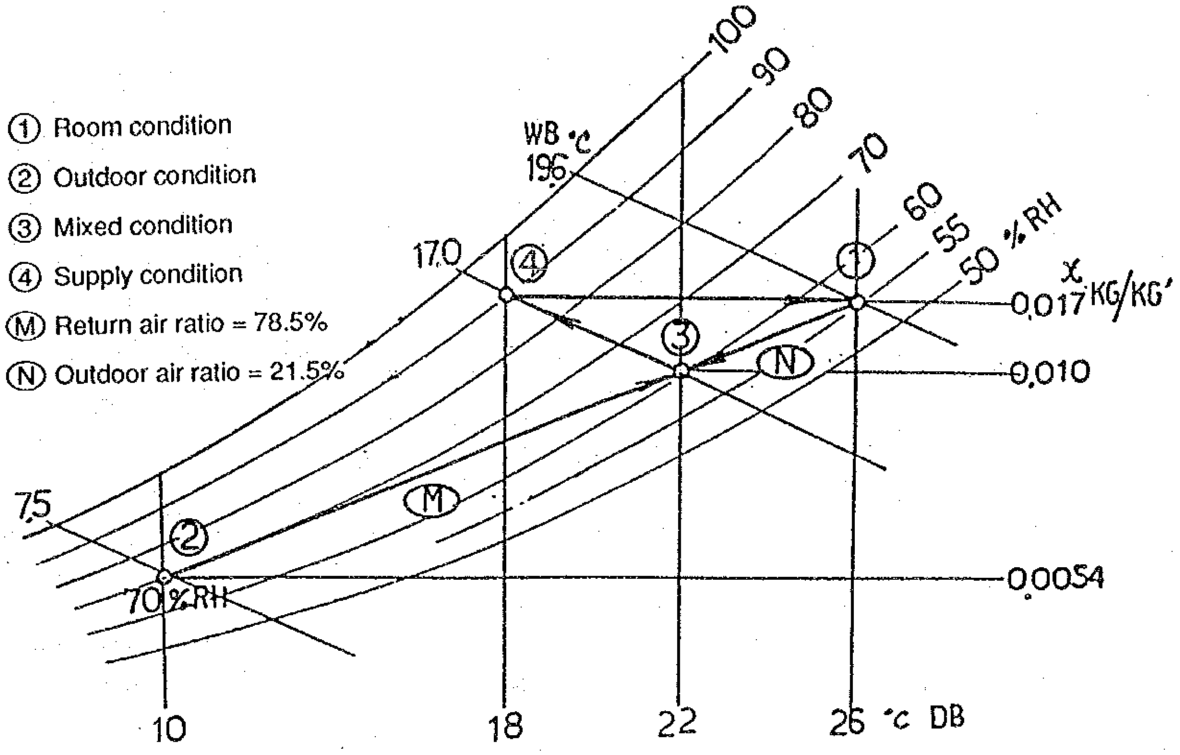
b. Air Conditioning Facilities

1) Maintenance of Dampers

The air conditioning facilities are superannuated in general.
Vanes are missing from outdoor air intake dampers, and outdoor, return and bypass dampers malfunction.

The supply air conditions are determined by the mixing ratio of the quantity of outdoor air taken in and that of indoor air returned; accordingly, the damper is an important element for air conditioning facilities. Figure 5.4.14 is a psychrometric chart showing changes in temperature and humidity of air for air conditioning. As seen from the chart, the mixing ratio of outdoor air taken in and return air varies within the range of 0 - 100 % depending on the conditions of outdoor air.

Figure 5.4.14 Psychrometric Chart



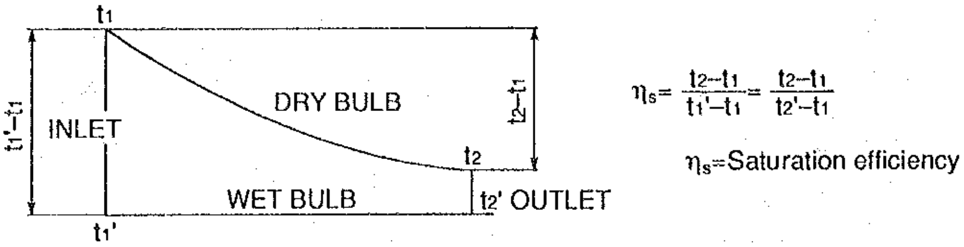
For maintaining the damper functions, it is necessary to periodically lubricate the moving parts, give a rust preventive coat for corrosion prevention, and repair broken vanes.

2) Improvement of Spraying Efficiency

The spray nozzles equipped on the air conditioners face in random directions, and thus no uniform spraying effect is expected.

Figure 5.4.15 shows the approximate values of the adiabatic saturation efficiency by spray direction of each spray bank.

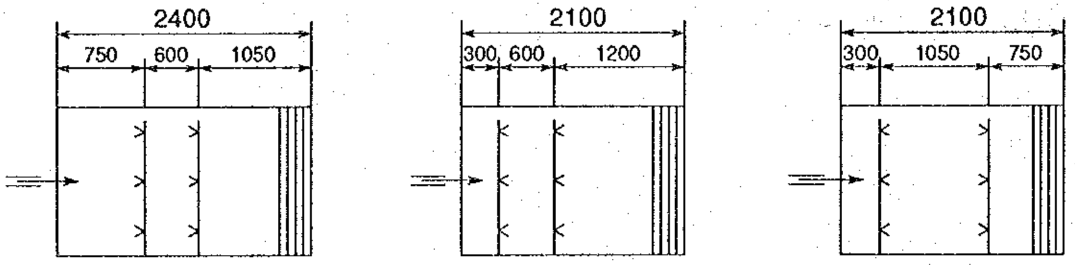
Figure 5.4.15 Saturation Efficiency by Spray Direction



$$\eta_s = \frac{t_2 - t_1}{t_1' - t_1} = \frac{t_2 - t_1}{t_2' - t_1}$$

η_s=Saturation efficiency

Adiabatic saturation change



2 bank back current
$\eta s = 90 \sim 98\%$

2 bank cocurrent
$\eta s = 80 \sim 90\%$

2 bank countercurrent
$\eta s = 85 \sim 95\%$

The following points should be taken into account to improve the saturation efficiency.

A spray nozzle should be provided for a cross section of 250 mm square. The nozzle of a bore of 3 mm and a spraying pressure of 1.5 - 2 kgf/cm^2 is in common use.

If air flow is deflected at the inlet of an air conditioner, the saturation efficiency is remarkably degraded. Therefore, where return air is largely deflected, as in the air conditioner in the weaving shop, it is advisable to provide the entire surface of the air conditioner inlet with a perforated plate of a pore diameter of approx. 10 - 15 mm and a pore ratio of 50 % or so.

3) Make-up Water Saving

The amount of make-up water for spraying is manually controlled, and accordingly a considerable amount of make-up water sometimes overflows from the air conditioner water tank. It is required to install an automatic water supply apparatus called ball tap in the make-up water supply pipe.
In the winter season, however, it is necessary to avoid freezing to additionally install an automatic drain tap which detects the ambient temperature. Further, only in the coldest season, water should be manually drained.

4) Direction of Air Duct Outlet

For the air ducts on the spinning and winding machines, a lot of air outlets are set such that they will blow air toward the ceiling. It is said that this is for the prevention of the influence on yarn under spinning and the mixing in of flies of different color threads. However, modifying the directions of the outlets to horizontal will enable the stable control of temperature and humidity. This is also effective in the improvement of the phenomenon that air is separated into two layers, upper and lower, when heaters are operating in the winter, due to the difference in specific gravity of air.

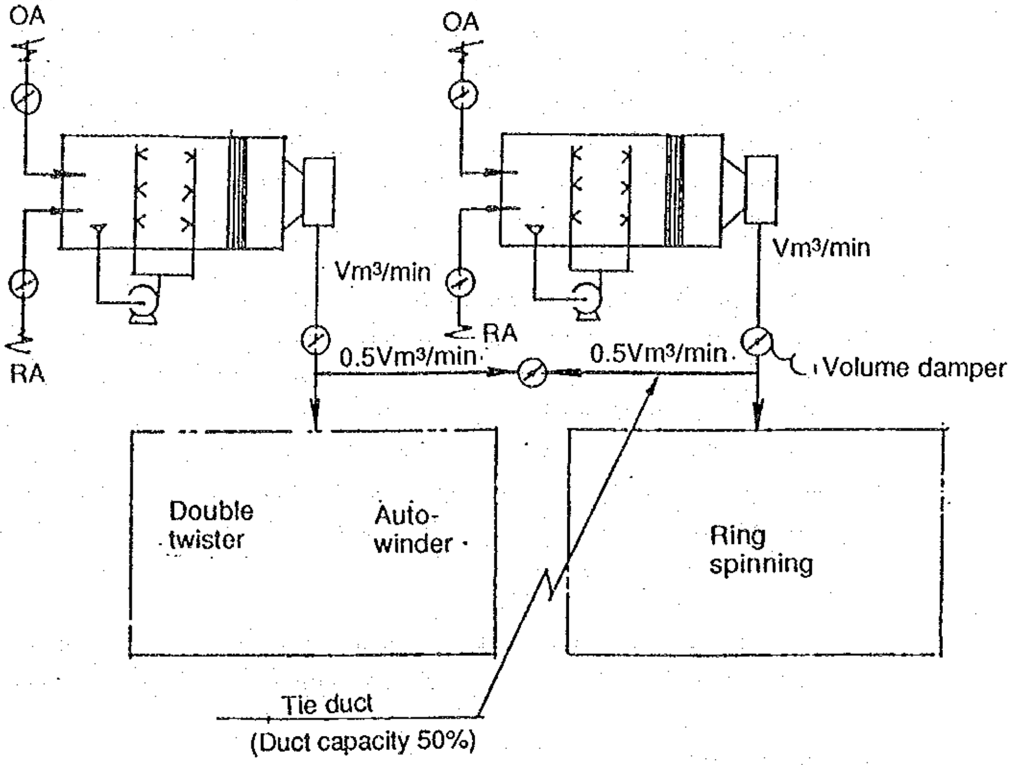
For this purpose, the blowing air speed should be controlled. For spinning shops, general setting is that the air flow per outlet is 20 m^3/min and the number of installations is 3 - 4 units per spinning machine. It is required to control the cross-sectional air speed at an air outlet to 4 m/s or so. If the air speed is too high in the existing equipment, a perforated plate or the like should be installed to control the cross-sectional air speed. It is advisable to conduct tests on the spinning machines in one row in the lengthwise direction before the installation to all the machines in the other rows.

In many cases, the scattering of dyed flies is coped with by suspending mesh curtains. The formation of flies is relatively controlled in the high humidity environment.

5) Integration of Air Conditioning Facilities

At present, there are two air conditioning systems (one is now out of operation due to failure). In a period when the heat load is low because of the reduction of production, it should be considered to integrate these two systems into one to provide air conditioning for both shops. 50 % of the rated air flow can be supplied through either system by connecting the main air ducts of the two air conditioners using a duct.

Figure 5.4.16 Integration of Air Conditioner



The effect of energy conservation by this measure was calculated, and the result of the calculation is as follows:

Power consumption of blowers and spray pump : 50 kW
Annual operating hours : 2400 h/y
Unit price of electric power : 0.7 Lv/kWh
Saved power : 50 × 2400 = 120,000 kWh/y
Saved charge for electricity : 0.7 × 120,000 = 84,000 Lv/y

The cost of the installation for the purpose is estimated to be 60,000 Lv or so, and is recoverable in a year.

This method is also effective in coping with the seasonal reduction of load and troubles as well as the reduction of production.

6) Direct Humidification

Where the working ratio is low and the operation area is limited, installing unit type humidifiers on walls or posts will effectively improve the humidity condition. This enables stopping the central air conditioning facility, except for in the winter when heating is provided. Applicable shops include the weaving, preparation and prespinning shops.

c. Pneumafil Suction Flute for Spinning and Twisting Machines

1) Installation and Control of Pneumafil Suction Flutes

In general, the routine control of the pneumafil suction nozzles for each spindle is considerably rough, which degrades the suction effect of the pneumatic nozzles.

The set position of each nozzle at the end of the suction flutes are uneven, and the bore of each suction nozzle of the spinning/twisting machines is not unified.
Some of the carding/spinning machines are provided with no suction flute.

For the adjustment of the distance and center of the flute suction nozzles, the workability is improved by using simple jigs such as polyvinyl chloride plates.

2) Control of Pneumafil Suction Pressure

Some spinning/twisting machines are operated with the cleaning air introducing end port in the pneumafil suction duct kept open; suction blowers are continuously operated when they are stopped in doffing.

The periodical measurement of the suction pressure of facilities equipped with pneumafil suction apparatus, makes it possible to check performance and find troubles.

Japanese companies specify 100 - 130 mmAq as the control standard for suction pressure of carding/spinning machines. An excessive suction pressure results in the loss of electric energy, and the following means are taken for the prevention of the loss:

- Replace with small suction blowers.
- Cut impellers of suction blowers.
- Employ concentrated suction systems with separate blowers.
- Control the number of revolutions in groups using inverters.

Automatic winders are usually controlled so that their suction pressure will be 1000 - 1200 mmAq. In case there are four or more units of automatic winders, connecting the suction ducts of the suction blowers makes it possible to selectively stop the suction blowers. This is widely implemented for a measure for energy conservation.

(4) Steam Supply

a. Steam Pressure

1) Steam Pressure and Available Quantity of Heat

The factory receives saturated steam of 8 - 10 kg/cm^2 from the Heat Supply Public Corporation and supplies it to steam using facilities in every shop. Steam is used at the supply pressure in each shop, except for some program controlled machines.

Most of the steam using facilities in the preset factory, are of indirect heating type, such as dryers and room heaters. Such facilities utilize only the latent heat of steam, and discharge other heat as condensate. Therefore, the utilization factor is increased with the increase of the latent heat per unit weight of steam. Table 5.4.19 shows the relation between steam pressure and total heat and latent heat. It turns out from the table that steam of a lower pressure is more advantageous as long as a required temperature difference is ensured. For example, when the steam pressure is reduced from 10 kgf/cm^2 to 4 kgf/cm^2, then the available latent heat is increased by 26 kcal/kg and thus the required steam flow is reduced by 5.1 %.

Table 5.4.19 Saturated Steam Table

Pressure (G) kg f ／cm²	Temp. ℃	Specific Enthalpy kcal／kg	Latent Heat kcal／kg
1.0	119.61	646.18	526.26
2.0	132.88	650.56	517.15
3.0	142.92	653.66	509.96
4.0	151.11	656.03	503.90
5.0	158.08	657.93	498.59
6.0	164.17	659.49	493.82
7.0	169.61	660.81	489.46
8.0	174.53	661.93	485.42
9.0	179.04	662.90	481.65
10.0	183.20	663.74	478.09

For example, a TEVE calender uses 8.5 kgf/cm^2 steam. The processing temperature is 135 - 140 °C. Accordingly, if the steam is depressurized to obtain 4 kgf/cm^2 steam of a saturation temperature of 151 °C, then the required steam flow is reduced by approx. 4 %.

2) Harmful Influence of Excessive Steam Pressure

2-1) Increase in Loss of Radiated Heat

The heat radiation from parts provided with no thermal insulation, such as steam pipes and valves, are increased with the rise of steam temperature. For example, if the steam pressure is reduced from 10 kgf/cm^2 to 4 kgf/cm^2, then the saturated steam temperature is reduced from 183 °C to 151 °C and the heat radiation is reduced by approx. 25 %.

2-2) Increase in Steam Leakage

The steam leakage from corrosion pores in steam pipes and valve glands, is increased with the increase in the steam pressure. For example, if the steam pressure is reduced from 10 kgf/cm^2 to 4 kgf/cm^2, then the leakage is reduced by approx. 35 %.

2-3) Influence on Product Quality

For dryers and calenders, the quality of products is largely influenced by processing temperature. Especially, for the calenders, it is desirable to reduce the steam pressure to prevent harmful influence on quality.

2-4) Influence on Controllability

In steam indirect heating in the dry finishing shops and steam direct blowing heating in the wet finishing shops, the temperature is usually controlled by adjusting the steam valve travel.

In this case, with a higher steam pressure, a slight difference in the valve travel varies the flow rate more largely, which results in the difficulty in control. If the control is difficult, we tend to set the temperature to a high value for safety, and this increases the steam consumption.

2-5) Influence on Service Life of Facility

When the steam pressure is high, the steam passing speed is increased on the sheet surface of valves and traps, resulting in the acceleration of the wear in sheet surfaces. The higher the steam pressure is, the larger thermal stress is applied to tubes of dryers and air conditioner erofin heaters, which induces steam leakage.

3) Individual Steam Pressure Setting for Each Machine

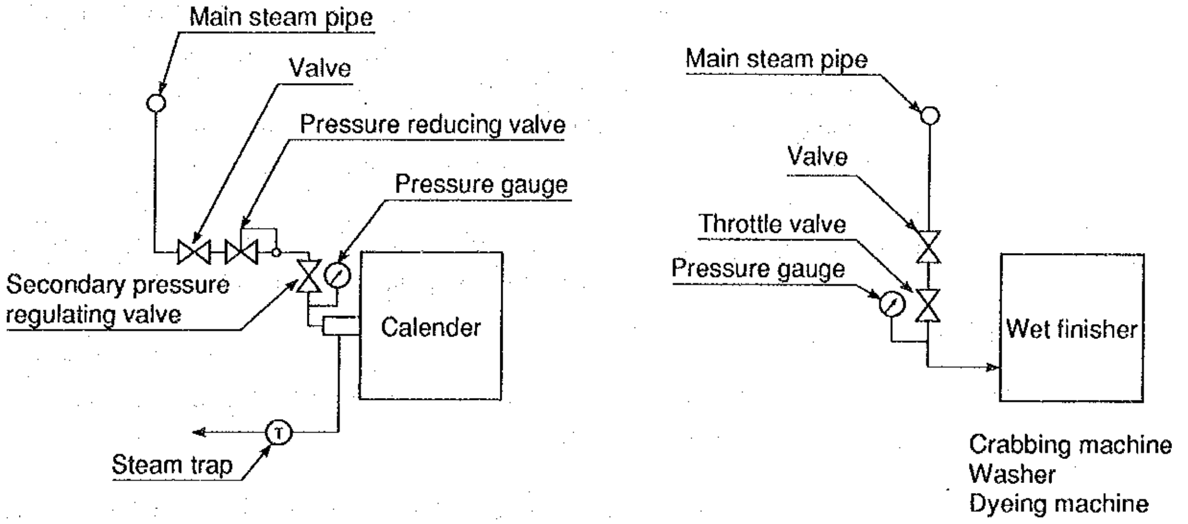
For every machine using steam, the optimum steam pressure should be found by varying the steam pressure by stages and thus examining the influence of the pressure on the product quality, temperature rise time and processing time and the steam consumption.

For calenders and any other machines in the dry finishing shop the steam pressure of which may directly influence the productivity and quality, each of them should be provided with a pressure reducing valve for the reduction and stabilization of pressure.

For such machines as wet finishing machines which directly blow steam, a two stage series valve system may be employed with the steam pressure 4 - 5 kgf/cm^2.

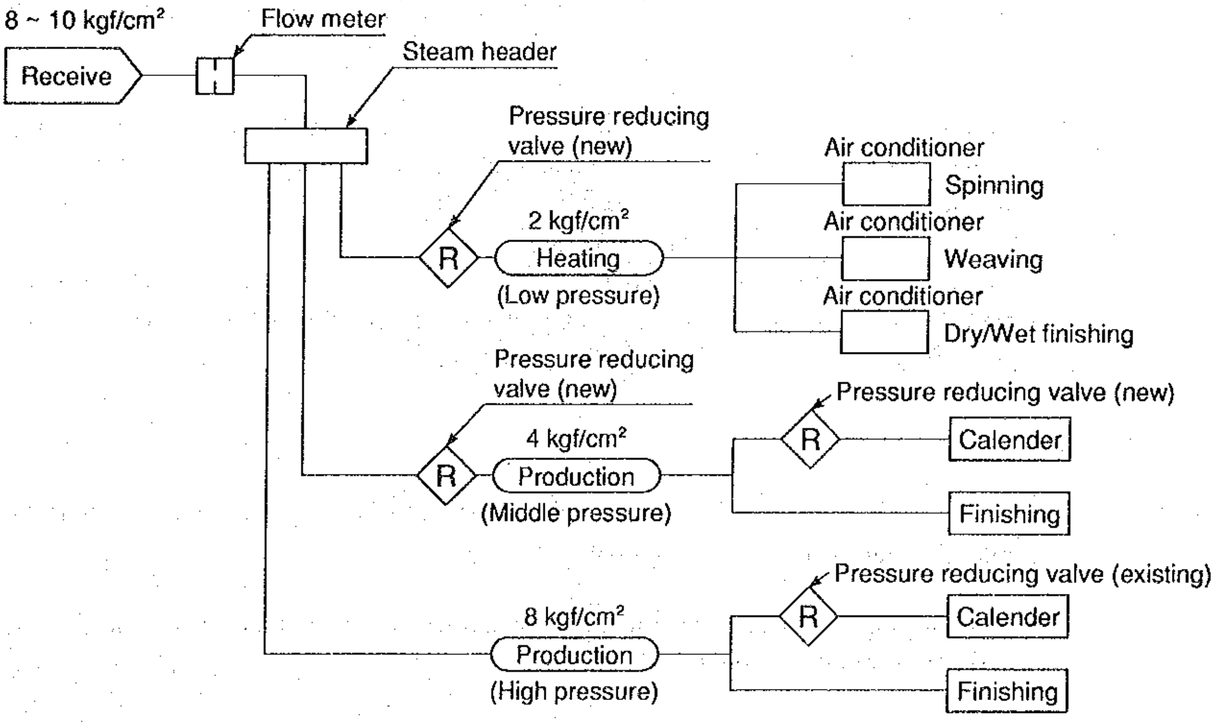
Figure 5.4.17 is a schematic diagram of a method for pressure reduction by machines and groups.

Figure 5.4.17 Steam Pressure Reduction



Temperature control by
A: pressure gauge

Flow adjustment by
B: 2-stage valve



4) Pressure of Steam for Heating

For the reason mentioned above, the pressure of steam supplied to the air conditioner erofin heaters, should be lowered as much as possible, and the reduction through the main pipe of steam for heating is desirable. The set pressure should be determined by reducing the steam pressure step step by step and observing the progress. However, it is naturally necessary to correct the outdoor air taking in and put the facilities in place, including the cleaning of the heaters, before taking the step above.

The condensate which has been collected in the recovery tank from the steam heaters, is re-vaporized, and the vapor is discharged to the atmosphere through the vent pipe.

When condensate is released under the atmospheric pressure, the rate of re-vaporization is increased with the increase in the supply pressure. Accordingly, reducing the pressure reduces the loss of re-vaporization as well.

If the steam pressure is reduced from 8 kgf/cm^2 (G) to 2 kgf/cm^2 (G), then the available latent heat will be increased from 485.4 kcal/kg to 517.2 kcal/kg, reducing the steam consumption by 6.1 %.

5) Considerations for Reduction of Pressure

With the reduction of the pressure, the specific volume of steam is increased and the pressure loss is increased in proportion to the second power of the current. For the piping, in which the pressure is largely decreased, unnecessary valves should be removed and minimum modification made to the piping.

The size of a pressure reducing valve should be determined based on the required steam flow and the pressure before/behind the pressure reducing valve, not based on the pipe bore.

Some of the existing pressure gages evidently indicate a wrong reading. The pressure gage is one of the most important instruments for quality control. The existing pressure gages should be periodically calibrated.

b. Steam Trap

The present factory introduced the mechanical type steam traps in the beginning of 1993, and has achieved the remarkable reduction of steam.

Some of the traps were checked for their operation, and all of them were found to be correctly functioning, as shown in Table 5.4.20.

Table 5.4.20 Working of Steam Trap

Machine	Heater	Type of Trap	Size inch	Surface Inlet	Temp℃ Outlet	Operation
Teve Dry Press	Roll	Armstrong #811	3/4	147	129	Normal
Teve Dry Press	Bed	Armstrong #800	3/4	145	127	Normal
Teve Dry Press	Roll	Armstrong #811	3/4	153	122	Normal
Teve Dry Press	Bed	Armstrong #800	3/4	159	122	Normal
Dryer		Armstrong #800	1	145	118	Normal

The steam trap will be worn with the passage of time, and accordingly, steam leakage will inevitably occur in the future. It is necessary to prepare control ledgers and periodically check the traps. It is also required to pay attention to the condensate tank temperature and the steam blow out from the vent pipes.

c. Prevention of Heat Radiation

The thermal insulation of the steam piping in the factory is generally favorable, but insufficient thermal insulation is found at many points in the piping, valves and flanges involved in the steam collectors in the subcenters.

Table 5.4.21 shows the heat radiation from the steam pipes and so on in the three subcenters, and the expected effect of the insulation, if provided, for them.

Table 5.4.21 Insulation of Steam Pipe & Valve in Steam Substation

Size	Pipe	Valve			Total	Radiant Heat		
		(A)	(B)	(C)		Present	Insulated	Decrease
inch	m	m		m	m	kcal/h	kcal/h	kcal/h
$\frac{3}{4}$	2.5	1.05	0	0	2.5	620	60	560
1	10.1	1.21	2	2.4	12.5	3,750	310	3,430
1 $\frac{1}{2}$	0.1	1.20	1	1.2	1.3	530	40	490
2	3.0	1.28	1	1.3	4.3	2,130	150	1,990
2 $\frac{1}{2}$	1.6	1.50	5	7.5	9.1	5,570	360	5,210
3	1.7	1.56	4	6.2	7.9	5,580	350	5,230
4	2.5	1.58	3	4.7	7.2	6,360	380	5,980
5	16.1	1.68	2	3.4	19.5	20,480	1,170	19,310
6	1.2	1.78	3	5.3	6.5	8,000	450	7,550
8	0.9	1.87	3	5.6	6.5	10,150	550	9,610
10	2.7	1.95	2	3.9	6.6	12,480	660	11,820
Total	42.4		26			75,640	4,460	71,190

Note: (A) Equivalent Length per piece
(B) Number
(C) Equivalent Length
Inner Temperature 175 °C, Emmisivity 0.9
Room Temperature 25 °C
Insulation : Glass Wool 60 mm, Total Area 31.5 m^2

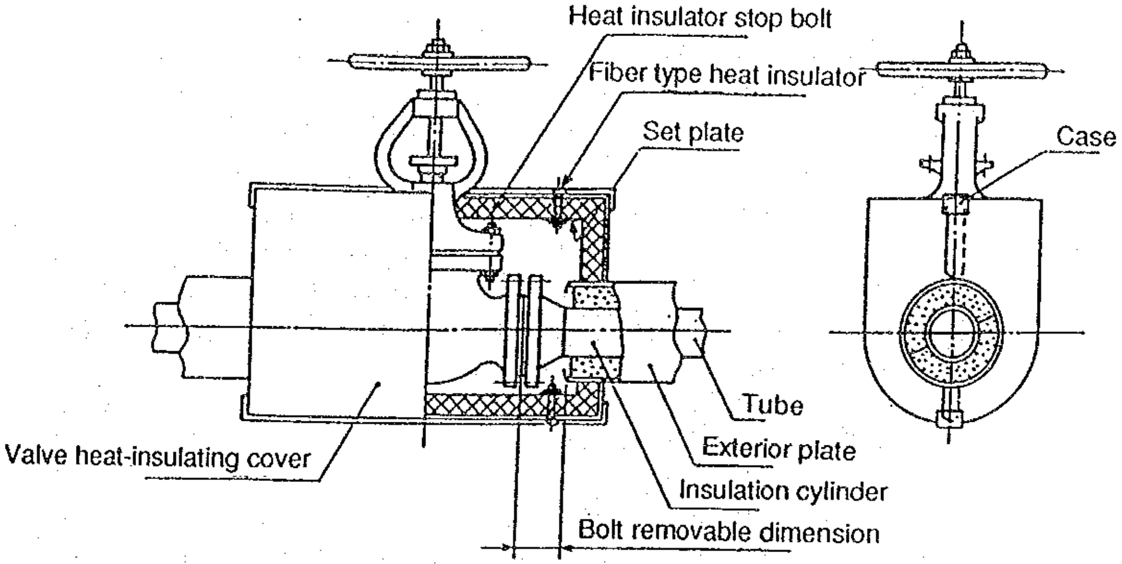
Expected quantity of steam heat saved: 71,190 kcal/h × 661.9 / 485.4 × 8,760 h/y
= 850,385 Mcal/y

Saved cost : 850,385 Mcal/y × 0.61 Lv/Mcal = 518,730 Lv/y

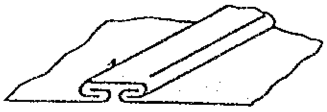
A simple thermal insulation for valves are provided as follows: A valve is enclosed by an aluminum-covered box which can be divided into two for removability, and the inside of the box is stuffed with glass wool. This method is simple and can be implemented by employees of the factory. The cost of material for the insulating device (Refer to Figure 5.4 18) is estimated to be 4,000 Lv or so, and recoverable in a short period.

Figure 5.4.18 Insulation of Valve & Flange

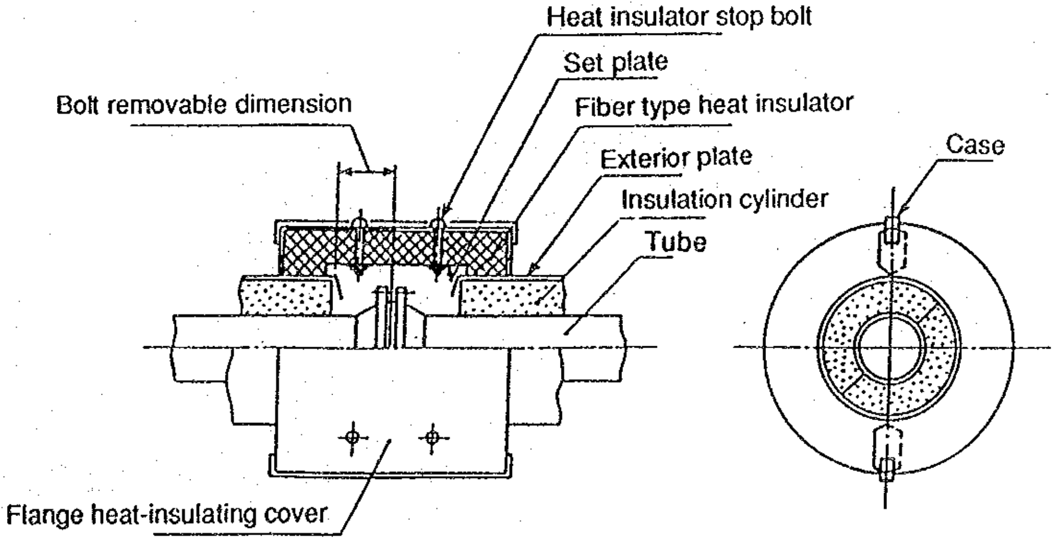
Heat Insulation of Valve



Details of case



Heat Insulation of Flange



(5) Water

a. Consumption and Unit Consumption rate of Water

1) Unit Consumption Rate of Water

The unit consumption rate was calculated based on the production in 1992, and the calculation result is as follows:

Water unit consumption rate : 461,800 m^3 / 525,000 m = 880 ℓ/m

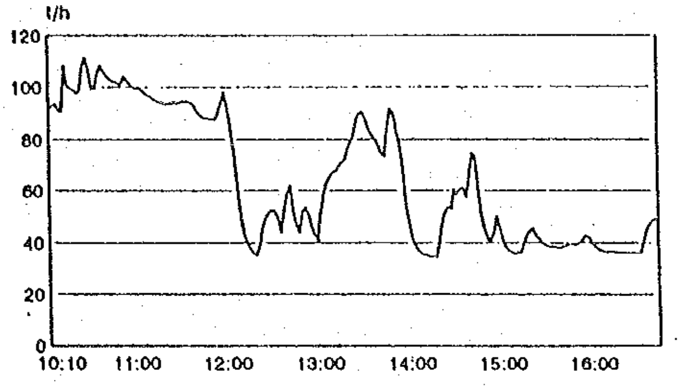
For Japanese companies in a similar form of operation, the unit consumption rate of water is 170 - 200 ℓ/m. The present factory consumes approx. 4 times as much water as similar factories do in Japan. However, if the production in 1989 (2352 Km) is achieved with the current water consumption, then the unit consumption will be 200 ℓ/m, and equal to the Japanese level.

2) Result of Flow Rate Measurement

The flow rate of the feed water pump for well water was measured using an ultrasonic flowmeter. Figure 5.4.19 shows the result of the measurement over two days. The consumption of well water largely fluctuates from hour to hour, from day to day, but the water balance table (Table 5.4.22) was made based on the measured values.

The total drain flow rate was also measured by spot check.
As a result, the instantaneous flow rate was 160 m^3/h. If the average water consumption of the present factory is added to that of Runo, the resultant value is 162 m^3/h and almost equal to the above value.

Figure 5.4.19 Flow Rate of Well Water



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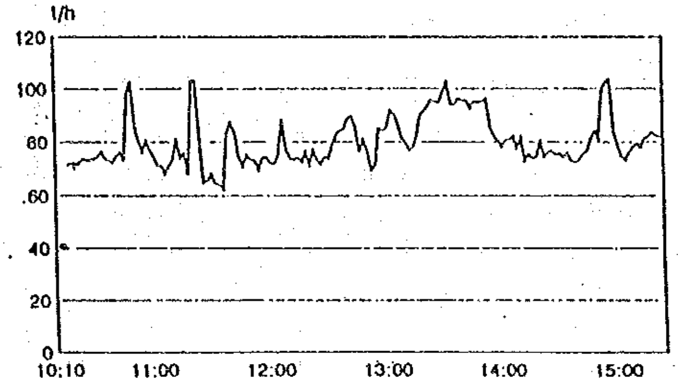

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Table 5.4.22 Water Balance

Classification	Factory statistical		Actual value m³/h		Total amount of
	value m³/month	m³/h	NITEX	RUNO	waste water
City water	15,000	43	47	9	
Ground water	20,000	57	70	36	
Total	35,000	100	117	45	160

b. Rationalization of Consumption of Water for Processing

In crabbing, washing and dyeing shops, cleaning and cooling operations are performed, and accordingly, facilities in such shops consume a large quantity of water. These machines, except for some computer controlled machines, have been conventionally operated based on operators' "intuition and experience", and the judgment of cleaning end point also depends thereon. This operation largely reflects the difference between individuals, and thus allows for a margin. Water is usually used as hot water; therefore, saving water leads to heat energy saving.

To reduce the water consumption, the following measures should be taken:

- Do not continuously feed water in dye bath cleaning. Use batch processing and repeat draining and water filling for the purpose.
- Set a standard number of cleaning times for each type of cloth.
- Collect lots to be subjected to the same process to get the amount of one batch process as close to a specified value as possible.
- Grasp the end point of cleaning and cooling for each type of materials to be processed by a scientific method. Standardize the operation using timers to set a required time and so on. The end point of cleaning is scientifically determined by measuring the electric conductivity and absorbance of effluent.
- Install feed water valves in two stages, that is, install a valve dedicated for opening/ closing and a throttle valve, for stabilizing the water supply. Using a secondary side pressure gage together enables the highly sophisticated adjustment of water supply.

c. Rationalization of Water for General Use

1) Control of Water Storage Tank Level

It was observed that a large quantity of well water, pumped up from the 300 m^3 water storage tank, was overflowing. The installation of a water level controller, which detects the level in the water storage tank and turns on/off one of the deep well pumps, will prevent the waste of electric power. A two stage water level controller may be provided, as required, to turn on/off two deep well pumps.

2) Prevention of Overflow of Make-up Water for Air Conditioners

Refer to Item (3) b. 3).

3) Sealing Water for Carding Machine Vacuum Pump

The vacuum pumps are being continuously operated for periods other than a cleaning period. While the pumps are running, pump water sealing water and silencer water are also being fed. Water and electric power will be saved by previously scheduling the cleaning time and operating the pumps according to the schedule.

d. Control of Water

The 1992 annual cost for water supply/drain is as enormous a sum as 868,500 Lv. Therefore, the rationalization of water consumption, in combination with energy conservation, will largely reduce the cost. Taking individual measures to rationalize the water consumption step by step, will reduce the water unit consumption rate without fail. To control the water unit consumption rate, it is necessary to grasp an exact value of the current water consumption rate. It is desirable to install a cumulative flowmeter for well water in addition to the existing cumulative flowmeter for city water.

The total quantity of effluent contains timelags and includes the quantity of effluent from Runo, and thus varies in a different way from the water supply flow rate. To cope with this, it is advisable to provide a triangle weir in an open area in the drain conduit as shown in Figure 5.4.20, and check the flow rate from time to time. This enables the evaluation of the waste water treatment capability.

Figure 5.4.20 Flow Measurement by Weir

Flow through weir

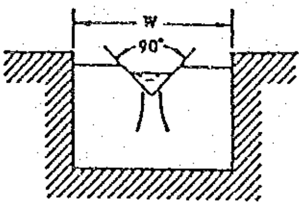
A. Triangle Weir

From Strickland's formula

$$Q = 60\left(1.334 + \frac{0.0205}{\sqrt{H}}\right) H^{5/2}$$

However, the following conditions must be met $\theta = 90^\circ$, $H > 50$mm, $W > 7H$, $D > 3H$.

where Q: Flow rate (m³/min);
H: Water depth from top of weir (m);
W: Water channel width (m);
D: Height from bottom of water channel to top of weir (m);



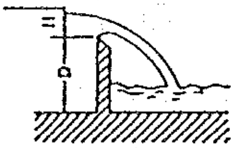
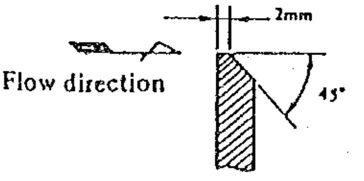
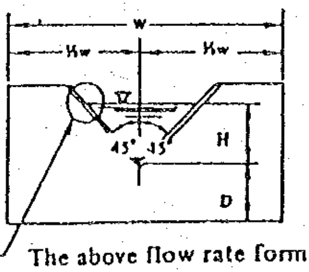


Table of Rectangular Triangle Weir Flow Rate (m³/min)

H (mm)	0	1	2	3	4	5	6	7	8	9
50	0.0478	0.0530	0.0527	0.0553	0.0579	0.0605	0.0633	0.0662	0.0690	0.0720
60	0.0751	0.0782	0.0814	0.0847	0.0881	0.0914	0.0950	0.0988	0.1022	0.1060
70	0.1099	0.1137	0.1178	0.1219	0.1261	0.1302	0.1348	0.1390	0.1443	0.1481
80	0.1528	0.1575	0.1625	0.1675	0.1724	0.1775	0.1828	0.1882	0.1935	0.1989
90	0.2048	0.2103	0.2161	0.2219	0.2278	0.2339	0.5401	0.2462	0.2524	0.2590
100	0.2658	0.2722	0.2788	0.2857	0.2927	0.2997	0.3067	0.3139	0.3214	0.3288
110	0.3362	0.3437	0.3516	0.3595	0.3674	0.3754	0.383=	0.3819	0.4002	0.4086
120	0.4178	0.4258	0.4347	0.4436	0.4225	0.4614	0.4707	0.4892	0.4898	0.4900
130	0.5085	0.5184	0.5284	0.5385	0.5482	0.5585	0.5689	0.5794	0.5898	0.6004
140	0.6113	0.6222	0.6332	0.6441	0.6555	0.6670	0.6784	0.6899	0.7014	0.7135
150	0.7255	0.7375	0.7495	0.7818	0.7744	0.7869	0.7995	0.8121	0.8251	0.8383
160	0.8514	0.8645	0.8778	0.8915	0.9053	0.9190	0.9328	0.9498	0.9608	0.9752
170	0.9897	1.0040	1.0184	1.0303	1.0480	1.0630	1.0780	1.0940	1.1080	1.124
180	1.0390	1.1550	1.1720	1.1880	1.2040	1.2210	1.2370	1.2540	1.2700	1.287
190	1.3040	1.3210	1.3390	1.3560	1.3730	1.3910	0.4090	1.4280	1.4460	1.464
200	1.4810	1.500	1.519	1.537	1.558	1.575	1.594	1.613	1.633	1.652
210	1.672	1.692	1.712	1.732	1.752	1.772	1.783	1.814	1.835	1.856
220	1.877	1.898	1.920	1.941	1.963	1.984	2.007	2.029	2.051	2.073
230	2.098	2.119	2.142	2.165	2.188	2.211	2.234	2.253	2.281	2.304





Shape of cutout

The above flow rate formula applies to the following range.

W: 0.5 to 1.2m

H: 0.07 to 0.26m < W/3

D: 0.1 to 0.75m

The reading of the cumulative flowmeters should be recorded everyday, and if any abnormal change is observed, the cause should be sought and proper measures taken. Further, the water unit consumption rate should be monthly graphed, and concrete means for water saving taken for steady improvement.

(6) Space Heating and Ventilation

a. Evaluation of Heating Load

1) Present Situation of Heating Load

After the renewal of the steam traps, 7 - 8 t/h of steam is used for heating in the winter season. In seasons other than winter, the quantity of steam utilization is reduced to 1 - 2 t/h, and 6 t/h, the difference between winter and other seasons, is regarded as the quantity of steam used for heating.

We made the study in a season when no heating is provided, and so, was not able to sample required date or make any observation. However, the validity of the heating load was analyzed and evaluated based on the numeric value above.

Heating load is roughly classified into two: Loss of heat by heat conduction through the building perimeter, and loss of heat by ventilation due to draft.

2) Loss of Heat by Conduction

Table 5.4.23 shows the result of calculating the loss of heat for various parts of the buildings.

Table 5.4.23 Heat Loss Through Building Perimeter

Part	Section	Area m^2	Overall heat transfer coefficient kcal/ (m^2 · h · °C)	Room temp. °C	Heat loss kcal/h	Rate %
Outer wall	Single glass window	252	5.5	25	31,900	1.6
	Double glass window	889	2.2	25	45,000	2.2
	Lower brick wall	1,420	1.6	20	40,900	2.0
	Entire brick wall	2,561	1.6	25	94,200	4.7
	Subtotal	5,122			212,000	10.6
Roof	Single glass window	3,442	5.5	30	530,100	26.5
	Double glass window	2,052	2.2	30	126,400	6.3
	Slated roof	19,808	1.75	30	970,600	48.5
	Tin roof	950	4.2	30	111,700	5.6
	Subtotal	26,252			1,738,800	86.9
Floor	Terrazzo	20,264	0.5	15	50,700	2.5
Total					2,001,500	100.0

Note: The premises of the calculation:

- Outdoor temperature : 2 °C (average temperature from December to March)
- Indoor temperature : Average : 25 °C, Upper part : 30° C, Lower part : 20 °C, Floor surface : 15 °C
- Underground temperature: 10 °C (estimated value)

The heat loss per floor area is calculated as follows:
2,001,500 / 20,264 = 98.8 kcal/(m^2 h)

The result of the calculation is equal to general values, 90 - 110 kcal/(m^2 h), of buildings of the same construction.

However, the heat loss is larger in rooms with single glass windows or of flap plate construction, such as the woolen spinning, fabric preparation and fabric modification rooms.

3) Loss of Heat by Ventilation due to Draft

Since it is hard to grasp the quantity of a draft, the heat loss by ventilation is found by heat balance calculation.

Table 5.4.24 shows the result of the heat balance calculation.

Table 5.4.24 Heat Balance of Space Heating

	kal/h	%	Note
Heat Input			
Steam	2,912,400	79.6	485.4 × 6,000
Condensate	204,000	5.6	(100–60) × 6,000 × 0.85
Electric Power	541,800	14.8	630 kWh × 860 kcal/kWh
Total	3,658,200	100.0	
Heat Output			
Loss by Heat Conduction	2,001,500	54.7	
Loss by Ventilation	1,656,700	45.3	(Duct 15.7%) (Clearance 29.6%)
Total	3,658,200	100.0	

Note: The premises of the calculation:

- Steam for heating: Pressure : 8 kgf/cm^2 (G), Latent heat: 485.4 kcal/kg
  It is premised that 15 % is flash-vaporized after a steam trap.
- Utilization of condensate : It is premised that heat is utilized at a temperature from 100 °C to 60 °C.
- Electric power for production : 630 kW, estimated based on the power consumption of the period from January to March in 1992, 1,084.230 kWh.

The flow of air leaking in through gaps and the number of ventilation times are calculated based on the result of the heat balance calculation.

- The specific weight of air at an outdoor temperature of 2 °C and an atmospheric pressure of 712 mmHg:

$$1.20 \times \frac{712}{760} \times \frac{273}{(273 + 2)} = 1.20 \text{ kg/m}^3$$

- The quantity of leaking-in air:

$$\frac{1{,}656{,}700}{0.24 \times 1.20 \times (25 - 2)} = 250{,}100 \text{ m}^3\text{/h}$$

provided the specific heat of air = 0.24 kcal/(kg °C)

- The number of ventilation times

Volume of space in buildings = area of floor × average height of ceiling
= 20,264 × 6.5 = 131,700 m^3
Number of ventilation times = 250,100 / 131,700 = 1.9 times/h

This number of ventilation times is slightly larger than general values, 0.5 - 1.5 times/h, of buildings of the same construction. Leaking-in air comes in and goes out through gaps in the outer walls and roofs of the buildings, entrance doors, and gaps in the dampers of the outdoor air inlets of the air conditioners. In the outdoor air inlet of the dry finishing shops studied, observed were missing vanes of the dampers, shutout failure of the vanes, and defective seal around the vanes. With the dampers closed, the flow of air passing through these points was measured, and the measured value was 10,860 m^3/h. In addition, the dampers at the outdoor air inlets of the other air conditioners had similar defects.

With the premise that an equal quantity of outdoor air leaks in through the eight air conditioners, the total of the eight units is 86,900 m^3/h, and equivalent to approx. 35 % of the total quantity of leaking-in air.

When the quantity of outdoor air leaking in through the air conditioners is subtracted from the total quantity of leaking-in outdoor air, a value of 163,200 m^3/h is given, and this is the quantity of air leaking in through gaps in the buildings.

Regarding the cross section of building as a smokestack, the quantity of leaking-in air and the area of gaps in the buildings were calculated based on the draft effect due to the difference between outdoor temperature and indoor temperature:

where,

$P = H (r_a - r_i)$

P : Draft (mmAq)
H : Height from the floor level to the highest level (height of ceiling + 1 m) 7.5 m
r_a : Specific weight (kg/m^3) of outdoor air (2 °C) 1.20 kg/m^3
r_i : Specific weight (kg/m^3) of indoor air (30 °C) 1.09 kg/m^3

$P = 7.5 (1.20 - 1.09) = 0.836$ mmAq

The speed of indoor air leaking-out:

$v = (2 g P/r_i)^{1/2} = (2 \times 9.8 \times 0.836 / 1.09)^{1/2} = 3.88$ m/s

The area of gaps in the buildings:

$A = 163,200\ m^3/h / (3.88\ m/s \times 3,600\ s/h) = 11.7\ m^2$

The area of parts in contact with outdoor air (Table 5.4.23):

$S = (5,122 + 26,252) = 31,374 \text{ m}^2$

The ratio of the area of gaps in the buildings to the area of parts in contact with outdoor air:

$11.7 / 31,374 \times 100 = 0.037\ \%$

It turns out from the calculation result that the air leaking out through the gaps with an area of 1/3,000 or so of the total area of the building perimeter is equivalent to 1/3 of the heating load.

b. Measures to Reduce Steam Flow for Heating

1) Prevention of Leakage from Outdoor Air Intake Dampers of Air Conditioners

Approx. 15 % of the heating load will be reduced in heating seasons by completely preventing outdoor air from leaking in through the outdoor air intake dampers.
The existing dampers have a lot of voids on the periphery, and it is hard to completely close vanes. As already implemented in the air conditioners in the weaving machine room, therefore, it is effective to completely close the dampers by placing an iron plate on the upper face thereof or covering them with a thick vinyl sheet and then placing a plate thereon.

2) Control of Draft Leaking into Buildings

It was observed in the study that there were a lot of openings and voids as listed below:

- Broken glasses of the skylights
- Openable glass windows which cannot be completely closed
- Broken ceilings
- Gaps in the junctions between the flap roofs and wall faces of the buildings for the woolen spinning shop
- Gaps in the junctions between the steel frames and wall faces of the light weight steel frame buildings
- Gaps in portions of the walls where pipes or cables pass through
- Gaps at upper and lower part of the entrance doors
- Openings in the air exhaust supply ducts for the production machines
- Skylights for emitting indoor air of the wet finishing room which was not completely closed.

It is advisable to check gaps in each shop, write the check result into the buildings' layout drawings, take a measure one by one, and delete an eliminated gap from the drawings.

If these gaps are reduced to half, the heating load will be reduced by approx. 15 %.

If it is premised that the required fresh air taken in per worker is 20 m^3/h with a margin allowed for, then 600 workers require 12,000 m^3/h of air. Even if the outdoor air intake dampers are completely closed and the leakage from other gaps is reduced to 1/2, the quantity of ventilated air is still 80,000 m^3/h or so. Accordingly, with respect to the working environment, there is no fear that these measures result in the indoor air pollution.

3) Control of Heating Temperature

The heating temperature is set in accordance with room temperature suitable for respective operations. When a room heater is operating, the indoor temperature tends to be high at the upper part of the room and low at the lower because of the difference in specific weight of air.

However, the temperature will be evenly distributed in the direction of height by adjusting the direction of the flow of air discharged from the ducts and the air speed at each outlet.

For the local low temperature parts due to drafts leaking in and the outdoor air radiation cooling, taking the following measures will reduce the total heating load: Repairing gaps, providing the glass windows with a curtain, installing ceiling plates, and providing local heating using unit heaters.

For out-of-operation periods, such as night time and holidays, the indoor temperature control value should be lowered to the extent that the start of operation is not hindered.

Letting the other conditions be unchanged, the reduction of the indoor heating temperature from 25 °C to 24 °C will reduce the quantity of heat consumed as follows:

Reduction of heat loss by conduction through building	: 79,900 kcal/h
Reduction of heat loss by draft leaking in	: 72,000 kcal/h
Total	: 151,900 kcal/h

The rate of the reduction of heating load : 151,900 / 3,658,200 × 100 = 4.2 %

When in a period of the reduction of production, areas out of operation may be isolated using vinyl sheets to reduce the area of heating coverage.

At present, the heating temperature is controlled by the power department. In working hours, however, the heating temperature control should be added to the temperature and humidity controls, and transferred to a person in charge of each shop.

c. Air Supply/Exhaust of Production Machines

1) Spinning Machine Pneumafil Exhaust

Pneumafil exhaust of the four spinning machines is discharged outdoors through the centralized duct. In the heating season, the outlet of the duct should be shut and pneumafil exhaust should be discharged indoors. This will reduce the quantity of outdoor air taken into the room, and further, power to the pneumafil blowers will contribute as power input to the indoor temperature rise. In the present situation of exhaust, discharge in the room will cause no problem in the working environment. The reduction of heating load by this method is as follows:

Quantity of outdoor air taken into pneumafil apparatus:
$30\ \mathrm{m^3/min.} \times 60 \times 4 = 7{,}200\ \mathrm{m^3/h}$
Rate of the above quantity to the total quantity of drafts:
$7{,}200 / 163{,}200 \times 100 = 4.4\ \%$
The reduction of quantity of heat required to heat outdoor air:
$7{,}200\ \mathrm{m^3/h} \times 1.2\ \mathrm{kg/m^3} \times 0.24\ \mathrm{kcal/kg} \times (25 - 2) = 47{,}700\ \mathrm{kcal/h}$
Pneumafil apparatus power heat:
$3.7\ \mathrm{kWh/h} \times 0.8 \times 4 \times 860\ \mathrm{kcal/kWh} = 10{,}200\ \mathrm{kcal/h}$
Total of heating load savable : $47{,}700 + 10{,}200 = 57{,}900\ \mathrm{kcal/h}$
Rate of heating load reduction : $57{,}900 / 3{,}658{,}200 \times 100 = 1.6\ \%$

2) Air Exhaust/Supply of Dryer

The exhaust duct and cooling outdoor air intake duct of the dryer are included in the openings. As mentioned in Item (1) b., the damper of the exhaust duct should be controlled and air for cooling should be taken indoors.

3) Ventilation in Wet Finishing Shop

In the wet finishing shop, generated steam is discharged outdoors, and the hanging wall and the ventilating gallery window are provided for preventing indoor condensing. In addition, the forced exhaust blower is installed in the dyeing shop.

However, there are gaps at both ends of the hanging wall, and the forced exhaust blower is faulty. The equipment, though provided, does not work, and requires repair for maintaining proper ventilation.

d. Expectancy of quantity of steam savable

The expectancy of heat load reduction for each of the measures mentioned above, is as follows:

Reducing the steam pressure : 6.1 %
Completely closing the outdoor air intake dampers : 15 %
Preventing drafts from leaking in through gaps in the buildings : 15 %
Lowering the heating temperature : 4.2 %
Emitting pneumafil exhaust indoors : 1.6 %
Taking in dryer cooling air indoors : 1.3 %

These measures are classified into two types, measures effective by themselves and measures whose effectiveness is influenced by the other measures. The total effect is calculated as follows:

$$\{1 - (0.15 + 0.15 + 0.016 + 0.013)\} \times (1 - 0.061) \times (1 - 0.042) = (1 - 0.396)$$

The average monthly steam consumption in the period from April, 1992 to November in the same year was multiplied by 4, and the resultant steam consumption for four months is subtracted from the steam consumption in the period from December, 1992 to March, 1993. The resultant value was taken as annual heating steam consumption. Assuming that the portion of production power in the heating input was constant and the reduction of load led to the reduction of steam and hot water, the quantity of steam saved and the cost saved by the overall measures were calculated. The calculation result is as follows:

Quantity of steam savable : 10,594,300 Mcal/season × 0.396/0.852
= 4,924,100 Mcal/season
Cost savable : 4,924,100 Mcal/season × 0.61 Lv/Mcal
= 3,003,700 Lv/season

These measures are extensive, but almost all of them can be coped with through management.

(7) Waste Heat Recovery

a. Present Situation of Waste Heat Recovery

At present, heat of condensate in the wool fabric dryer steam heater is recovered as hot water for shower by the multipipe heat exchanger. However, the dryer is intermittently operated, and accordingly, hot water is not continuously recovered.

Steam condensate in each shop is stored in the tanks, and utilized as hot water for the fabric preparation room and the office. Flash steam produced from condensate is not recovered.

Hot effluent of 50 - 90 °C produced in the wet finishing shop, is discharged without being utilized.

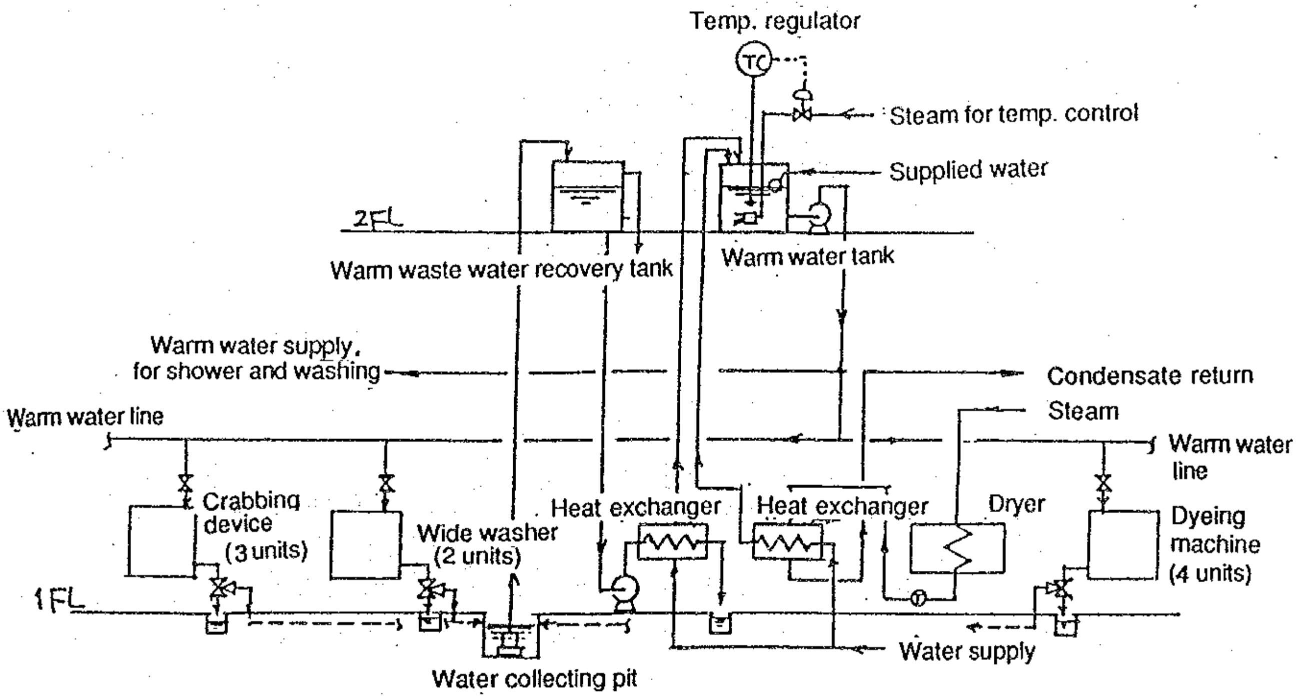
Though 3,500 kg of hot effluent of 100 °C per batch is produced in the top dyeing shop, it is difficult to economically recover the waste heat in the present operation of 4 - 5 batches per day.

b. Waste Heat Recovery of Hot Effluent in Finishing Shop

Hot effluent is now intermittently drained, and varies in temperature. To economically recover heat, it is necessary to select only effluent at a temperature of some degree or above and continuously process it.

As shown in Figure 5.4.21, a recovering facility should collect only hot effluent of 50°C or above in a pit, store it in an effluent recovery tank, and continuously exchange heat with fresh water by a specific quantity. Fresh hot water should be stored in a hot water tank and be fed according to the shop load.

Figure 5.4.21 Waste Heat Recovery from Warm Effluent



It is advisable for the reason of layout to use two of the 8 m^3 tanks out of use at the second floor of the drying room for the effluent recover tank and fresh hot water tank.

Since hot effluent contains waste fibers and other foreign matters which may stick to the heat transfer face of a heat exchanger to hinder heat exchange, a screen should be installed in a water collection pit.

A heat exchanger should be convenient to back wash cleaning and overhaul cleaning. The plate type heat exchanger, easy to disassemble and clean, is in wide use.

It is advantageous in the long term to use corrosion resistant stainless steel for heat exchanger material.

An automatic switching valve with a temperature sensor is preferable to selectively recover effluent depending on temperature in the drain process. A system which turns on a lamp according to a temperature sensor to indicate the timing for recovering hot effluent, is a minimum necessity.

To supply fresh hot water at a constant temperature, it is preferable to control the fresh hot water tank temperature by blowing in steam.

Table 5.4.25 shows the recoverable waste heat in the finishing shops.

Table 5.4.25 Recoverable Heat In Finishing Process

Item	Unit	Wet Finishing		Dry Finishing	Total
Object		Crabbing Machine Wide Washer Washer	3 2 4	Dryer 2	
Operating Time	h	3,000		2,000	
Effluent Flow	kg/h	5,000		600	
Temperaure	°C	60		170	
Effective Heat	kcal/kg	33		150	
Recoverable Heat	Gcal/y	495		180	675

Evaluation of recoverable heat : 675,000 Mcal/y × 0.61 Lv/Mcal = 411,800 Lv/y

The cost of waste heat recovery equipment is estimated to be 500,000 Lv or so based on examples in Japan, and thus, the investment will be recovered in 1.2 years.

c. Utilization of Flash Steam

The quantity of flash steam generated from condensate can be reduced by reducing the steam pressure used. To cope with flash steam generated even after the reduction of the pressure, a method as shown in Figure 5.4.22 is in wide use. A spray is installed in the middle of the atmospheric air releasing vent pipe of a recovery tank to cool and collect flash steam.