If the surface temperature is lowered to 40°C by heat insulation, the amounts of heat radiated will be as follows.

Right side:	70 kcal/(m²h) x 17.14 m² =	1,200 kcal/h
Left side:	68 kcal/(m²h) x 17.14 m² =	1,166 kcal/h
Front:	70 kcal/(m²h) x 7.98 m² =	559 kcal/h
Rear:	70 kcal/(m²h) x 10.26 m² =	718 kcal/h
Top:	70 kcal/(m²h) x 16.53 m² =	1,157 kcal/h
Total		4,800 kcal/h

Therefore, the amount of heat radiation that can be saved by heat insulation will be as follows:

36,717 kcal/h – 4,800 kcal/h = 31,917 kcal/h.

(b) Economic effects

The amount of heat radiation that can be saved by heat insulation (31,917 kcal/h) can be calculated in terms of fuel as follows, assuming that boiler efficiency is 69%, low-level heating value of fuel oil 9,700 kcal/kg, and the latent heat of evaporation 80% of the total heat content of steam.

$$\frac{31{,}917 \text{ kcal/h}}{9{,}700 \text{ kcal/kg} \times 0.80 \times 0.69} = 5.96 \text{ kg/h}$$

If each cooker is used 2.5 hours twice a day (except on Saturdays when it is used only once), 50 weeks a year, the amount of annual saving will be:

5.96 kg/h x 2.5 h x 11 times x 50 weeks = 8,200 kg/year

How soon the investment in heat insulation expenses can be recovered is calculated below.

The total area requiring heat insualtion (assuming that the cookers have flat surfaces without the ribs of H-shaped steel and flat bar) is as follows:

Right side:	8.02 m²
Left side:	8.02 m²
Front:	4.96 m²
Rear:	4.96 m²
Top:	8.93 m²
Total:	34.89 m²

If heat insulation 25 mm thick costs 50 U$S/m², the cost of heat insulation will be:

50 U$S/m² x 34.89 m² = 1,745 US$S

Because fuel oil costs 0.15 U$S/kg, fuel saving will amount to:

8,200 kg/y x 0.15 U$S/kg = 1,230 U$S/year

Therefore, the investment can be recovered within two years as shown below.

1,745 ÷ 1,230 = 1.4 years

If the operation rate of the heat insulation of all cookers and sterilizers is assumed to be 50%, the annual heavy oil saving will amount to:

8,200 kg/y X 5 sets X 50% = 20,500 kg/year.

(5.2) Improvement on Air Venting from Autoclaves

The key to energy conservation is to lower the consumption rate of heating steam used for the autoclaves for sterilizing the cans. Air in the autoclaves prevents heat transmission and must be discharged as quickly as possible to make the heat of injecting steam effective for sterilization.

The cookers examined showed a satisfactory heat pattern with little difference in temperature distribution in the box, but come-up time is rather long (50 minutes). Generally, an autoclave which is well air-purged has a come-up time of about 15 to 20 minutes.

The specific gravity of air is about 1.6 times that of steam at the same temperature. In the autoclave, air temperature rises slower than steam so that the difference in specific gravity between air and steam increases.

Theoretically, steam should be injected from above and air vented downward. The autoclaves now in use have 14 nozzles on two 20A pipes mounted on both sides of the bottom (2.5 mm in diameter for the cookers, and 3 mm in diameter for the sterilizers) to horizontally inject steam into the autoclaves.

It would be better to change the positions of the 20A pipes to the top inside the box and to make steam inject downward into the box diagonally to its bottom.

The autoclaves have only one air vent in the forward part of the right. It is recommended that another air vent be added to the forward part of the left and that the valve be also used for air purge.

The above-mentioned improvements should shorten come-up time to raise efficiency. Try to make these improvements on the autoclaves, one at a time.

The autoclaves are filled with cans and may have a turbulent steam flow so that they may not always operate according to the theory. It is necessary, however, to study how to raise the temperature as quickly as possible.

An instance of improvement made on a similar plant in Japan is shown below for your reference. In this instance, a cylindrical autoclave 5 m^3 is used, in which branch pipes are connected as shown in Figure 5–2–13. The branch pipes have many holes 6 mm in diameter, through which steam slowly runs from top to bottom in the autoclave. If steam runs in much more at a point than the others, air will be mixed, preventing air purge. A punched metal sheet is used at points where air is liable to stay in the can containers to ensure easy flow of air.

As a result of the above modification, air purge time was shortened and temperature rise time was also shortened by 7 minutes, raising the operating rate of the autoclave. Steam discharge was sharply reduced, and steam consumption was cut by about 20%. The investment in (a) installation of a steam distributor, (b) installation of three air vent valves, and (c) punched metal sheet was recovered in eight months thanks to the reduction in steam consumption.

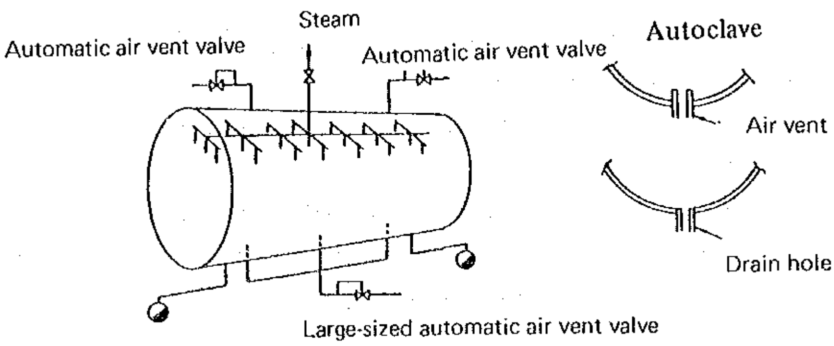


Figure 5–2–13 Air Vent of Autoclave

(5.3) Prevention of Heat Radiation from Autoclaves During Non-Use

As shown in the cooker heat balance table, a heat quantity of about 20% is needed to raised the temperature of the cookers. Except when inserting material into or removing it from the cookers, they should be kept covered to prevent their box temperature from falling.

(5.4) Temperature Conditions for Sterilization

Sterilizing time can be logarithmically shortened by raising the steam pressure of the autoclaves.

In the case of a cylindrical, horizontal autoclave which has high pressure resistance, sterilizing time can be shortened by raising steam pressure to about 3 kg/cm^2 Check the pressure resistance of the autoclaves in use, and try to raise their steam pressure within a permissible range.

5.2.3.2 Oil Heater

Additive oil is heated to about 50 ~ 60°C by the steam heater located in the upper part of the room, and again heated to about 80 ~ 85°C (with the thermostat set to 85°C) by the electric heater of the oil adder before it is added.

These steam oil heater and electic heater also need heat insulation.

5.2.3.3 Continuous Washer

The continuous washer cleans the surfaces of seamed cans moving on the net conveyor in the chamber, using an alkaline detergent and steam-heated hot water. The surface temperature of the chamber itself is high (87°C or 90°C).

There are some water leaks, which must be completely repaired. Heat insulation is also necessary.

5.2.3.4 Continuous Cooker

(1) Use of Continuous Cooker

A continuous cooker is used to process large amounts of small fish, such as sardines.

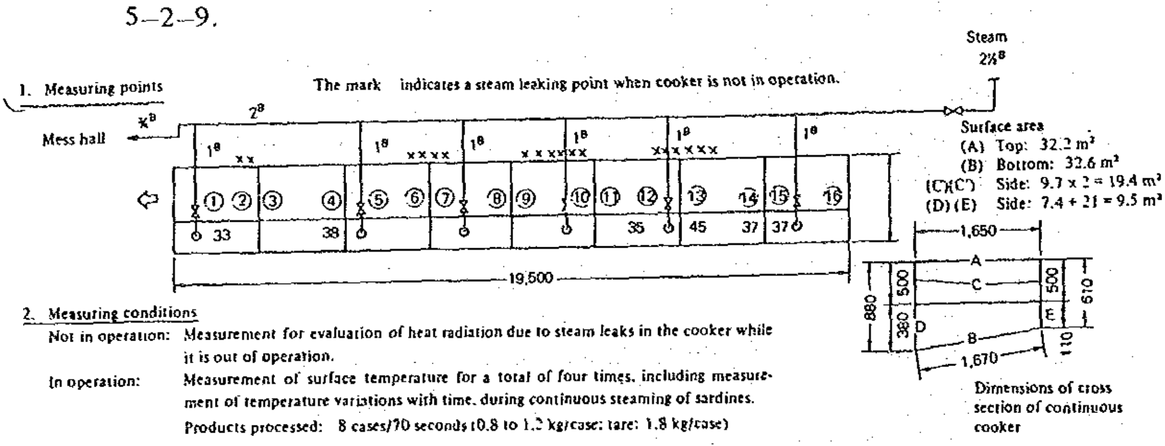
The continuous cooker is a trapezoidal tunnel type with both sides open, measuring about 1650 mm wide, 745 mm high on the average, and 19,500 mm long. Steam is injected into the cooker at six points at the bottom of the conveyor net in the tunnel at a pressure of less than 1 kg/cm^2

After dissecting and cleaning sardines, about 0.8 to 1.2 kg of them are placed in a plastic case and inserted into the continuous cooker. It takes 32 to 33 minutes to pass the continuous cooker. The processing capacity is about 329 kg/h to 493kg/h (about 411 plastic ases).

(2) Surface Temperature of Continuous Cooker and Heat Radiation from it

The surface temperatures measured of the continuous cooker are shown in Figure 5–2–14, and the amounts of heat radiation calculated are shown in Table 5–2–9.

1. Measuring points



2. Measuring conditions

Not in operation: Measurement for evaluation of heat radiation due to steam leaks in the cooker while it is out of operation.

In operation: Measurement of surface temperature for a total of four times, including measurement of temperature variations with time, during continuous steaming of sardines.

Products processed: 8 cases/70 seconds (0.8 to 1.2 kg/case; tare: 1.8 kg/case)

3. Data from measurements (March 22, 1988 when cooker was not in operation; March 23, 1988 when cooker was in operation)

Operation	Measuring point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average temperature	Ambient temperature	Measuring conditions
Not in operation	C	37	39	40	40	42	42	42	42	41	41	42	43	42	41	41	38	°C 40.7	°C 27	Operation suspended
	D	33			38							35		37		37				
	A				39															
In operation	I	91	91	92	91	92	92	95	95	96	96	94	93	94	91	92	89	92.7	28	Measuring start
In operation	II	91	94	94	93	92	95	95	96	97	96	96	96	95	95	94	93	94.5	28	5 minutes after start
	III	94	95	95	95	94	95	96	96	97	95	95	96	97	95	95	92	95.2	28	15 minutes after start
	IV	95	95	93	92	96	96	96	96	97	96	93	96	96	93	94	92	94.8	29	25 minutes after start

Measuring instrument: Contact surface thermometer Temperatures of (C) and (C') are the same.

Figure 5–2–14 Continuous Cooker Surface Temperature Measurements

Table 5–2–9 Amounts of Heat Radiation During Continuous Cooker Operation

Location	Radiating area (m^2)	Surface temperature (°C)	Heat radiation (kcal/h)
Horizontal-up surface	32.2	94.8	26,470
Horizontal down surface	32.6	91.8	18,590
Vertical surface	28.9	94.8	19,860
Total	93.7		64,920

Note: Ambient temperature = 27.3°C

(3) Heat Balance

(a) Steam consumption rate

Because the factory has no steam flow meter, the steam consumption rate was estimated from the difference in boiler evaporation on the day on which boiler efficiency was measured. The evaporation rate while the continuous cooker is out of use is estimated at 0.5 to 0.7 tons/h, and the evaporation rate while the continuous cooker is in operation at 2.2 tons/h. Thus, the steam consumption rate of the continuous cooker is estimated to be about 1.5 tons/h. This is slightly higher than normal for steam running through 2" piping at 6 kg/cm².

(b) Weight of heated objects

Sardines: 1.0 kg/case x 411 cases/h = 411 kg/h

Cases: 1.8 kg/case x 411 cases/h = 740 kg/h

(c) Heat balance

		Weight (kg)		Heating value (Mcal/h)	Percentage (%)
Heat input	Steam	1500	1500 x (660.8 – 27.3)	950	100.0
Heat output	Sardine	411	411 x 0.85 x (100 – 27.3)	26	2.7
	Case	740	740 x 0.45 x (100 – 27)	24	2.5
	Cleaning water	600	600 x (50 – 20)	18	1.9
	Heat radiated			65	6.8
	Exhaust, etc.			817	86.0
	Total			950	100.0

The steam consumption rate will be 3.6 kg steam per kilogram of sardines, about 8 times higher than the batch type cooker.

(4) Steam for Preheating

Steam is injected into the continuous cooker to preheat it for about 20 minutes before its operation. The quantity of steam required for it is calculated as follows:

Approximate weight of continuous cooker

Casing:	1.5 tons
Conveyor:	2.0 tons
Total:	3.5 tons

Heat required to raise temperature

Q1 = 0.11 x 3,500 x (100 − 27.3) = 27.990 kcal

Heat radiated during temperature rise (assuming it to be the same as in steady operation)

Q2 = 65,000/3 = 21,700 kcal

Total 49,690 kcal

Required quantity of steam: 49,690/539 = 92 kg

The factory now consumes 1,500/3 = 500 kg about 5 times as much.

(5) Problems and Remedies

The continuous cooker is the largest steam consuming unit. It has low thermal efficiency, and must be improved as regards adjustment of exhaust duct draft, the method raising the temperature of the cooker itself, and the choice between this and a batch type cooker.

(a) Inadequate instruments for management

It is necessary for energy management and quality control to standardize the operating conditions, record operation data from time to time, and use the recorded data for improvement of operation.

For this purpose, install thermometers in the middle of the steam inlets to determine temperature distribution in the continuous cooker. Also install an injection steam pressure gauge. It is important to mark these instruments at pointer positions corresponding to the standard operating conditions to facilitate adjustment.

(b) Heat loss due to steam leaks while cooker is out of use

Steam was leaking even while the continuous cooker was not in use. Therefore, the surface temperature of the continuous cooker was about 40°C as shown in Figure 5–2–14. The amount of heat radiated from the cooker was calcualted as shown in Table 5–2–10.

Table 5–2–10 Amount of Heat Radiated from Continuous Cooker When not in Use

Location	Radiating area (m^2)	Surface temperature (°C)	Heat radiation (kcal/h)
Horizontal up surface	32.2	40.0	3630
Horizontal down surface	32.6	35.0	1470
Vertical surface	28.9	38.8	2400
Total	93.7		7500

Note: Ambient temperature = 27.0°C

The above can be calculated in terms of steam quantity as follows:

7500/(600 − 41) = 12 kg/h

This corresponds to a steam leak out of a hole about 3 mm in diameter, and to about 2% of the amount of evaporation from the boiler when the continuous cooker is not in use. If total annual downtime is 2400 hours, steam loss will be about 30 tons/year.

This steam leak and other leaks from the valves and glands are due to inadequate maintenance. Once a steam leak occurs, the leaking point continues to grow due to the erosive action of steam. It is necessary, therefore, to periodically check the equipment and replace defective parts early.

The steam injection pipes may have the trouble of an enlarged nozzle hole worn with time. If so, steam distribution in the continuous cooker will not be uniform. It is also necessary to periodically check and maintain the steam injection pipes.

In the case of the continuous cooker and other devices that are used only for a limited period of the year, close the main valve and use a blind plate, if possible, to block the steam passage, thus preventing heat radiation from the piping connected to the equipment when it is not in use.

The present steam piping diagram is as shown in Figure 5–2–15. A 3/4-inch steam pipe for mess room is branched from the 2-inch steam header that leads to the continuous cooker so that the main valve to the continuous cooker cannot be closed. Therefore, the piping layout must be improved as shown in Figure 5–2–16.

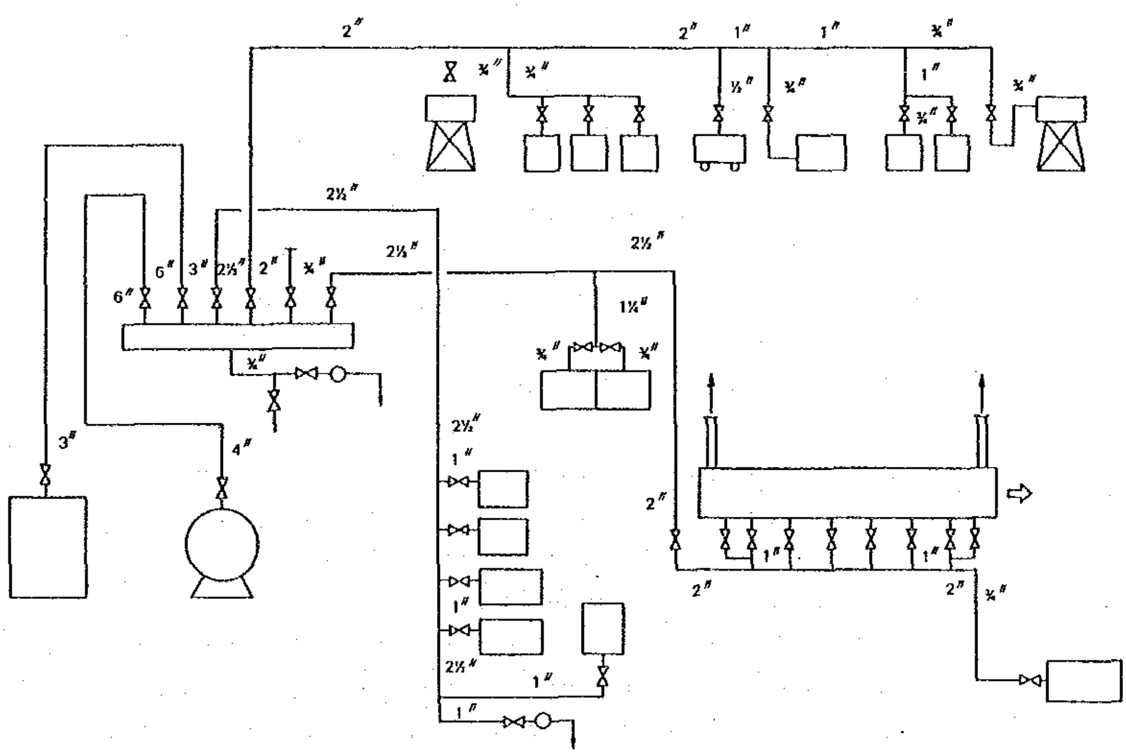


Figure 5–2–15 Steam Piping Diagram

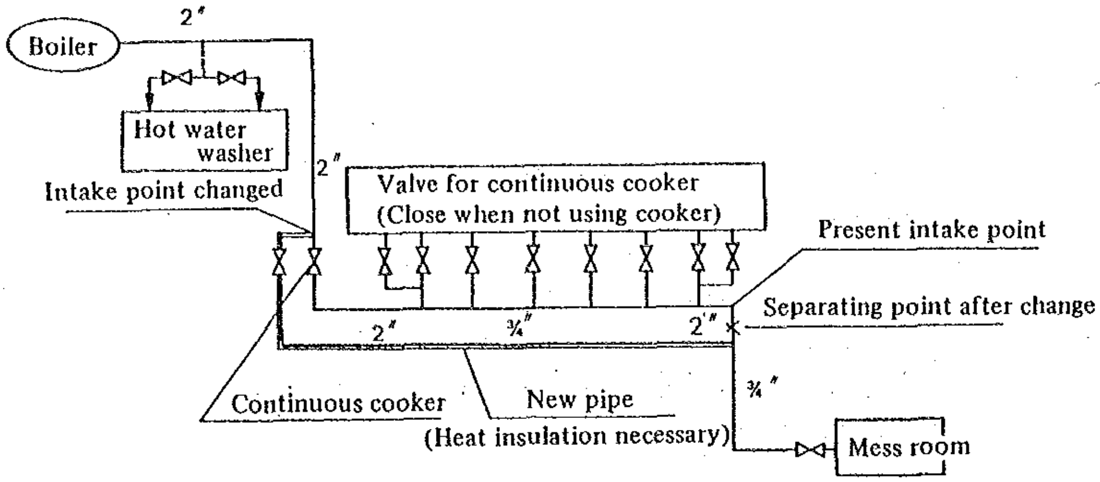


Figure 5–2–16 Improvement Procedure for Steam Piping to Mess Room Equipment

(c) Improvement of exhaust duct

The duct mounted on both ends of the continuous cooker have so large an exhaust capacity that they quickly draw out injected steam and take in cold outside air. A look at the heat balance shows a 86% loss in exhaust, etc.

Ventilating capacity of duct

Draft $P = H(ra - rs)$ mmAq

$H = 10$ m

$ra = 1{,}176$ kg/m^3 (27°C)

$rs = 0.578$ kg/m^3 (100°C)

Therefore, $P = 5.98$ mmAq

Air current rising velocity $v = \sqrt{(2g \cdot P/rs)}$ m/s

$= 14.3$ m/s

The two ducts have a cross sectional area of 0.25 m^2, and have a steam exhaust capacity of about 15 tons/h

$14.3 \times 0.5 \times 3600 \times 0.578 = 14.9$ tons/h.

Either suspend a baffle plate in the cooker in such a way that it will not stand in the way of material movement on the conveyor, or install dampers in the duct and adjust them not to produce a negative pressure in the cooker. Steam can be saved and preheating time can be shortened in this way.

(d) Use of batch cookers for small lots

The continuous cooker is suited to processing large amounts of fish by continuous operation, but has lower thermal efficiency than the batch cookers. If batch cookers are available, it would be better to use them to process small lots.

(e) Heat radiation from the surfaces of continuous cooker

The amount of heat radiated from the surfaces of the continuous cooker is 65,000 kcal/h. If the continuous cooker is heat-insulated with rock wool 25 mm thick, the amount of heat radiation from the cooker surfaces will decrease to 6200 kcal/h with a resultant fuel saving of about 6.9 tons/year. Because the operation rate of the continuous cooker is low, however, the economic advantage of heat insulation is low. It would be better to take other remedial measures first.

(f) Improvement of water sprinkling method at continuous cooker inlet

The present shower head has so narrow a sprinkling angle that the showei does not cover the whole area of the tray. The cleaning water cools the conveyor net of the continuous cooker. It is suggested that the shower head be replaced with an appropriate one and be relocated on the conveyor.

5.2.3.5 Boiler

The steam supplied from the boiler is used as an energy source for the cooker, sterilizer, continuous cooker, etc., and plays an important role in the production process.

(1) Boiler specifications

Type:	3-pass flue and smoke tube boiler
Evaporation rate:	8 t/h
Steam pressure:	10 kg/cm^{2}G (rated)
Fuel:	Fuel oil (Hl = 9,700 kcal/kg)
Heating surface:	183 m^2
Year of manufacture:	1986
Structure:	As shown in Figure 5–2–17

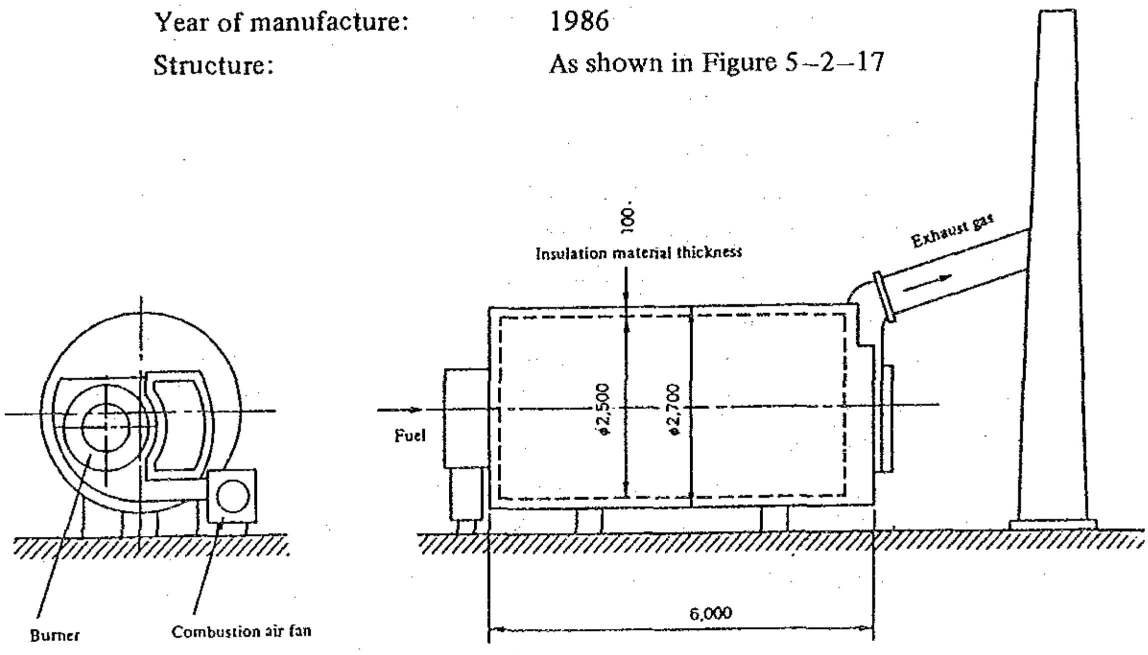


Figure 5–2–17 Boiler Structure

(2) Survey Items and Collected Data

The boiler was surveyed on March 23, 1988.

The survey involved measurements by combined use of the instruments that had been brought by the Japanese team and the meters mounted on the boiler, and visual inspection of operating condition.

(a) The data collected by use of the instruments and meters are as follows: The measuring points are shown in Figure 5–2–18.

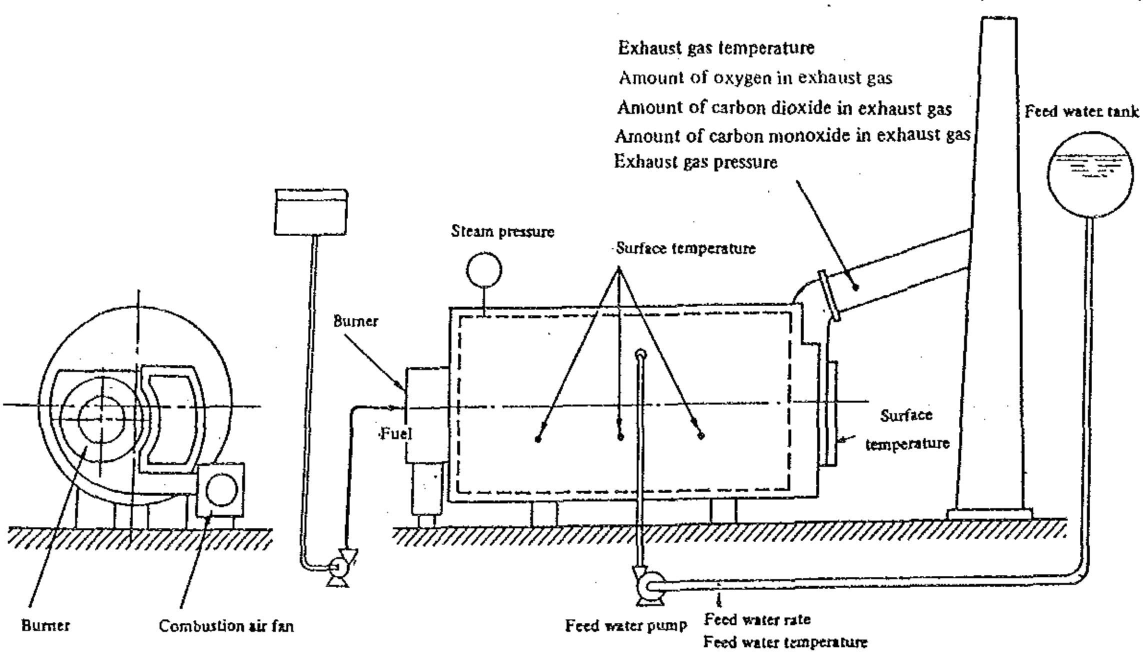


Figure 5–2–18 **Boiler Measuring points**

1) Exhaust gas temperature and pressure
2) O_2 %, CO_2 %, and CO% in exhaust gas
3) Feed water rate and temperature
4) Fuel oil flow rate and temperature
5) Furnace casing surface temperature
6) Ambient (reference) temperature
7) Steam pressure
8) Quality of feed water and boiler water

(b) Visual observation items are as follows:

1) Combustion
2) Control methods of combustion and water supply
3) Furnace casing and piping heat insulating condition
4) Steam leaks
5) Equipment maintenance
6) Smoke

(3) Boiler Heat Balance

(a) Boiler heat balnce was determined on the basis of data for 10:30 to 11:30 on March 23. The details of the data area as follows:

1) Kind of fuel:		Fuel Oil
2) Fuel consumption (volume)	(Efv)	0.232 m^3/h
3) Fuel consumption (weight)	(Efw)	0.232 x 0.932 x 1000 = 216.2 kg/hour
4) Fuel heating value (low level)	(Hl)	9,700 kcal/kg
5) Fuel specific gravity	(Sgf)	0.932
6) Fuel specific heat	(Cp)	0.45 kcal/(kg°C)

7)	Fuel temperature	(Tf)	32°C
8)	Ambient temperature	(To)	22°C
9)	Combustion air temperature	(Ta)	22°C
10)	Combustion air specific heat	(Cp')	0.31 kcal/(Nm^3 °C)
11)	O_2% of dry exhaust gas	(O_2)	14.0% (As shown in Figure 5–2–19)
12)	CO_2% of dry exhaust gas	(CO_2)	5.0%
13)	CO% of dry exhaust gas	(CO)	1.4% (As shown in Figure 5–2–23)
14)	Exhaust gas temperature	(Tg)	185°C
15)	Exhaust gas pressure	(Pg)	-9.0 mmH_2O
16)	Blow water	(Fb)	0
17)	Feed water rate (volume)	(Fwv)	2.247 m^3/h
18)	Feed water rate (weight)	(Fww)	2.247/0.00100172 = 2,243 kg/h
19)	Feed water temperature	(Tw)	19°C
20)	Steam pressure	(Ps)	8 kg/cm^2G
21)	Steam enthalpy	(h")	661.93 kcal/kg
22)	Feed water enthalpy	(h')	19.031 kcal/kg
23)	Amount of theoretical combustion air	(Ao)	10.77 Nm^3/kg – fuel
24)	Amount of theoretical wet exhaust gas	(Go)	11.53 Nm^3/kg – fuel
25)	Air ratio	(m)	2.9
26)	Actual amount of wet exhaust gas	(G)	31.99 Nm^3/kg – fuel

(b) Heat input

Heat input per kilogram of fuel was calculated.

1) Heat of fuel combustion (H1)

$$H1 = 9{,}700 \text{ kcal/kg}$$

2) Sensible heat of fuel (Qs)

$$Qs = Cp \times (Tf - To) = 0.450 \times (32 - 22) = 4.50 \text{ kcal/kg}$$

3) Heat input total (Qi)

$$Qi = H1 + Qs = 9{,}700 + 4.50 = 9{,}704.50 \text{ kcal/kg}$$

(c) Heat output

Heat output per kilogram of fuel was calculated.

1) Heat possessed by steam (Qv)

$$Qv = \frac{Fww}{Efw} \times (h'' - h') = \frac{2{,}243}{216.2} \times (661.93 - 19.031)$$
$$= 6{,}669.85 \text{ kcal/kg}$$

2) Heat taken away by exhaust gas (Qg)

$$Qg = G \times Cp \times (Tf - To) = 31.99 \times 0.33 \times (185 - 22)$$
$$= 1{,}720.74 \text{ kcal/kg}$$

3) Heat radiated from boiler casing (Qr)

$$Qr = \frac{900 \times 5.7 + 1{,}800 \times 5.7 + 120 \times 50.9}{216.2} = 99.44 \text{ kcal/kg}$$

Average temperature and surface area of front plate:

105°C, 5.7 m^2

Average temperature and surface area of rear plate:

145°C, 5.7 m^2

Average temperature and surface area of shell plate:

40°C, 50.9 m^2

4) Other heat loss (Qm)

Qm = 1,214.47 kcal/kg

5) Heat output total (Qo)

Qo = Qv + Qg + Qr + Qm = 6,669.85 + 1,720.74 + 99.44 + 1,214.47 = 9,704.50 kcal/kg

(d) Heat balance table

The above are summarized as shown in Table 5–2–11.

Table 5–2–11 Boiler Heat Balance

Heat input			Heat output		
Item	kcal/ kg	%	Item	kcal/kg	%
Combustion heat of fuel	9,700.00	99.95	Heat possessed by steam	6,669.85	68.73
Sensible heat of fuel	4.50	0.05	Heat taken away by exhaust gas	1,720.74	17.73
			Heat radiated from boiler casing	99.44	1.02
			Other heat loss	1,214,47	12.51
Total	9,704.50	100.00	Total	9,704.50	100.00

(4) Problems and Remedies

(a) Effect of reducing the amount of heat taken away by exhaust gas (1)

Exhaust gas temperature is not so high (about 185°C), but a large amount of heat is taken away by exhaust gas because its flow rate is high. One of the methods of reducing the amount of heat taken away by exhaust gas is to reduce exhaust gas flow itself. This can be achieved by adjusting combustion air for fuel to the proper amount. The ratio of the actual amount of air to the amount of air theoretically required for burning fuel is called as air ratio, which can usually be obtained by measuring the amount of oxygen in exhaust gas shown in Figure 5–2–19. The present amount of oxygen in exhaust gas is 14.0% and the air ratio is about 2.9 as shown in Figure 5–2–20. If the amount of oxygen in exhaust gas is reduced to 4.5%, the air ratio will be 1.27, which will result in reducing the amount of exhaust gas by about 55%.

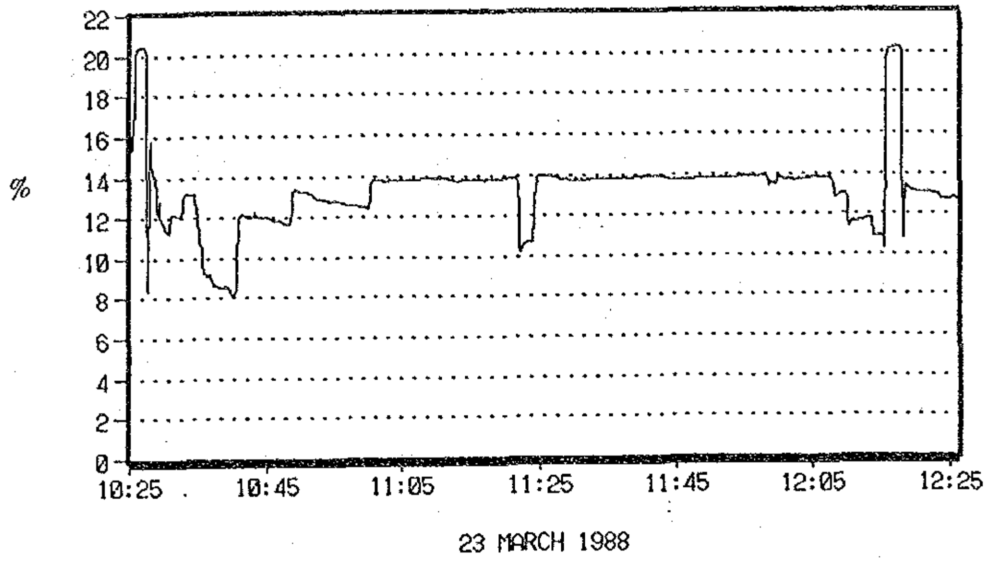


Figure 5-2-19 Amount of Oxygen in Exhaust Gas (%)

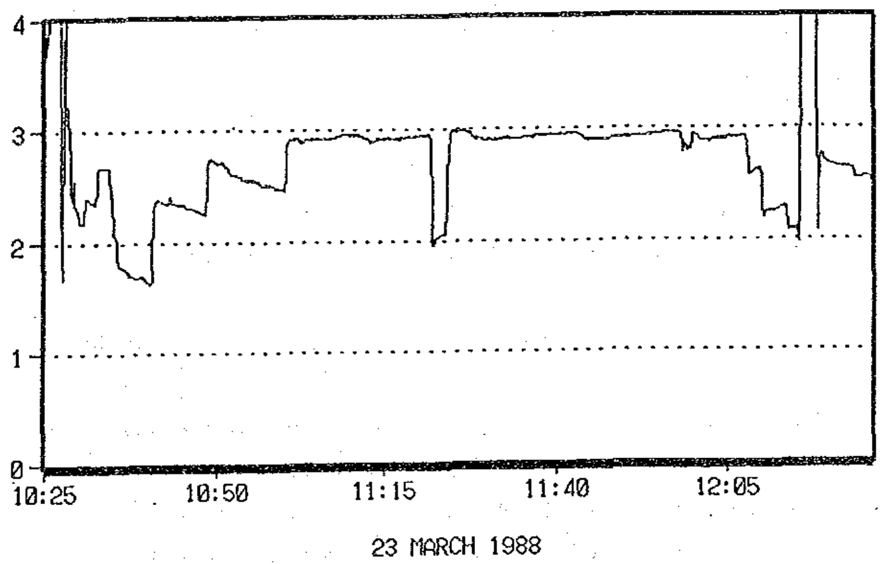


Figure 5-2-20 Air Ratio

Table 5–2–12 Reducing the Amount of Heat Taken Away by Exhaust Gas by Improving the Air Ratio

No.	Item		Unit	Present (a)	Improved (i)
1	Amount of oxygen in exhaust gas		%	14.0	4.5
2	Air ratio	m		2.90	1.27
3	Amount of theoretical combustion air	Ao	Nm^3/kg	10.77	10.77
4	Amount of theoretical exhaust gas	Go	Nm^3/kg	11.53	11.53
5	Actual amount of air	A	Nm^3/kg	31.23	13.68
6	Actual amount of exhaust gas	G	Nm^3/kg	31.99	14.44
7	Exhaust gas temperature	tg	°C	185	185
8	Heat taken away by exhaust gas	Qg	kcal/kg	1,720.74	776.73

This method of reducing the amount of air is based on the adjustment of the opening of the air intake damper for the combustion air fan. This adjustment does not require installation of additional devices so that no direct investment is needed.

The fuel saving rate (S) by this reduction in the air ratio can be calcualted by the following equation.

$$S = 1 - \frac{H1 - Qga}{H1 - Qgi} = 1 - \frac{9{,}704.5 - 1{,}720.74}{9{,}704.5 - 776.73} = 0.1057 = 10.57\%$$

where H1: Low-level heating value of fuel (kcal/kg);

Qga: Present amount of heat taken away by exhaust gas by kilogram of fuel (kcal/kg);

Qgi: Amount of heat taken away by exhaust gas after the proposed improvement (kcal/kg).

The amount of yearly saving can be calculated from the annual fuel consumption of 420 Kl x 0.932 x 1000 = 391,440 kg as follows:

391,440 x 0.1057 x 0.15 US$/kg = 6,206 US$/year

(b) Effect of reducing the amount of heat taken away by exhaust gas (2)

Another method of reducing the amount of heat taken away by exhaust gas is to lower the temperature of exhaust gas itself. This can be achieved by lowering the temperature of exhaust gas discharged from the stack, normally by recovering waste heat from exhaust gas for feed water preheating, combustion air preheating, etc.

The boiler operates at low load level so its exhaust gas temperature is 185°C. It is not necessary, therefore, to lower the exhaust gas temperature any more. Because fuel oil is used, excessive lowering of exhaust gas temperature could cause corrosion of the metal heating surfaces of the heat exchanger by the sulfur compounds in exhaust gas. However, the factory has plans to use natural gas instead of fuel oil in the future. Therefore, recovery of waste heat by feed water preheating after the use of natural gas is studied here.

The sulfur content in natural gas is not analyzed. However, if sulfur of about 50 ppm is assumed to be contained, it is recommended to use an economizer with the parallel flow of exhaust gas and feed water using the tube and fin of the heat transfer surface that are made of 18-8 stainless steel.

Feed water temperature is about 19°C. If it is preheated to 50°C by exhaust gas, exhaust gas temperature will be as follows:

$$\text{Amount of heat taken by feed water} = \frac{2.243\ (49.980 - 19.031)}{216.2}$$

= 321.08 kcal/kg

$$\text{Exhaust gas temperature after improvement} = \frac{776.73 - 321.08}{0.33 \times 14.44} + 22 = 117°C$$

Table 5–2–13 **Heat taken away by Exhaust Gas by Feed Water Preheating after Improving Air ratio**

No.	Item		Unit	Present (a)	Air ratio improvement and feed water preheasting	
					Air ratio improvement	Feed water preheating
1	Feed water temperature	tw	°C	19.0	19.0	50.0
2	Air ratio	m		2.90	1.27	1.27
3	Actual amount of exhaust gas	G	Nm^3/kg	31.99	14.44	14.44
4	Exhaust gas temperature	tg	°C	185	185	117
5	Heat taken away by exhaust gas	Qg	kcal/kg	1,072.74	776.73	455.65

Assuming that feed water will be preheated after improving the air ratio, the fuel saving rate (S) by feed water preheating can be calculated by the following equation.

$$S = 1 - \frac{Hl - Qga}{Hl - Qgi} = 1 - \frac{9{,}704.5 - 776.73}{9{,}704.5 - 455.65} = 0.0347 = 3.47\%$$

where Hl: Low-level heating value of fuel (kcal/kg);

Qga: Present amount of heat taken away by exhaust gas per kilogram of fuel (kcal/kg);

Qgi: Amount of heat taken away by exhaust gas after

The amount of yearly saving can be calculated from the annual fuel consumption of 420 x (1 – 0.1057) Kl/y X 0.932 X 1,000 = 350,025 kg/y as follows:

350,025 kg/y X 0.0347 X 0.15 U$S kg = 1,822 US$/y

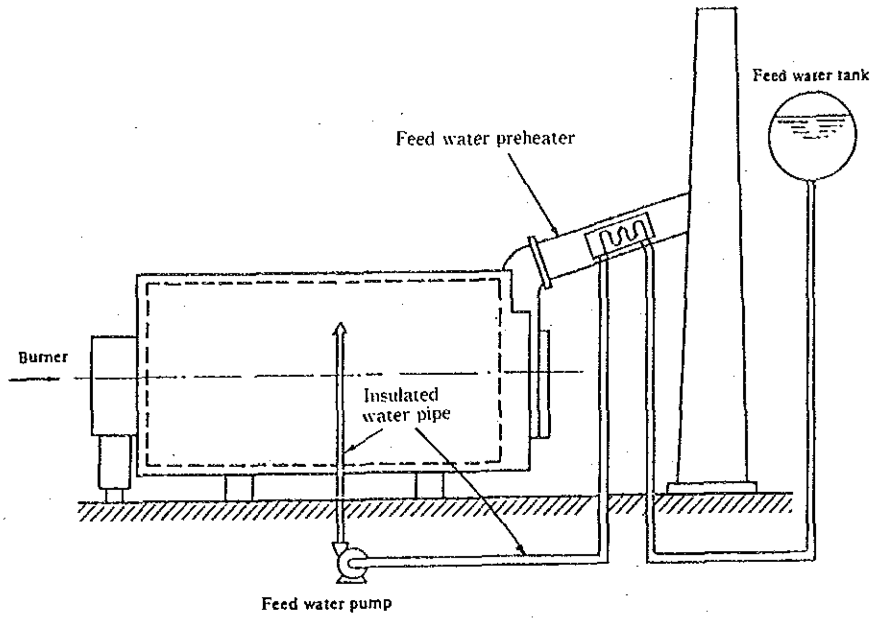


Figure 5–2–21 Position of Installing Feed Water Preheater

Install a feed water preheater in the exhaust gas flue connected to the stack as shown in Figure 5–2–21 so that preheated feed water will be supplied to the suction end of the feed water pump. The stack has sufficient draft because exhaust gas pressure is -9 mmH_2O, and there will be no problem from the increased resistance to exhaust gas flow resulting from installation of feed water preheater installation in the flue. The factory has a feed water tank on the roof, which provides sufficient head to force the water into the pump. At a water temperature of about 50°C, therefore, there will be little possibility of cavitation in the pump. Before executing this plan, however, it is necessary to talk with the pump manufacturer and confirm that there will be no cavitation. The installation of a feed water preheater and heat-insulation of the feed water piping for preheated feed water are estimated to cost about US$10,000.

(c) Reducing heat radiation from boiler casing and pipings

The casing of this boiler is well heat-insulated, so the surface temperature of the shell is approximately 40°C. However, the front plate around the burner had a surface temperature of about 105°C and the rear plate of the smoke tube a surface temperature of about 145°C, indicating somewhat inadequate heat insulation. The front and rear plates are heat-insulated thinner perhaps because of the need for opening them when cleaning the flue or smoke tube. If they are heat-insulated thicker to lower their surface temperature to 80°C, heat radiation from them will decrease as follows:

$[(900 - 500)\ kcal/(m^2 h) + (1{,}800 - 600)\ kcal/(m^2 h)] \times 5.7\ m^2 = 8{,}550\ kcal/h.$

This corresponds to an annual fuel saving as calculated below.

$$\frac{8,550}{9,700} \times 3,025 \times 0.15 \text{ US\$/kg} = 400 \text{ US\$/y}$$

If this work for thicker heat insulation is done at the time of periodic repairs, there will be little extra cost required for it.

The manhole, safety valve mount, the steam pipes to oil heater and burner are not heat-insulated. It is recommended that they be heat-insulated to prevent heat radiation loss.

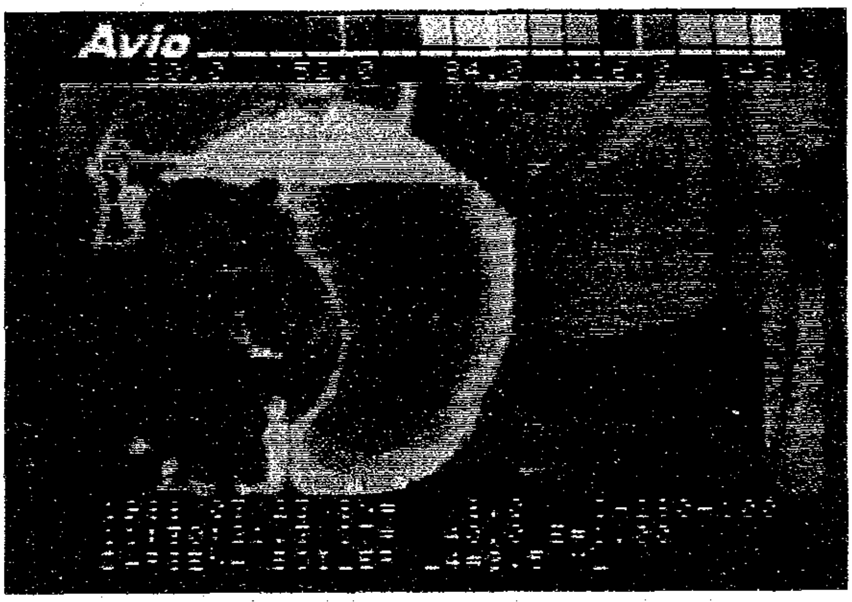


Figure 5–2–22 Thermal Picture of Boiler

(d) Feed water quality management

The quality of feed water and boiler water was as shown in Table 5–2–14.

Both the feed water and boiler water showed abnormally high electric conductivity, which means the water contains a large amount of impurities. If the electric conductivity of feed water is high, boiler water will also have high electric conductivity. Therefore, feed water quality must be thoroughly controlled.

Table 5–2–14 Quality of Feed Water and Boiler Water

Measurement	Feed water			Boiler water		
	Temperature	pH	Electric conductivity	Temperature	pH	Electric conductivity
First time	19.3°C	7.84	3.60 mS/cm	40.1°C	11.71	>20 mS/cm
Second time	21.3°C	7.87	3.93 mS/cm	46.9°C	11.57	>20 mS/cm
Reference	25°C	7~9		25°C	11 ~ 11.8	<4.5 mS/cm

This factory directly uses municipal water for the boiler and therefore does not control feed water quality except that it periodically has boiler water quality checked by an inspection company, which suggests that blowoff frequency be increased because boiler water has high salt content. If the factory tries to maintain boiler water quality by blowoff, 87% of feed water (3.93/4.5 = 0.87) must be blown off. Therefore, this method is inpracticable.

In this case, boiler water quality adjustment by blowoff will not only by ineffective but also cause energy loss. The impurities in the water will also cause corrosion to shorten boiler life. It is recommended, therefore, the feed water quality control be enforced first.

(e) Improvement of combustion

This boiler normally has a very small load compared with its capacity, and employs a small-capacity burner installed in place of the original larger one. And yet, the load is still too small for the burner capacity. If the present load is to continue for a long period of time, the burner should be replaced with a still smaller one.

It is difficult to completely atomize the heavy oil, and in this case about 1% carbon monoxide is generated as shown in Figure 5–2–23. A small amount of black smoke from the stack was observed.

This means incomplete combustion, which must be eliminated by choosing a burner of the proper capacity and enforcing the management of burner tip hole size, atomizing steam pressure, and the air ratio.

The air ratio is too high as shown in Figure 5–2–20, presumably because combustion air was increased to suppress the generation of black smoke. However if the air ratio decreases at about 12:05 as shown in Figure 5-2-20 and Figure 5–2–23 was observed that the amount of generated CO decreased. It is considered that an too mouch high air ratio lowers combustion flame temperature and thus causes CO to be generated.

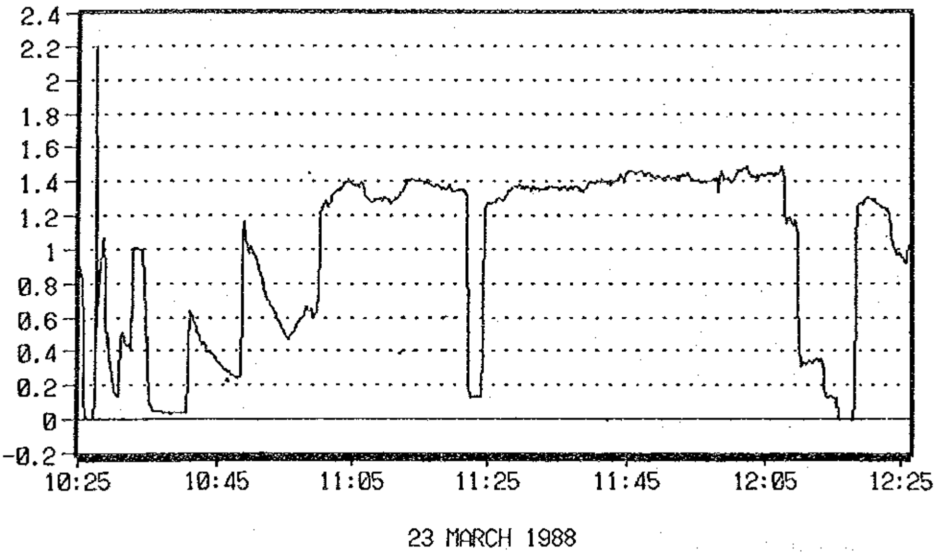


Figure 5–2–23 Amount of Carbon Monoxide in Exhaust Gas (%)

Steam pressure is controlled by a combustion ON/OFF method. So the boiler is air-purged before igniting it again to prevent explosion. If air purge is frequently used, a proportional combustion method, for example, should be used to prevent cold air from entering the boiler as much as possible.

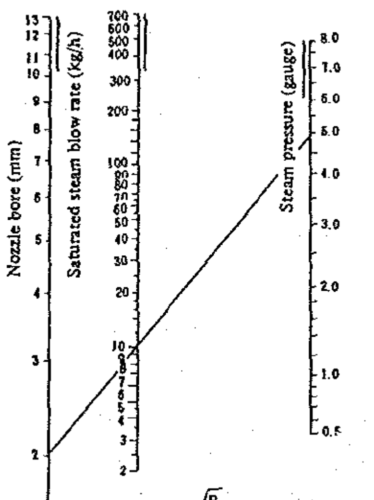
When the boiler is shut down after the day's work, a large amount of cold air is drawn into the boiler through the air intake of the combustion air fan due to the draft effect of the stack. This is equivalent to forced cooling of the boiler. If the boiler is kept hot till the next morning, the fuel required to start up the boiler can be saved. It is recommended that, after the day's work, the fan air intake be closed with a plate to prevent cold air from entering the boiler.

5.2.3.6 Steam Line

(1) Steam Leakage

Steam leakage from the steam piping is relatively small except from around the continuous cooker. However, steam leaks were found from the glands of small-diameter valves for the autoclaves and continuous can washer. Small steam leaks can, if they are left as they are, rapidly wear the leaking points due to steam blowing faster than sound velocity, making it difficult to repair the equipment in progress of steam leakage.

If a valve gland has a hole 1 mm in diameter, the amount of steam leaking from it can be calculated from Figure 5–2–24. If steam pressure is 6 kg/cm^2, coefficient of discharge is 0.8, and if steam supply time is 3,025 h/y, the amount of leaking steam will be 2.9 kg/h from Figure 5–2–24. This amounts to an annual steam loss of about 700 kg.



$$G = 1.99 \times A \times \sqrt{\frac{P}{V}} \times 3{,}600$$

G: Exhaust steam rate (kg/h) A: Nozzle area (m^2)

P: Steam pressure (absolute) (kg/m^2)

V: Steam specific volume (m^3/kg)

Note: This diagram is based on coefficient of discharge at 1, but the coefficient is in the range of 0.97 to 0.65 depending on the shape of the orifice. So multiply the steam blow rate read from the above diagram by 0.8, and consider it as the actual steam blow rate.

Figure 5–2–24 Nozzle Diameter and Steam Injection Rate

(2) Steam Trap Management

The steam trap mounted in the main steam piping to the batch cooker for discharging condensate does not serve its primary purpose, but function as a condensate generator due to radiated heat from pipe. The steam trap should be mounted at a point as close to the main piping as possible. The steam trap mounting procedure is shown in Figure 5–2–25.

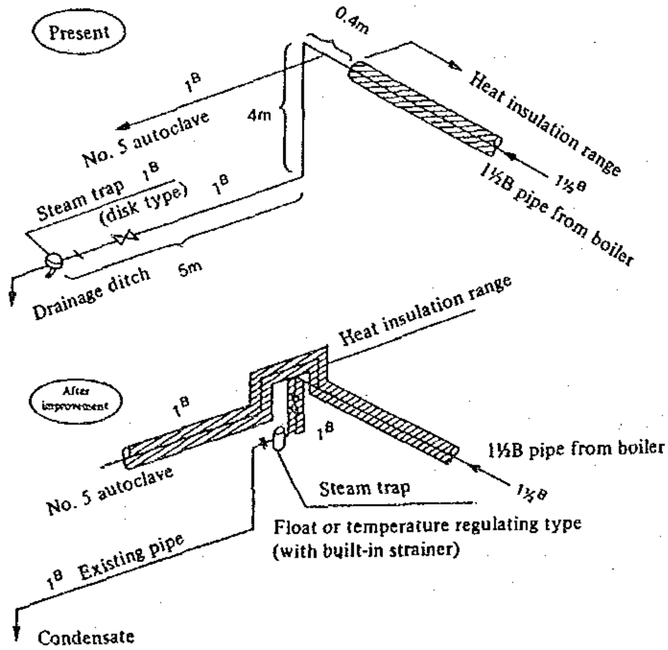


Figure 5–2–25 Improvement Procedures for Steam Trap Mounting Position

The steam trap is a disk type, which chatters at intervals of 10 to 20 seconds, causing much loss of steam.

A disk trap with 1" bore produces a steam loss of 0.02 to 0.025 kg per chattering. Thus, this trap produces an annual steam loss amounting to:

$0.025 \times 60/15 \times 60 \times 3{,}025 \times 1/1{,}000 = 18$ t/y

Steam trap life is about five years, though it varies depending on the type and manufacturer. Replace it at appropriate intervals. It is recommended that the present type steam trap be replaced with a float type or bucket type when it must be renewed.

(3) Loss of Heat by Radiation from Bare Parts of Piping

Data on the bare parts of the piping obtained by the survey is shown in Table 5–2–15.

Table 5–2–15

Process	Surface area of heat radiating part					Percentage (%)
	Pipe	Valve	Flange	Other	Total	
Production process	10.55	*	0.48		11.03	38.00
Boiler room	13.07	2.82	0.53	1.60	18.02	62.00
Total	23.62	2.82	1.01	1.60	29.05	100.00
Percentage (%)	81.30	9.70	3.50	5.50	100.0	

Notes: 1. The heat radiating areas were calculated according to the "data sheet" published by the Energy Conservation Center.

2. The 6-inch valve attached to the boiler was calculated as for use of 20 kg/cm^2 and the others as 10 kg/cm^2.

3. The valves in the production process are a small-diameter screw type, so their length is doubled and included in the piping length.

As shwon in Table 5–2–15, the bare parts of the piping in the boiler room account for a high percentage, and the heat radiating area can be reduced to one-third simply by heat-insulating them.

Table 5–2–16 shows the amount of heat radiated from bare parts and calculation results illustrating the effect of heat insulation to reduce heat radiation loss.

Table 5–2–16 Amount of Heat Radiation from Bare Pipes

Process	Total amount of heat radiation (kcal/h)			Reduction of heat radiation by heat insulation (kcal/h)
	Convective heat transfer	Radiating heat transfer	Total	
Process	13,350	12,510	25,860	22,830
Boiler room	15,480	19,860	35,340	32,230
Total	28,830	32,370	61,200	55,060

Notes: 1. Surface temperature: 10°C subtracted from saturation temperature corresponding to steam pressure

2. Emissivity was calculated referring to "Engineering of Heat Transfer" by the Japan Society of Mechanical Engineers.

3. Heat radiation amount was calculated according to the programs in "Introduction to Heat Calculation by Pocket Computer."

As shown in the above data, radiation loss accounts for a high percentage. Radiation loss varies considerably depending on the shape, color, and smoothness of the surface. If the color of the present heat insulation that covers the steam piping is changed from dark orange to silver by coating it with aluminum paint, for example, radiation loss will decrease as follows:

Present surface emissivity: $\epsilon_1 = 0.87$

Surface emissivity after color change: $\epsilon_2 = 0.50$

$\epsilon_1 - \epsilon_2/\epsilon_1 = (0.87 - 0.50)/0.87 = 0.42$

That is, radiation loss will be reduced by 42%.

Although the surface area of the bare parts of the piping is less than one half of the surface area of a cooker, the amount of heat radiated from it is larger than that of a cooker because the piping has a high emissivity due to the paint color and is always filled with steam of high temperature.

If the bare parts of the piping are heat-insulated, fuel can be saved as follows:

$$\frac{55{,}060}{9{,}700 \times 0{,}80 \times 0.69} = 10.3 \text{ kg/h}$$

$$10.3 \text{ kg/h} \times 3025 \text{ h} = 31{,}160 \text{ kg/year.}$$

Because the bare parts of the piping have a smaller surface area than the cookers and because a large amount of fuel can be saved, heat insulation will produce a high economic effect.

5.2.3.7 Water Lines

(1) Water Lines

Figure 5–2–26 shows the feed water system.

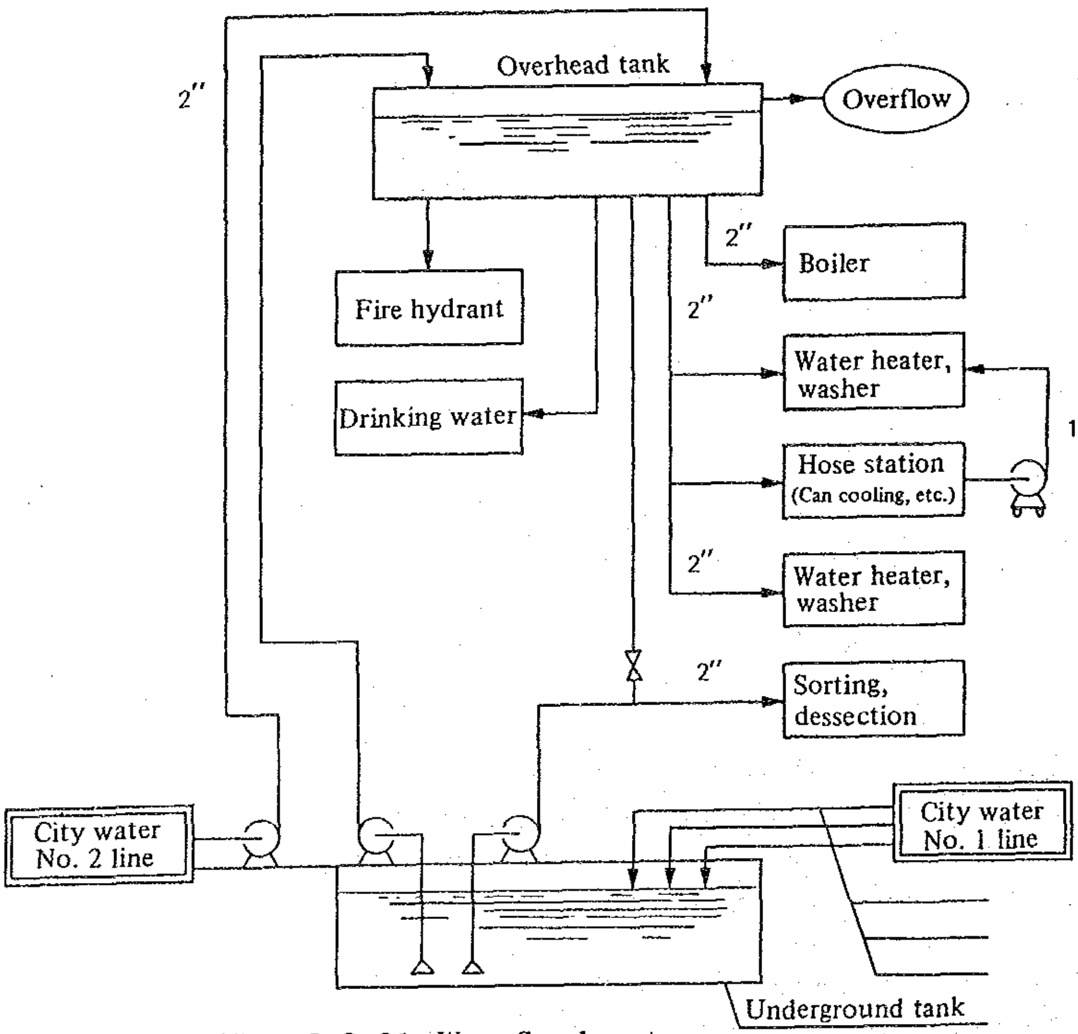


Figure 5–2–26 Water Supply system

City water is taken in through two water lines. The No. 1 line consists of two 1.5" pipes leading to the underground tank 80 m^3 in capacity. The No. 2 line is a 1.5" pipeline through which the water is pumped up into the overhead tank.

Water consumption by use estimated from the actual loads and general data is shown in Table 5–2–17.

Table 5–2–17 Water Consumption by Use (Estimate)

Use	Consumption (m^3/D)	Basis of calculation (estimation)
Boiler	10	0.7 ~ 20 T/H x 11 H/d
Drinking water	14	140 persons x 100 ℓ/d
Can cooling	*12	30 ℓ/m x 20 min x 20 batches
Cooking case washing	15	$\frac{1.0\ kW \times 102 \times 0.5}{20\ m}$ x 100 mid/d (Pressure pump)
Can washing	2	280 ℓ/H x 10H
Sorting, dissecting, washing	24	$\frac{2.5\ kW \times 102 \times 0.5}{30\ m}$ x 90 min/d (Pressure pump)
Others	3	
Total	80 m^3/D	

* Recoverable water

The factory told us that a service integrating meter would be soon installed. The amount of water supply is unknown at present, but is assumed to be about 70 to 80 tons/day from the data on water consumption by use.

The city water supply capacity is not quite sufficient so that the underground water tank is used to fill the gap.

Water is mostly distributed from the overhead water tank, but cleaning water for use in the sorting and dissecting processes is supplied under pressure by a special pump. Water for cleaning the cooked fish cases is supplied using a portable pump.

(2) Rational Use of Water

(a) Determining water consumption rate

It is necessary first to obtain actual data on water consumption in order to rationalize the use of water. Statistical management of water consumption per unit production quantity provides a clue to improvement in the use of water. An integrating flow meter is necessary to determine water consumption, but it is also possible to periodically measure water consumption from water level changes in the underground water tank and overhead water tank.

(b) Checking the underground water tank for leakage

The underground water tank is often found leaking. It is suggested that the underground water tank be checked for leakage on holidays by observing change in water level without supplying or discharging water.

(c) Regarding pipeline

The pipeline to the water inlet of the underground water tank is complex and has pipes that are unused. It is recommended to prevent waste by operational errors that the unnecessary pipes be removed and the pipeline be put in order.

(d) Reuse of water

After cans are sterilized at high temperature, they are cooled by watering from hose from above the box pallet. This cooling water is the only waste water that can be reused for cleaning purposes. The present contact cooling efficiency is low, so it is necessary first of all to save water by about 20% to 30% by changing the present method to a shower. About 12 m^3/day, or about 15% of the amount of water used, can be recovered for reuse. This will amount to an annual saving of about 3,300 m^3.

(e) Reducing cleaning water

The container cases for cooked fish in the sorting and dissecting processes are cleaned with water pressurized to 2 to 3 kg/cm^2.

If the present method is replaced by the method using a 40 kg/cm^2 high-pressure cleaning pump shown in Table 5–2–18, a higher cleaning effect can be expected, possible saving water by 30 to 50% and shortening work time by 30 to 50%.

The water saving effect can be summarized as shown in Table 5–2–19.

Table 5–2–18 Specifications of High-Pressure Cleaning Pump (for reference)

Type of pump	Portable
Shape and dimensions	Cubicle 890L x 510W x 940H
Discharge pressure	40 kg/cm^2 G
Discharge rate	23 ℓ/min
Power	3 HP

Table 5–2–19 Estimated Amount of Water Saving Based on 30% Water Saving by High-Pressure Cleaning

	Present water consumption	Estimated water saving	Annual water saving
Material fish container and case washing	15 m^3/D	4 m^3/D	1100 m^3
Sorting, dissecting, washing	24 m^3/D	7 m^3/D	1925 m^3
Total	39 m^3/D	11 m^3/D	3025 m^3

Note: The number of working days per year was assumed to be 275 days.

By taking the measures described above, the required quantity of water can be reduced by about one-third. A flowchart of an improved water system is shown in Figure 5–2–27.

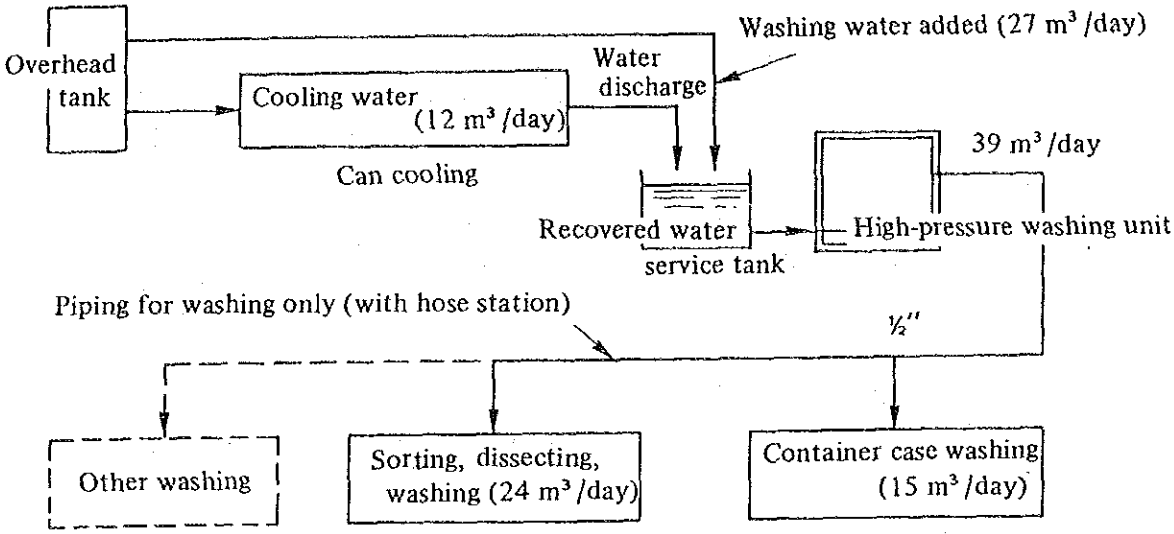


Figure 5–2–27 Flowchart of an Improved Water System (for reference)

5.2.3.8 Power Receiving and Distributing and Electrical Facilities

(1) Outline of Electrical Equipment

The factory does not have transformers, and directly receives electric power from the electric power company D.E.B.A. at 380 volts. Contract demand was 70 to 73 kW at peak time and 108 to 132 kW at non-peak time in the autumn of last year.

The incoming panel distributes electric power 14 ways to the office, computer, etc. The load is mainly small-sized motors of less than 5 kW.

The factory has a 70-kVA generator for lighting in emergencies, but it is not used so often because there are few, if any, power failures.

(2) Measurement of Power Consumption

The loads at the following points were measured for two days, on March 22 and 23, using a watt-power factor meter, AC clip-on power meter, 12-point recorder, etc.

Receiving point
Office
Factory
Branches

The results are shown in Table 5–2–20 and Figure 5–2–28.

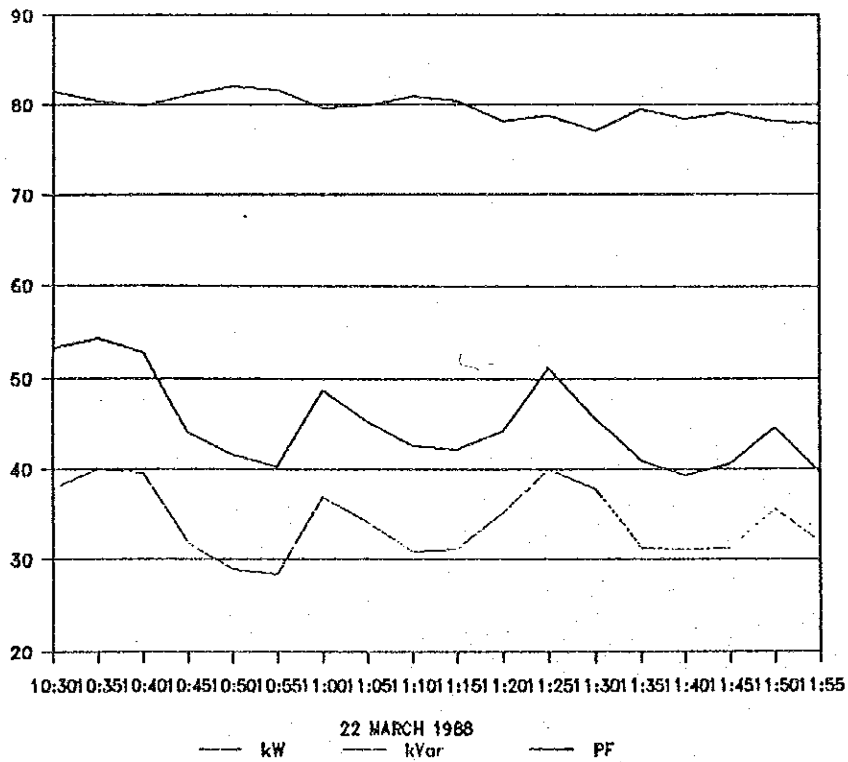


Figure 5–2–28 Power receiving

Table 5–2–20 Power Loads Measured

	kW			kVar			P.F.		
	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Receiving	45.06	54.3	39.3	34.12	40.0	28.5	79.71	82.0	77.1
Office	20.51	22.6	17.4	27.13	28.5	25.6	60.19	64.2	55.9
Factory	23.53	32.1	14.4	8.63	15.2	3.0	94.16	98.5	89.4
Computer	8.52	12.4	7.4	5.21	8.3	4.2	85.35	87.4	82.3
#5-8 Brch	3.19	4.5	1.9	15.19	17.0	13.8	20.81	31.2	11.3
#9-12Brch	12.56	22.1	9.5	17.51	23.6	14.5	57.32	66.7	54.2

(3) Problems with Use of Electric Power and Remedial Measures

(a) One line diagram and motor list

Because the factory has no one line diagram, it is difficult to have a general idea of the electric power system. If a chart such as shown in Figure 5–2–3 is prepared, it will be easier to manage electricity and help prevent accidents.

The factory has neither a motor list. If motor specifications and quantity are recorded, such data will be useful when replacing defective motors and selecting motors of the correct capacity. It will also help in drawing up energy conservation plans.

(b) Monthly report on electricity consumption

It is basically necessary for electric power management to prepare a monthly report specifying power consumption, demand fee, energy charge, power factor penalty, taxes, and payments so that the data therein can be compared with production.
tion.

(c) Power factor

According to the contract with the electric power company, if the power factor is less than 85%, a penalty must be paid. Data for the year was not available, but the fact that a total of about 860A was paid for three months in the period of November last year through January this year indicates that an improvement must be made.

As shown in Table 5–2–20, the power factor for the office was particularly low, causing the overall power factor to lower.

There was a 40 kVar condenser on the wall in the next room to the incoming and distribution panel, but it was left unconnected. This condenser should be used to improve the power factor. Specifically, connect 20 kVar of it to the load end of the main switch on the incoming panel via a switch, and the other 20 kVar to the air conditioner line for the office via a switch. This arrangement should be so made that the condenser is turned off if either of their loads stops.

If the condenser is connected, the power factor will change as calculated below. Because the voltage is 370 V in contrast to the rated voltage of 380 V, the capacitance will be:

$40 \times (370/380)^2 = 37.9$ kVar.

Even when the receiving reactive power is maximum (Table 5–2–20), the power factor will be:

$$54.3/\sqrt{54.3^2 + (40.0 - 37.9)^2} = 0.99$$

The power factor for mean power varies with the open time of the condenser, and therefore cannot be calculated, but can be improved to such an extent that no penalty needs to be paid.

If the power factor is improved, apparent power will decrease and the resistance loss of the cable upstream of the condenser will also decrease.

This was calculated about the office cable as follows:

Cable: 3-phase, 22 mm^2, 50 m, resistance 0.849 ohm/km

Measured values

Mean power: 20.5 kW Mean reactive power: 27.1 kVar

Mean apparent power: $\sqrt{(20.5^2 + 27.1^2)} = 34.0$ kVA

Current $I = 34.0 \times 1{,}000/(\sqrt{3} \times 370) = 53.1$A

Actual capacitance of condenser

Rated capacitance: 20 kVar Voltage: 370V

$20 \times (370/380)^2 = 19$ kVar

After power factor improvement

Apparent power: $\sqrt{(20.5^2 + (27.1 - 19.0)^2)} = 22.0$ kVA

Current $I' = 22.0 \times 1{,}000/(\sqrt{3} \times 370) = 34.3$A

Reduction in resistance: $3 \times 0.849 \times 0.05 \times (53.1^2 - 34.3^2) \times 3{,}025/1{,}000$

$= 633$ kWh/y

A similar calculation about the cable (3-phase, 80 mm^2, 0.234 ohm/km, 25 m) that connect the service meter to the incoming panel gives a resistance reduction of 149 kWh/year.

The expected economic effect will be a saving of (633 + 149) x U$S0.06 = U$S47/y from the reduced resistance and no payment of power factor penalty (860 A for 3 months). The proposed improvement can be accomplished at a small cost of wiring an unused device.

5.2.3.9 Summary

The following are the effects of the aforementioned improvement that can be estimated quantitatively.

Item		Possible annual amount of saving	%
Heat insulation of autoclave	Heavy oil	20,500 kg	5.2
Prevention of leakage of continuous cooker steam		2,900	0.7
Improvement of boiler air ratio		41,400	10.6
Heat recovery of boiler exhaust gas		12,100	3.1
Heat insulation of boiler		2,700	0.7
Prevention of leakage of steam pipe		800	0.2
Exchange of steam trap		1,700	0.4
Heat insulation of steam pipe		31,200	8.0
Total		113,300	29.0
Improvement of power factor	Electric power	800 kwh	0.4

5.3 Results of Survey of Textil Factory

5. Survey of the Use of Energy in Model Factories

5.3 Textile Factory Survey Results

5.3.1 Outline of the Factory

(1) Name of the factory : WELLS (Argentina) S.A.

(2) Type of business : Textiles

(3) Location of the factory : Soldado de las Malvinas (Ex Inglaterra) 231
1,650 San Marine, Prov. Buenos Aires

(4) Summary

WELLS S.A. is a medium-sized textile factory which has spinning machines with about 3,000 spindles to produce 600,000 meters of woollen textile per annum, and holds a market share of 5 to 6 percent. There are two larger woollen textile factories and five or six others of about the same size in Argentina. WELLS produces cashmere and tropical textiles, the latter mainly in winter. About 30 percent of the production is exported to Bolivia, Chile, etc.

Degreased wool and polyester are purchased, and dyed, spinned, woven, and finished into products.

Due to the recession since last year, the factory was forced to shorten the operating time from 24 hours a day to 16 hours a day, and lay off 30 percent of the work force.

As energy saving measures, WELLS already executed complete steam condensate recovery and installation of condenser to improve the power factor.

(5) Number of employees : About 300, including one engineer

(6) Survey period : October 3 to 7, 1988

(7) Survey members

Name	Assignment
Mitsuo Iguchi	Chief
Takashige Taniguchi	Textile process
Akira Koizumi	Heat management
Genzo Ema	Heat management
Teruo Nakagawa	Heat management
Toshio Iimori	Electric management

INTI members

Name	Assignment
Mr. Ernesto M. Leikis	Chief
Mr. Marcelo A. Silvosa	Unit operation and process
Mr. Jorge A. Fiora	Unit operation and process
Mr. Alberto Berset	Heat using equipment
Mr. Anibal A. Monzon	Heat using equipment, mobile unit driving
Mr. Miguel A. Bermejo	Electric power receiving and distributing equipment
Mr. Arturo D. Verghelet	Electric power receiving and distributing equipment
Mrs. Patricia M. Kohler	Heat using equipment

(8) Interviewed

Mr. Ing. Hector H. Marsan — Factory superintendent

Mr. Saverio Deugenio	Chief of Maintenance
Mr. Carlos Lening	Supervisor of Services

(9) Production

Table 5–3–1 Production

Year	1983	1984	1985	1986	1987
Cashemere (km)	545.7	660.4	567.9	377.5	338.9
Tropical (km)	588.8	578.4	476.5	477.1	272.5
Total (km)	1134.5	1238.8	1044.4	854.6	611.4

(10) Energy consumption

Table 5–3–2 Energy Consumption

Year	1983	1984	1985	1986	1987
Natural gas 1000 $\times Nm^3$	1609.8	1674.9	1051.6	1145.9	883.1
Elect. power Mwh	3708.3	3766.5	3305.5	3329.6	2186.1
Energy/product					
Natural gas Nm^3/m	1.42	1.35	1.01	1.34	1.44
Power kwh/m	3.27	3.04	3.16	3.90	3.58

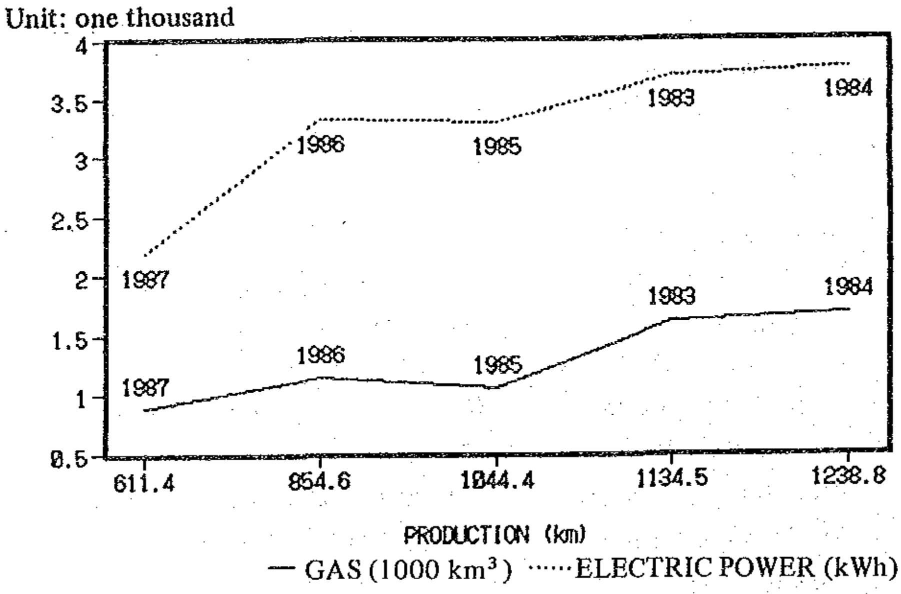


Figure 5–3–1 Production and Energy Consumption

Unit: one thousand

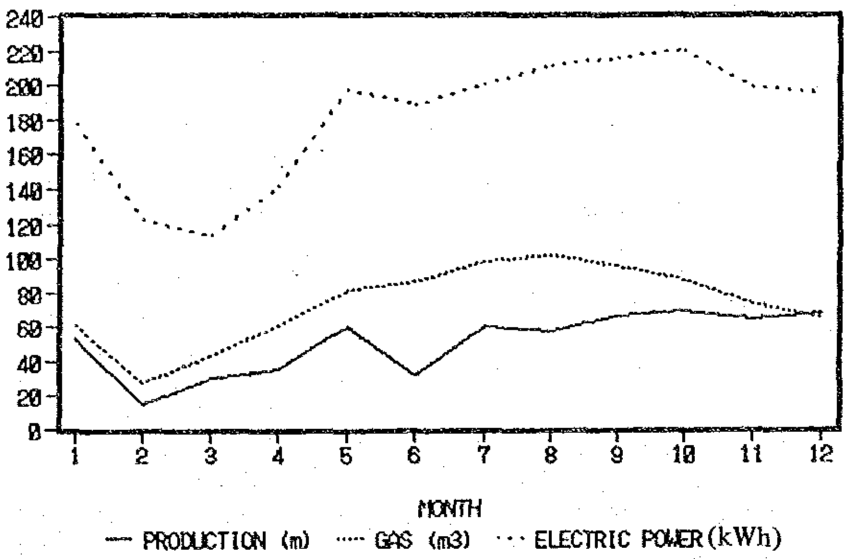
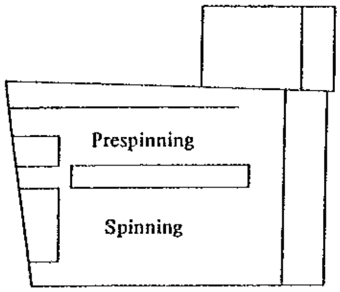


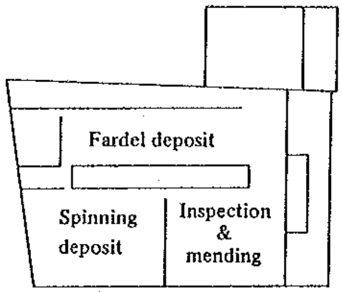
Figure 5–3–2 Monthly Production and Energy Consumption in 1987

Electric Power unit price	0.06 U$S/kWh
Natural Gas unit price	0.08 U$S/Nm³

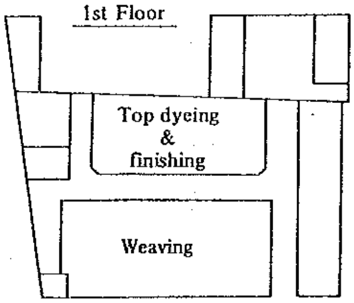
(11) Factory layout



1st Floor

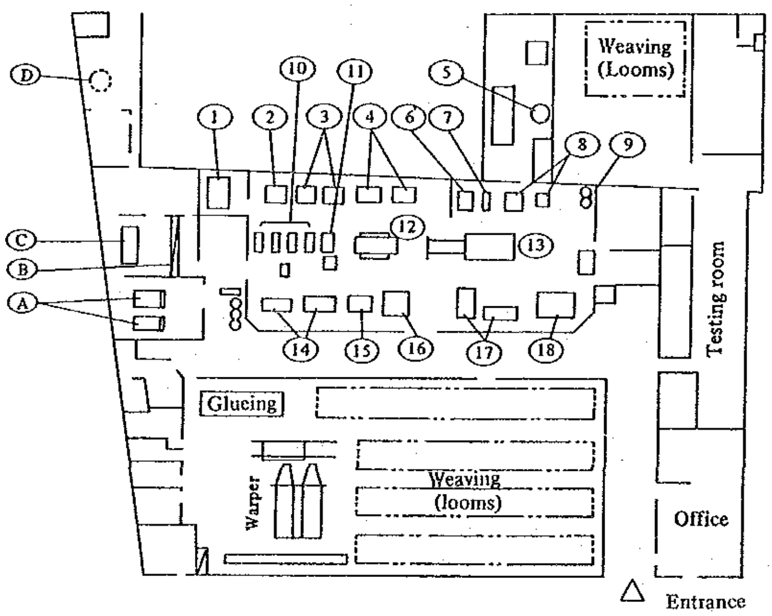


2nd Floor



Ground floor

No.	Machine name	No.	Machine name
A	Steam boiler	8	Open washing
B	Electric Distribution B/D	9	High press autoclave
C	Air compressor	10	Wet sley
D	Water reservoir	11	Dry sley
		12	Poting
1	Singeing	13	Dryer
2	Poting	14	Shearing
3	Code washing	15	Iron press
4	Open width washing	16	Open decatizer
5	Hydroextractor	17	Automatic decatizer
6	Top dyeing (20 sps)	18	Carbonizer
7	Top dyeing (10 sps)		



Ground floor (Ditail)

Figure 5–3–3 Factory Layout

(12) Production process

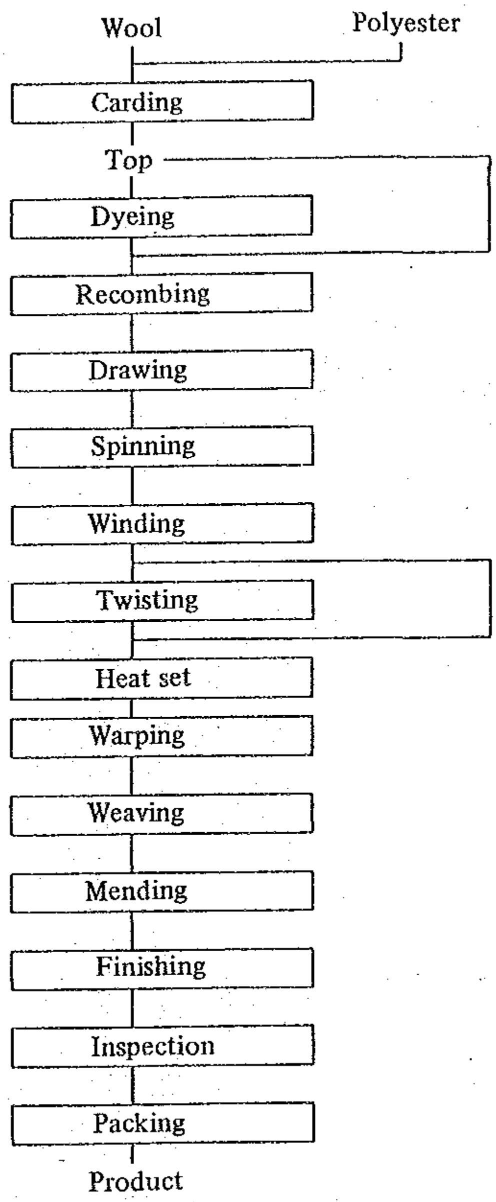


Figure 5–3–4 Production Process

(13) One line diagram

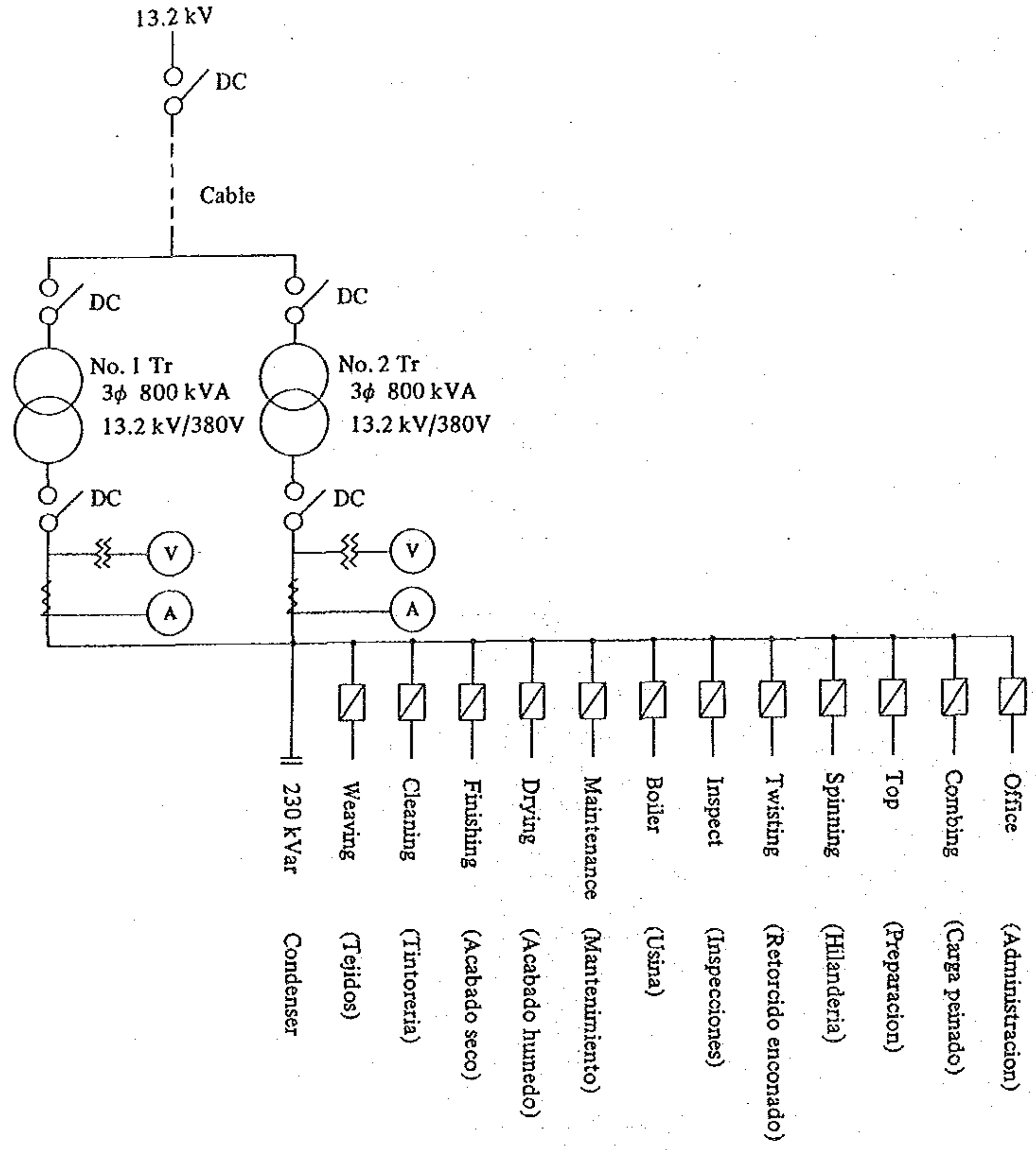


Figure 5–3–5 One Line Diagram

(14) Outline of main equipment

Table 5–3–3 Major Energy Consuming Equipment

Name	Number	Specification
Boiler	2	3.2 t/h 7 kg/cm^2 2 pass 4.5 t/h 10 kg/cm^2 3 pass Flue and smoke tube type
Dyeing vat	7	Open vat (2) Pressure vessel (2) Wince (2)
Dryer	1	Hot air circulation
Spinning machine	7 12 2	Ring Frame (432 spindles/F) LEPCO Auto winder
Weaving machine	68	Shuttle, Rapier
Air compressor	1	50 Hp

(15) Factory operation time

16 h/d x 312 d/y = 4,992 h/y

5.3.2 Energy Management

(1) Energy conservation target

The factory management has interest in energy conservation, gives instructions for effort toward maximum saving of energy. The board posted at the entrance to the factory carried a message of the factory superintendent that the employees are asked to cooperate in turning off the unnecessary lights and preventing idle operation of machinery to save electric power as requested by the government. The engineer in charge of energy was preparing an equipment improvement plan, but a concrete energy conservation target in a specific numeric value had not yet been set up, and no systematic energy conservation activities had not been started as yet.

The possible reasons are that WELLS has already enforced energy conservation measures for condensate recovery and improvement of the power factor, considers its operation as regular that offers little to reflect the workers' views on, and finds it difficult to make capital investments in the current climate of recession.

A textile factory consumes large amounts of hot water and steam in the dyeing process, and has a large number of motor-driven machines, including spinning machines and weaving machines. WELLS spends about U$S200,000 per annum for energy. Today, when the operating ratio is down and the working force reduced, energy conservation will be an effective means of cost reduction. It is recommended, therefore, that energy conservation be systematically promoted with a specific target set.

As shown in Figures 5–3–1 and 5–3–2, energy consumption tends to increase in the years or months in which tropical is produced more than cashmere. This may be due in part to the climate, but similar trends can also be seen in the scatter diagram showing the data for each month of 1987. Therefore, it would be better to set a separate energy saving target for cashmere and tropical to ensure accurate management.

(2) Determining energy consumption

To improve productivity and quality and reduce energy consumption, it is necessary to daily record their data and operating conditions, and thus obtain information on the exact conditions of the factory. If changes are noted in these values, or if a difference occurs between actual data and planned or design values, immediately check for the cause and take a remedial step to improve the situation.

WELLS checks the gas and electricity bills once a month to determine their consumption, but does not check daily consumption of gas and electricity. The factory checks the bills whether the figures are correct or not, but the meter check date varies from month to month so that it is not possible to directly relate energy consumption to production. Under such circumstances, anything abnormal in energy consumption can be determined only at a later date. It is impossible to check for its cause or take an appropriate step while observing the subsequent trends. WELLS is planning to record energy date at shorter intervals, and it is hoped that the factory management will do so as soon as possible. The simple action of recording actual energy consumption and telling it to the operators can automatically stimulate a saving mind.

This factory consumes steam as thermal energy, so it is recommended to install an integrating meter for feed water on the boiler feed water line, and record its readings every hour. This enables to determine steam consumption trends. Compare the recorded readings with machine operation, shutdown, and production, and find causes of energy loss. If daily totals of water supply and fuel consumption are recorded in a boiler ledger, and are compared, boiler efficiency and its variations can be assumed.

It is strongly recommended that a boiler ledger be prepared and kept because it will become possible to determine cleaning intervals by assuming the extent of contamination of the heating surfaces from changes in exhaust gas temperature, or check changes in recovery of drains from feed water temperatures over a long range of time. This will be effective for not only saving energy but also equipment maintenance.

As regards electricity, daily check the supply meter and record its readings.

(3) Education of engineer and training of employees in general

Even though the employees are interested in making improvements, they cannot do so if they do not know how. It is important, therefore, to educate the employees by training courses, etc.

The engineer of this factory has no opportunity to attend engineer training courses or exchange information with the engineers of other textile factories. One idea is to use the INTI located nearby to seek advice.

It is important for the factory management to tell the facts about energy consumption to the employees, call their attention to observation of the work standards and the problems close to themselves, such as prevention of idle machine operation and water conservation, and thus arouse their awareness of the importance of energy conservation.

(4) Equipment management

The pipelines of this factory are in order, and the condensate is completely recovered. The drawings are also well filed. However, about a half of the steam traps and some of the thermometers, flow meters, and temperature automatic controllers were found faulty of operation, missing the heat insulation, and leaking steam. It is necessary to assign serial numbers to all the valves and traps, record data on defects and repairs in a management ledger, and perform periodic maintenance on them.

5.3.3 Problems with Use of Energy and Remedial Measures

5.3.3.1 Normal-Pressure Dyeing Vat (Top dyeing)

(1) Heat balance

Wool and polyester fibers are top-dyed using a high-pressure dyeing machine and normal-pressure dyeing machine.

Top dyeing with the normal-pressure dyeing machine depends very largely upon the experience of skilled workers.

The heat balance of the top dyeing vat for 20 rolls was checked to identify problems about the equipment and operation.

(A) Range of heat balance calculation

The range of heat balance calculation is from filling the top dyeing vat with water to the end of dyeing.

After dyeing, measured data till the end of all processes was used in calculating steam consumption rate, etc.

(B) Items of heat balance calculation

(a) Heat inputs

i) Heat content of steam

ii) Electric power for dyeing liquid circulation pump

(b) Heat outputs

i) Effective heat output

- o Heat quantity consumed to heat polyester top
- o Heat quantity consumed to heat water and dyestuff
- o Heat quantity consumed to heat dyeing vat itself and its internal accessory parts
- o Heat quantity consumed to heat the circulation pump, changeover valves, pipe, etc. that are connected to the dyeing vat.
- o Heat quantity taken out by condensate

ii) Heat loss

- o Quantity of heat dissipated from the vat itself
- o Quantity of heat dissipated from the circulation pump, etc.
- o Evaporation heat loss from liquid surface in the vat, etc.

Heat balance calculation was made on the basis of room temperature as the reference.

(C) The basic data required for heat balance calculation is shown in Tables 5–3–4 and 5–3–5.

Table 5–3–4 Data for Calculation of Heat Quantity

Item		Material	Specific gravity	Weight calculation	kg	Specific heat (kcal/kg °C)
Top		Polyester	–	6.8 kg x 20 roll	136	0.239
	Heated liquid	Water (Vat)	1.00	3.95 m x 0.47 mH	1,856	1,000
		Water (Pump)	1.00		120	1,000
		Dyestuff, etc.	1.00		60	1,000
Subtotal					2,036	–
	Tank	Stainless	7.58	10.4 m x 2 mm	158	0.117
	Reinforcing material	Stainless	7.58	0.6 m x 3 mm	13	0.117
	Heater tube	Stainless	7.58	1.07 kg/m x 128.3 m	32	0.117
	Cage	Stainless	7.58	11.07 kg/pc x 20 pcs	226	0.117
	Jet tube	Stainless	7.58		51	0.117
Subtotal					480	–
	Circulation pump	Stainless	7.58		88	0.117
	Changeover valve	Stainless	7.58		80	0.117
	Pipe	Stainless	7.58		55	0.117
Subtotal					223	–

Note: 50 percent of the total weight of vat reinforcing material was covered in the calculation.

Table 5–3–5 Table of Calculation of Radiating Area

Item			Radiating area	m^2
		Sidewall surface	$(1.44\ m^2 \times 2) + (1.78\ m^2 \times 2)$	6.44
		Reinforcing material		1.20
	Subtotal			7.64
	Liquid surface		1.79 m x 2.21 m	3.95
	Bottom		1.79 m x 2.21 m	3.95
	Circulation pump			0.87
	Changeover valve			0.86
	Pipes		Pipe $1.39\ m^2$, Flange $0.36\ m^2$	1.75
Subtotal				3.48
Steam heater tube			21.7 mmϕ x 28.3 m	1.92

Note: 50 percent of the total surface area of the vat reinforcing materials was covered in the calculation.

(D) The measuring points used for heat balance calculation are shown in Figure 5–3–6.

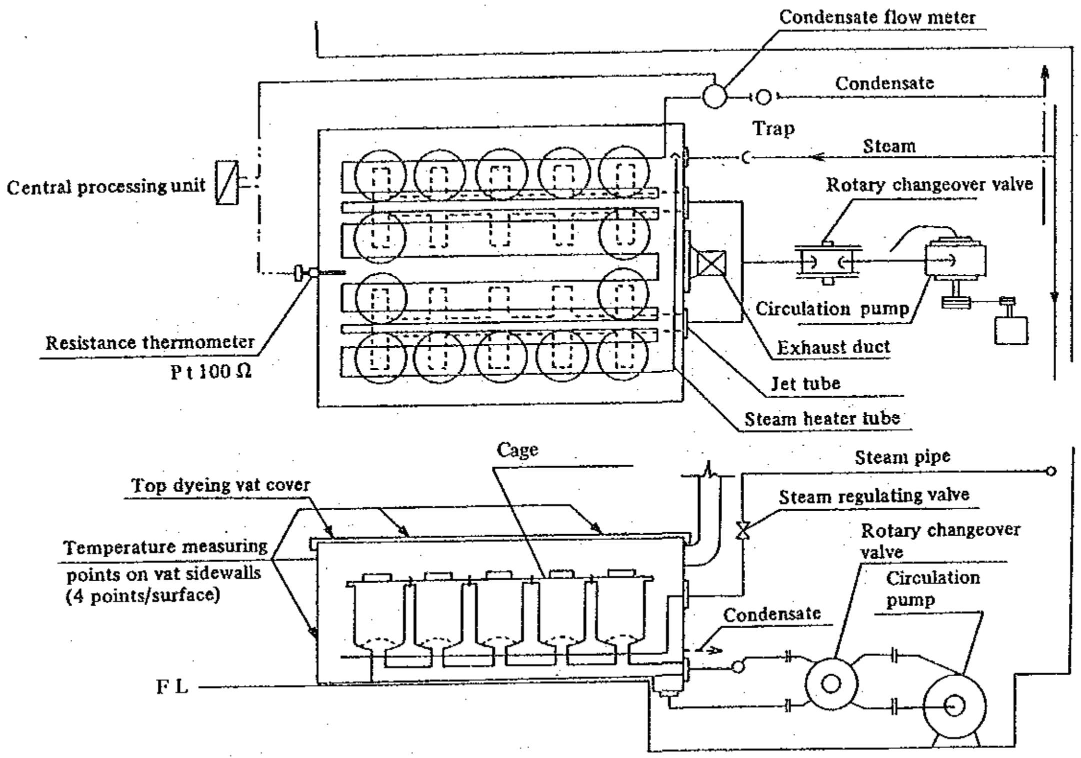


Figure 5–3–6 Vat

(E) Measurement results

(a) Data on polyester top temperature variations and steam consumption are shown in Figure 5-3-7.

These data were obtained for one cycle from 0.15 PM to 3.30 PM, October 5, 1988.

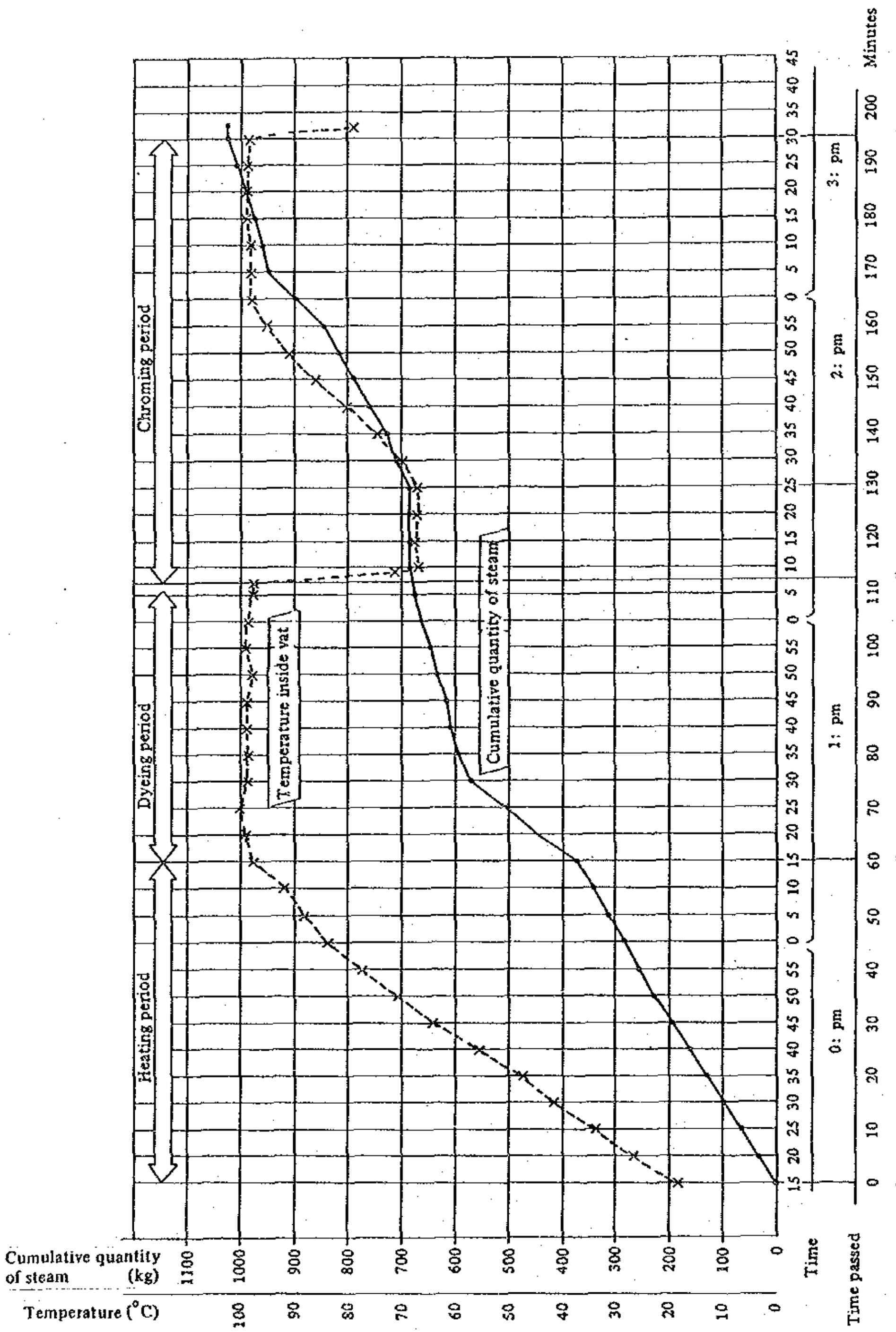


Figure 5-3-7 Heating Process of Top Dyeing (20-roll open Vat)

(b) The average temperatures of the heat radiating surfaccs used in heat radiation calculation and the results of the calculation are shown in Table 5–3–6.

Table 5–3–6 Calculation Results of Dyeing Vat Average Surface Temperature and Quantity of Heat Radiation

Item	Time	Heating period					Dyeing period
		0°.15'~0°.30' (15')	0°.30'~0°.45' (15')	0°.45'~1°.00' (15')	1°.00'~1°.15' (15')	0°.15'~1°.15' (60')	1°.15'~2°.07' (52')
Ambient temperature	to	26.7	27.7	28.5	29.0	Average 28.1	30.0
Dyeing vat outer wall surface (7.64 m²)	Surface temperature	28.7	50.6	69.1	86.9		90.4
	q	9	151	306	480		508
	Q	16	288	585	917	1,806	3,363
Vat lid (3.95 m²)	Surface temperature	26.8	36.4	55.6	72.5		77.6
	q	0	49	193	349		392
	Q	0	48	191	344	583	1,341
Pump and changeover valve (3.48 m²)	Surface temperature	29.7	49.3	73.7	88.7		915
	q	14	140	350	499		520
	Q	12	122	305	434	873	1,568
Total heat radiation	ΣQ	28	458	1,081	1,695	3,262	6,272
						Total	9,534 kcal

Note: Legend

q (kcal/m²h)

Q (Kcal) = q X Radiation area (m²) X Radiation time (h)

As shown in Figure 5–3–6, surface temperatures were measured at four points on each radiating surface except for the circulation pump.

Because it was necessary to regard heat radiation during the heating period as unsteady heat transfer, the heating period was divided into four parts, and the average temperature of every 15 minutes was shown for each of the four divided parts of the heating period.

Calculations were made with emissivity as 0.5 and on the assumption that there was no wind.

The bottom of the dyeing vat which directly contacts the floor was regarded as an infinite heat resistance, disregarding heat loss.

(c) Steam consumption from the heating of the dyeing liquid to the end of one cycle is shown in Table 5–3–7.

Table 5–3–7 Steam Consumption Per Cycle of Dyeing Operation

Item		Heating				Dyeing	Chroming	
	Time	0°15'~0°30'	0°30'~0°45'	0°45'~1°00'	1°00'~1°15'	1°15'~2°07'	2°07'~2°25'	2°25'~3°32'
		(15')	(15')	(15')	(15')	(52')	(18')	(62')
Cumulative quantity	kg	93	186	278	370	685	685	1,026
Consumption per section	kg	93	93	92	92	315	0	341
Consumption per unit time	kg/min	6.20	6.20	6.13	6.13	6.06	0	5.50
	kg/h	372	372	368	368	362	0	352
Steam pressure	kg/cm^2	4.8	4.8	4.8	4.8	4.8	–	4.8
Condensate temperature	°C	111	115	121	125	115	–	110

Note: Saturated steam pressure corresponding to pipe surface temperature was used.

(F) Heat input/output calculation

Heat input

(a) Heating period (60 minutes)

i) Heat taken in by steam

370 x (657.6 – 26.7) = 233,433 kcal

ii) Water supplied to the dyeing vat (Initial water temperature: 19°C)

2,036 x (19 – 26.7) = Δ 15,677 kcal

iii) Power consumption of dyeing liquid circulation pump

860 x 1.9 x 0.8 = 1,307 kcal

iv) Total heat input : 219,063 kcal

(b) Dyeing period (52 minutes)

i) Heat taken in by steam

315 x (657.6 – 30.0) = 197,694 kcal

ii) Power consumption of dyeing liquid circulation pump

860 x 1.9 x 0.8 x (52/60) = 1,133 kcal

iii) Total heat input : 198,827 kcal

Heat output

(a) Heating period

- Effective heat output is shown in Table 5–3–8.
- The quantity of heat taken out by condensate is shown in Table 5–3–9.

Table 5–3–8 Effective Heat Output

	Specific heat	Weight	Reference temperature	Final temperature	Quantity of heat	Percentage
	(kcal/kg °C)	(kg)	(°C)	(°C)	(kcal)	(%)
Polyester top	0.239	136	26.7	98	2,317	1.5
Water and dyestuff	1	2,036	26.7	98	145,167	94.7
Vat itself and accessories	0.117	480	26.7	98	4,004	2.6
Circulation pump and pipe	0.117	223	26.7	98	1,860	1.2
Total	–	–	–	–	153,348	100 %

Table 5–3–9 Heat Taken Out by Condensate

	0.15～0.30	0.30～0.45	0.45～1.00	1.00～1.15	Total	Average
Quantity of condensate (kg)	93	93	92	92	37.0	–
Condensate temperature (°C)	111	115	121	125	–	118
Heat taken out (kcal)	370 (118 – 26.7) = 33,781 kcal					

The temperature is kept constant during the dyeing period, and heat output includes only the heat taken out by condensate, heat radiated from the wall surfaces etc., and heat loss by evaporation from the liquid surface.

o Heat taken out by condensate

The amount of radiated heat is shown in Table 5–3–6. Other heat outputs are treated as the vaporization heat loss.

(G) Table of heat balance

o Heat balance for the heating period is shown in Table 5–3–10.

o Heat balance for the dyeing period is shown in Table 5–3–11.

Steam consumption per kilogram of polyester top is 1,026/136 = 7.54 kg/kg (Top) as shown in Tables 5–3–4 and 5–3–7.

(H) Evaluation of the tables of heat balance

(a) The largest loss of heat output is the vaporization heat loss from the liquid surface of the dyeing vat.

During the dyeing period, 84 percent of the heat is discharged outdoors.

(b) The heat loss by radiation from the vat side wall is small relative to the overall heat loss.

(c) Of the effective heat output during the heating period, the heat required for heating the water and dyestuff accounts for a large percentage (66 percent) of the total quantity of heat.

Excessive supply of water to the dyeing vat will result in heat loss.

(d) The steam consumption of 7.54 kg/kg is higher than the standard steam consumption of 4 kg/kg in Japan.

Table 5–3–10 Table of Heat Balance for Heating Period

Heat input	kcal	%
Heat taken in by steam	233,433	106.6
Water supplied to dyeing vat	△15,677	△ 7.2
Power consumption of circulation pump	1,307	0.6
Total	219,063	100.0

Heat output		kcal	%
Effective heat	Polyester top	2,317	1.1
	Water and dyestuff	145,167	66.3
	Vat itself and accessories	4,004	1.8
	Circulation pump and pipe	1,860	0.8
	(Subtotal)	(153,348)	(70.0)
Radiation Loss	Outer wall surface of dyeing vat	1,806	0.8
	Lid of dyeing vat	583	0.3
	Circulation pump and pipe	873	0.4
	(Subtotal)	(3,262)	(1.5)
Heat taken out by condensate		33,781	15.4
Heat of evaporation vapar and others		28,672	13.1
Total		219,063	100.0

Table 5–3–11 Table of Heat Balance for Dyeing Period

Heat input	kcal	%
Heat taken in by steam	197,694	99.4
Power consumption of circulation pump	1,133	0.6
Total	198,827	100.0

Heat output		kcal	%
Radiation Loss	Outer wall surface of dyeing vat	3,363	1.7
	Lid of dyeing vat	1,341	0.7
	Circulation pump and pipe	1,568	0.8
	(Subtotal)	(6,272)	(3.2)
Heat taken out by condensate		25,200	12.7
Evaporation from liquid surface		167,355	84.2
Total		198,827	100.0

(2) Proper bath temperature and its control method

(Step 1 to reduce vaporization heat loss from the liquid surface of the dyeing vat)

(A) Present problems

The bath temperature of the normal-pressure dyeing machine is generally 96°C – 98°C, which varies depending on the characteristics of the dyestuff.

At WELLS, however, the steam rate is controlled to a rather high target of 99°C using a dial remote thermometer.

A difference of 1°C around this temperature level causes a large difference in vaporization heat loss. As shown in Figure 5–3–8, an increase of water temperature from 98°C to 99°C doubles vaporization heat loss.

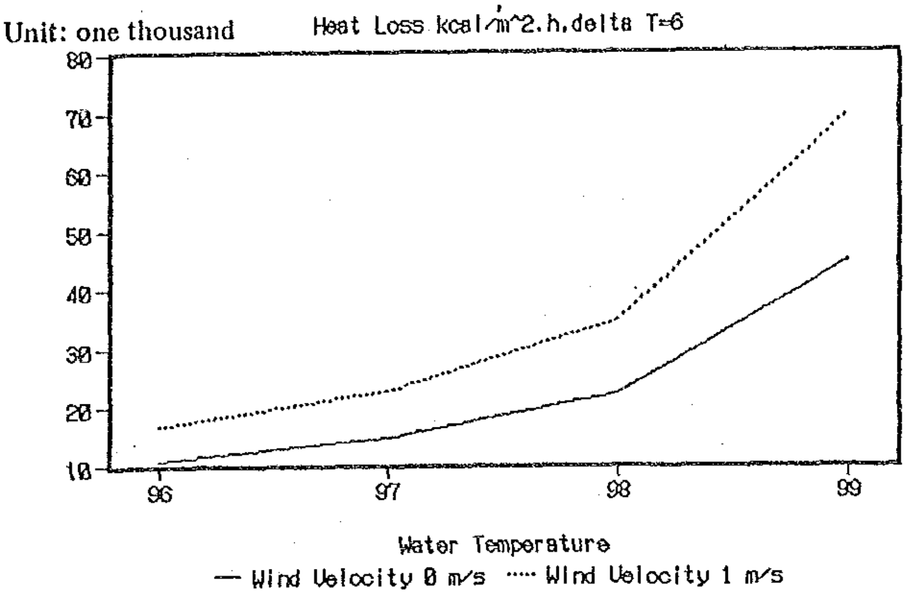


Figure 5–3–8 Vaporization Heat Loss

Therefore, it is necessary to examine the kind of dyestuff, dyeing time, etc. and try to lower the temperature as much possible.

(B) Study of water temperature automatic control system

It is proposed that a temperature regulator such as shown in Figure 5–3–9 be installed for the purpose of lowering the present water temperature for the dyeing period from 99°C to 97°C or 98°C.

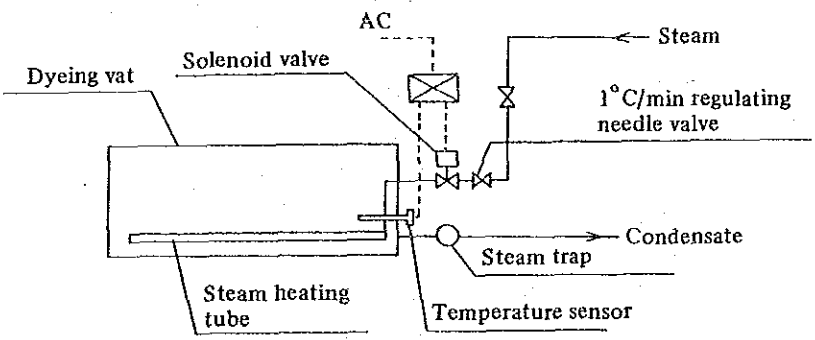


Figure 5–3–9 Automatic Temperature Regulator

The proposed temperature regulator consists of a control unit which maintains the water temperature constant and a needle valve which regulates heating speed.

If it is difficult to install an automatic temperature regulator, it is recommended that at least a needle valve be installed.

It is also recommended that a digital thermometer with an accuracy of 0.1°C be used.

(3) Exhaust rate control

(Step 2 to reduce vaporization heat loss from the liquid surface of the dyeing vat)

(A) Present problems

(a) If the duct has an excessive ventilation capacity, air velocity over the liquid surface of the dyeing vat will increase, and causes increased vaporization heat loss as shown in Figure 5–3–8.

When the vat is closed, it lowers the pressure inside the dyeing vat, thus causing boiling temperature to lower.

(b) Calculation of the ventilation capacity of duct

The differential pressure generated in the duct can be calculated as follows:

P : $H(\gamma_a - \gamma_s)$ mmAq

H : Duct height (5 m)

γ_a : Specific gravity of incoming air 1.164 kg/m^3 (provided that outside temperature is 30°C)

γ_s : Specific gravity of exhaust vapor 0.559 kg/m^3 (provided that steam is 100°C at atmospheric pressure)

P : $5(1.164 - 0.559) = 3.0$ mmAq.

If effective ventilation capacity is 1.5 mmAq, subtracting ventilation resistance from the ventilation capacity of 3 mmAq, draft rising velocity will be as expressed below.

$$V = \sqrt{2g \times P/\gamma_s} \text{ m/s}$$
$$= \sqrt{2 \times 9.8 \times 1.5/0.559}$$
$$= 7.3 \text{ m/s}$$

Therefore, the exhaust capacity for 100°C steam can be calculated as follows:

$$G = 3{,}600 \times V \times A \times \gamma_s$$
$$= 3{,}600 \times 7.3 \times 0.25^2 \times 0.559$$
$$= 918 \text{ kg/h}$$

Therefore, the present duct 250 mm square has an excessive steam exhaust capacity of about 1 ton/h.

(B) Improvement plan

(a) Step to prevent cold air from entering

The cover for the dyeing vat was found distorted nearly all over, and even have a clearance 800 mm long and up to 33 mm wide.

It is necessary first of all to completely repair the dyeing vat cover to ensure air-tightness.

(b) Installation of exhaust control damper

Install a control damper such as shown in Figure 5–3–10 to control inner pressure in such a way that, when the cover is closed on the dyeing vat, generated steam will slightly flow out through the clearance.

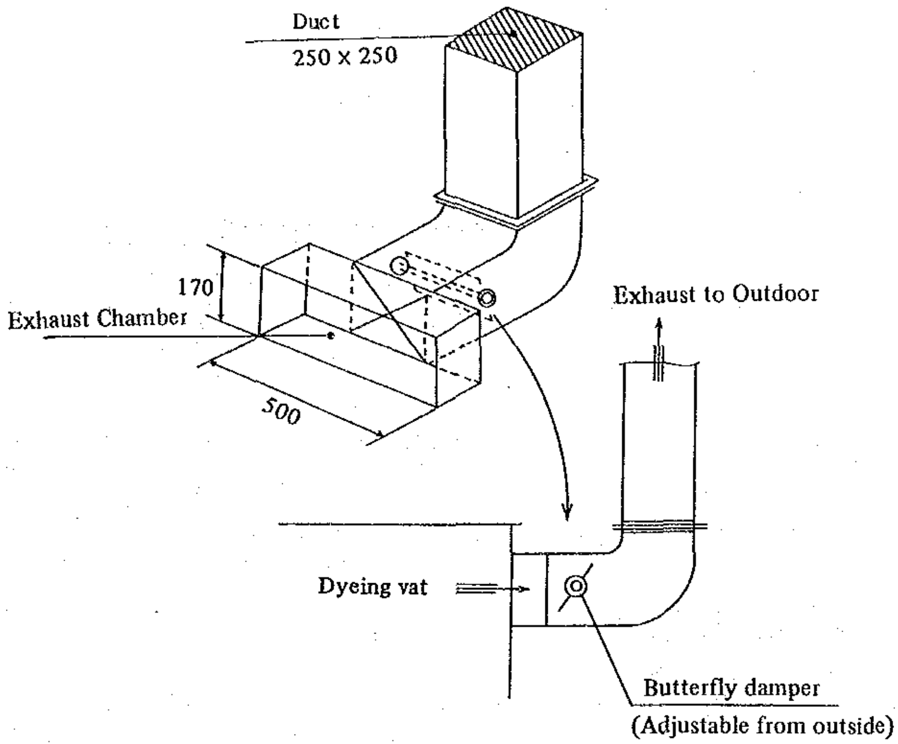


Figure 5–3–10 Installation of Damper for Duct

(c) Effect of improvement

It is assumed that the proposed damper will be installed in the duct, that the dyeing vat cover will be repaired to prevent excessive inflow of air, and that the water temperature for the dyeing period will be lowered from 99°C to 97°C.

Since the heat output as others for the dyeing period, is 167,355 kcal/52′ as shown in Table 5–3–11, it will be 48,900 kcal/(m² h), which is approximately equivalent to the value indicated by the no-wind line at 99°C shown in Figure 5–3–8. If the temperature is lowered to 97°C, heat taken away with vapor will be reduced to about 1/3.

Reduction of heat loss : 167,355 x 2/3 = 111,570 kcal/cycle.

Suppose 60 percent of the annual top production of 185 tons is by normal-pressure dyeing and that the yield is 90 percent. If processing quantity per cycle is 136 kg,

No. of cycles per year : 907

Reduction of heat loss : 111,570 x 907 = 101.2×10^6 kcal/y

Latent heat of vaporization : 499.6 kcal/kg

Saving of steam : $101.2 \times 10^6 / 499.6$ = 202.6 tons/year.

Since the amount of natural gas required for generating 1 ton of steam from the heat balance of boiler is

$$\frac{162.00}{2.199} = 73.7 \text{ Nm}^3/\text{t}$$

Natural gas can be saved

202.6 x 73.7 = 14,932 Nm^3/y

(4) Heat insulation of outer walls of dyeing vat

(A) Present problems

(a) The normal-pressure dyeing vat is not heat-insulated. Heat radiation per cycle from this vat is as shown in Table 5–3–12.

Table 5–3–12 Heat Radiation During Dyeing Cycle (kcal)

	Heating	Dyeing	Chroming	Total	Percentage
	0°.15'~ 1°.15'	1°.15'~ 2°.07'	2°.07'~ 3°.22'	0°.15'~ 3°.32'	(%)
Dyeing vat outer wall surface	1,806	3,363	4,923	10,092	54.0
Dyeing vat cover	583	1,341	1,886	3,810	20.4
Circulation pump, pipe	873	1,568	2,331	4,772	25.6
Total	3,262	6,272	9,140	18,674	100.0

Note: The surface temperature was not measured during the chroming period so it was assumed to be the same as that from the latter half of heating till the end of dyeing.

(b) The dyeing vat cover is removed too long for internal check. If it is absolutely necessary, make an inspection hole on the cover and try to decrease the time of an open vat to be as short as possible.

(B) Insulation method

As shown in the Table 5–3–12, heat radiation from the dyeing vat outer walls account for 54 percent of the total amount of heat radiation. Therefore, the outer walls must be heat-insulated.

Heat insulation conditions are as follows:

- o Not to lose the effectiveness of heat insulation when exposed to water.
- o Not to corrode the insulated surfaces due to the heat insulation material.
- o To have sufficient mechanical strength.
- o To be low in insulation cost.

To satisfy the above conditions, a jacket type air insulation system consisting of stainless steel boards 1 mm thick around the dyeing vat outer walls as shown in Figure 5–3–11, and airtight, is recommended.

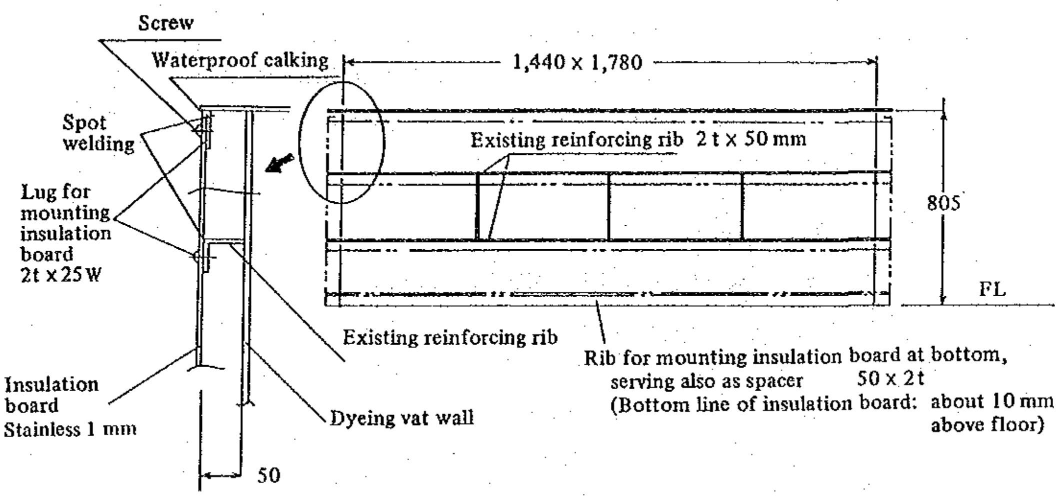


Figure 5–3–11 Dyeing Vat Heat Insulation Work

(C) Insulation effect

If an air layer 50 mm thick is made using stainless steel board 1 mm thick, heat radiation will be reduced as calculated below, provided that it is based on steady heat transfer.

i) The present overall heat transfer coefficient for the dyeing period is calculated.

Since $Q = K.A\,(t - t_0)$,

$Q = 3{,}363$ kcal/52′

$A = 7.64\ m^2$

$t = 99°C$

$t_0 = 30°C$

$$K = \frac{3{,}363 \times \frac{60}{52}}{7.64 \times (99 - 30)} = 7.4\ \text{kcal/(m}^2\,\text{h°C)}$$

ii) The overall heat transfer coefficient (k′) after the proposed insulation is calculated.

Since $\frac{1}{K'} = \frac{1}{K} + \frac{1}{C}$,

C : Equivalent heat resistance = 2.0

$$\frac{1}{K'} = \frac{1}{7.4} + \frac{1}{2.0}$$

$K' = 1.6\ \text{kcal/(m}^2\,\text{h°C)}$

iii) The amount of heat radiation reduced is calculated as follows:

$$\frac{Q'}{Q} = \frac{K' \times A' \times (t_1 - t_0)}{K \times A \times (t_1 - t_0)}$$

The proposed jacket type heat insulation reduces the heat radiation area by an amount corresponding to the reinforcing ribs.

$$\frac{Q'}{Q} = \frac{1.6 \times 6.76}{7.4 \times 7.64} = 0.19$$

Therefore, heat radiation will decrease to 19 percent.

(D) Economic effect of heat-insulating dyeing vats

Heat radiation from the dyeing vat outer walls (Table 5–3–12): 10,092 kcal/cycle

Annual reduction of heat radiation: $10{,}092 \times 907 \times 0.81 = 7.4 \times 10^6$ kcal/year.

Calculating it in terms of steam will give:

$$\frac{7.4 \times 10^6}{499.6 \times 1{,}000} = 14.8 \text{ t/y}$$

Evaluation of recovery of heat insulation expenses

The unit price of heat insulation for the surfaces of the dyeing vat was estimated from the ratio of heat insulation cost for the vessels and pipes.

Unit price of heat insulation on site: 60.30 U$S/$m^2$

$$C = 60.30 \times 1.5 \times 6.76$$
$$= 611 \text{ U\$S}$$

In the above equation, 1.5 is the coefficient of difficulty.

The time required to recover the investment.

Since the amount of natural gas required for generating 1 ton of steam from the heat balance of boiler is

$$\frac{162.00}{2.199} = 73.7 \text{ Nm}^3/\text{t}$$

, and the annual saving is

is $14.8 \times 73.7 \times 0.08 = 86.8$ U$S/y

Therefore, the expenses for heat insulation can be recovered in $\frac{611}{86.8} = 7.0$ y

The economic efficiency is not so good because the operation time is short at present. You are requested to consider the adoption of heat insulation at the time when the rate of operation has become high.

(5) Recovery and use of dye waste liquid heat

(A) Basic concept for waste heat recovery

Dye waste liquid are discharged intermittently at various temperature so that waste heat recovery is generally limited only from high-temperature waste liquid, storaging in a tank and then using a small heat exchanger. An example of waste heat recovery flow is shown in Figure 5–3–12.

It is desirable that recovered waste heat be used for the equipment from which it was recovered. The dyeing vats, however, have upper temperature limits of about 40°C for initial feed water and cooling water to ensure proper fixing of dye. Thus, it is necessary to use recovered waste heat for such machines as will not adversely affect product quality.

It is advised that recovered hot water be used for the open washer, for example, located adjacent to the normal-pressure dyeing vat.

(B) Points to note in recovering waste heat

(a) Selection of heat exchanger

Dye waste liquids have wool refuse, so the following precautions must be observed to prevent wool refuse from causing trouble.

i) A heat exchanger simple in construction, free of parts blocking liquid flow and hardly clogged up by wool refuse

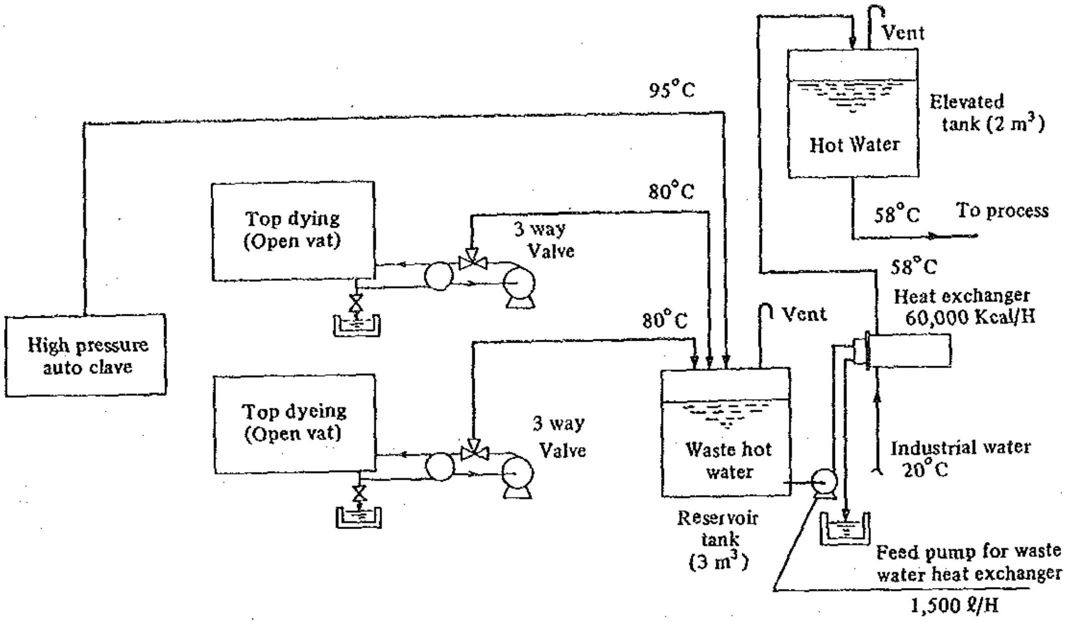


Figure 5–3–12 Top Dyeing Vat Waste Heat Recovery System Diagram

ii) Easy to disassemble and clean

iii) Low cost

A dual straight tube or plate heat exchanger is generally used to satisfy the above conditions.

(b) Using only high-temperature waste liquids

Low-temperature water is discharged during the transfer period from the dyeing process to the chroming process and during the cooling operation after the end of chroming.

To raise the efficiency of waste heat recovery, do not recover waste water 60°C or less but discharge it directly and use only high-temperature waste water.

(c) Heat insulation of waste water recovery tanks

It is desirable that the waste water tank and hot water recovery tank be heat-insulated because they have a large heat radiation area and are used for a long time.

(C) Effect of waste heat recovery

Table 5–3–13 Amount of Heat Recovered from Waste Heat

		High-temperature waste water (ℓ)	Waste water temperature (°C)	Temperature difference used (°C)	Amount of recovered heat (kcal/cycle)	Batches (Cycle/day)
Open vat	20 sps	2,000	80	30	60,000	4
Open vat	10 sps	1,000	80	30	30,000	4
Autoclave	No. 1	1,000	95	45	45,000	4
Autoclave	No. 2	1,000	95	45	45,000	4
Total		5,000	–	(38°C)	180,000	–

The amount of recoverable waste heat from the whole top dyeing equipment is shown in Table 5–3–13. If 70 percent of this amount is effectively used again and the latent heat of vaporization of steam 4.8 kg/cm²G is 499.6 kcal/kg the effect of waste heat recovery will be as calculated below.

$$G = \frac{180{,}000 \times 0.7 \times 4 \times 312}{499.6 \times 1{,}000} = 315 \text{ t/y}$$

This is, 315 tons of steam will be saved a year, the annual saving of fuel gas will amount to:

$$C = 315 \times 73.7 \times 0.08$$
$$= 1{,}857 \text{ U\$S/y}$$

This requires a considerable amount of capital investment, which, however, can be reduced if the existing idle tanks in the factory can be utilized. If two of the existing old tanks are reused for waste heat recovery, the investment will be recovered as calculated below.

Required capital investment:

Purchase of heat exchanger and filter (60,000 kcal/h, heat transfer area 2 m²):	U$S4,000
Purchase of feed pump and changeover valve for waste heat exchanger:	U$S2,000
Installation and heat insulation of tanks (25 m² x U$S60/m²):	U$S1,500
Appurtenant work:	U$S1,500
Total capital investment:	U$S9,000

The time required for recovery of the investment will be:

$$N = 9{,}000 \text{ U\$S} / 1{,}857 \text{ U\$S}$$
$$= 4.8 \text{ years.}$$

5.3.3.2 Dryer

The drying is in the latter half of the finishing process of woolen textile production, consumes much steam, and has much to do with production and quality.

The drying temperature, intake volume of fresh air, exhaust operation, and heat radiation loss are discussed below on the basis of our survey results.

(1) Heat balance

(A) Heat balance method

We tried to measure the quantity of steam (that constitutes heat input) from the volume of condensate, but could not measure it with an ultrasonic flow meter because steam was mixed in the condensate.

Therefore, the quantity of heat taken out was calculated from the measured values for the individual heat output items, and their total was regarded as the heat input. The heat output items are as follows:

Effective heat output.

- o Amount of heat applied to each of the constituents of woolen textile
- o Amount of heat for heating water contained in woolen textile
- o Amount of vaporization heat of the water contained in woolen textile

Heat loss

- o Heat loss taken away with exhaust air.
- o Heat radiation from the dryer itself
- o Other heat loss

(B) Measurement results

(a) Wollen textile tested

Product name	:	Tropical
Material	:	Wool 65%
		Polyester 35%
Unit weight (wet)	:	230 g/m (weaving width: 1.6 m)
Quantity tested	:	80 m/roll x 6 rolls
		480 m in total

(b) Water content measurements

The water content was measured using a sample 100 mm by 300 mm taken from each of the 5 rolls of woolen textile.

The water content was calculated by the following equation.

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

Z : Water content (%)

Gs : Absolute dry weight of woolen textile

Gw : Water weight in woolen textile

(c) Other measurement items

The items, measuring conditions, and results are shown in Table 5–3–14.

The internal structure of the dryer and temperature measuring points are shown in Figure 5–3–13.

Figure 5–3–14 shows the points where the surface temperature was measured to determine heat radiation.

Table 5–3–14 Table of Measuring Conditions

Measuring item		Measuring place	No. of measuring points	Measuring intervals	Measuring instrument	Measuring results
Water		Sample	10	Spot	Chemical balance	Table 5–3–15
Exhaust air velocity		No. 1 exhaust line	1	Continuous	Hot-wire anemometer	Table 5–3–16
		No. 1, No. 2 exhaust lines	5	Spot	Hot-wire anemometer	
Exhaust air	Temperature	No. 1, No. 2 exhaust lines	1 each	Continuous	Thermocouple	
	Humidity	No. 1, No. 2 exhaust lines	1 each	Continuous	Thermocouple	
Inside room	Temperature/humidity	Dryer side	1 each	Spot	Thermo-hygrometer	Table 5–3–16
Textile surface temperature		Dryer outlet	1	Continuous	Radiation pyrometer	149.6 °C
Drying temperature		Inside dryer	5	Continuous	Thermocouple	Figure 5–3–14
Dryer surface temperature		Top, etc.	7	Continuous	Thermocouple	Table 5–3–17
		Front, bottom	1 each	Spot	Contact surface thermometer	Figure 5–3–15

Note: Measuring time was from 14:02 to 14:40.

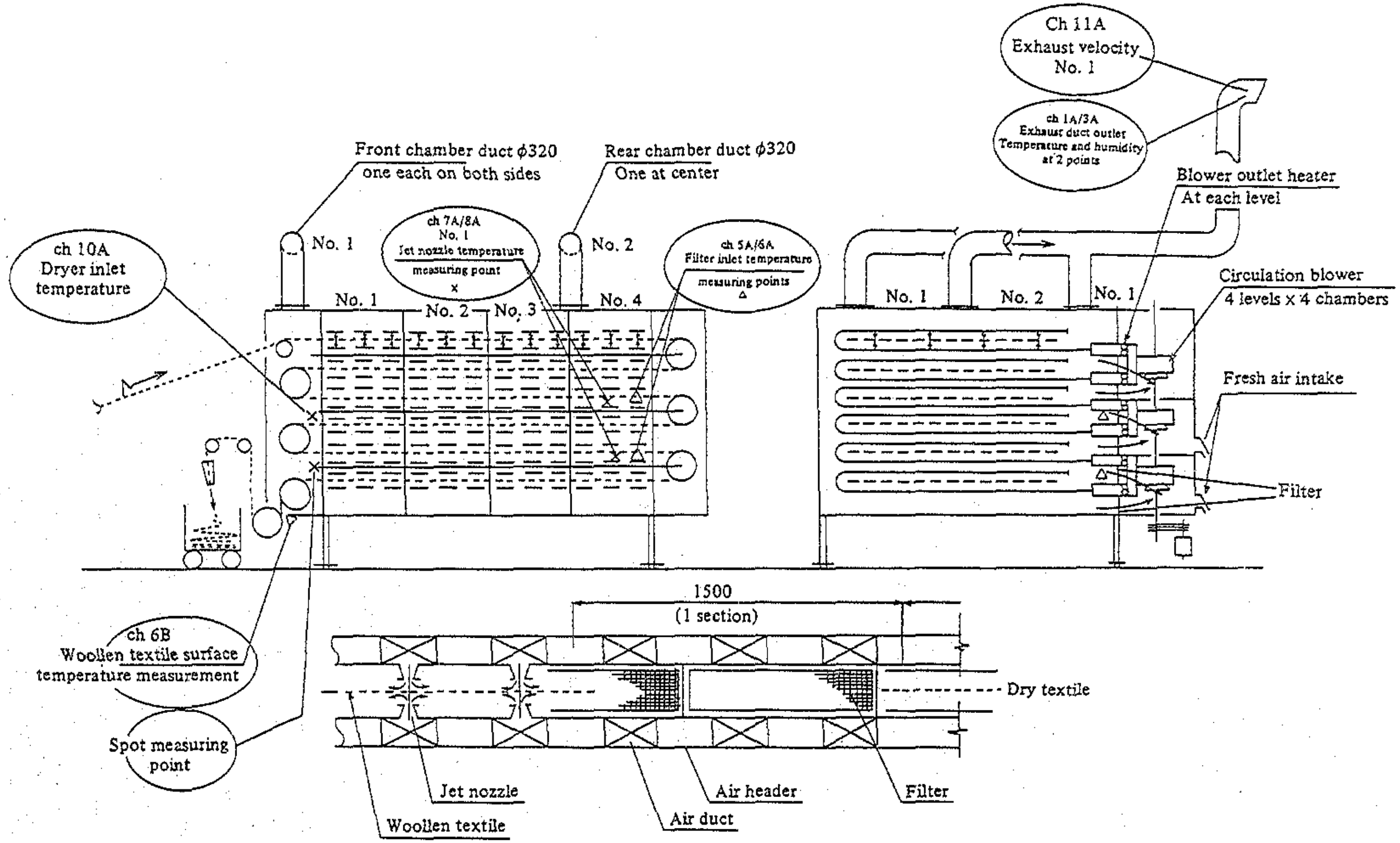


Figure 5−3−13 Dryer Structure and Measuring Points of Temperatures and Exhaust Velocity

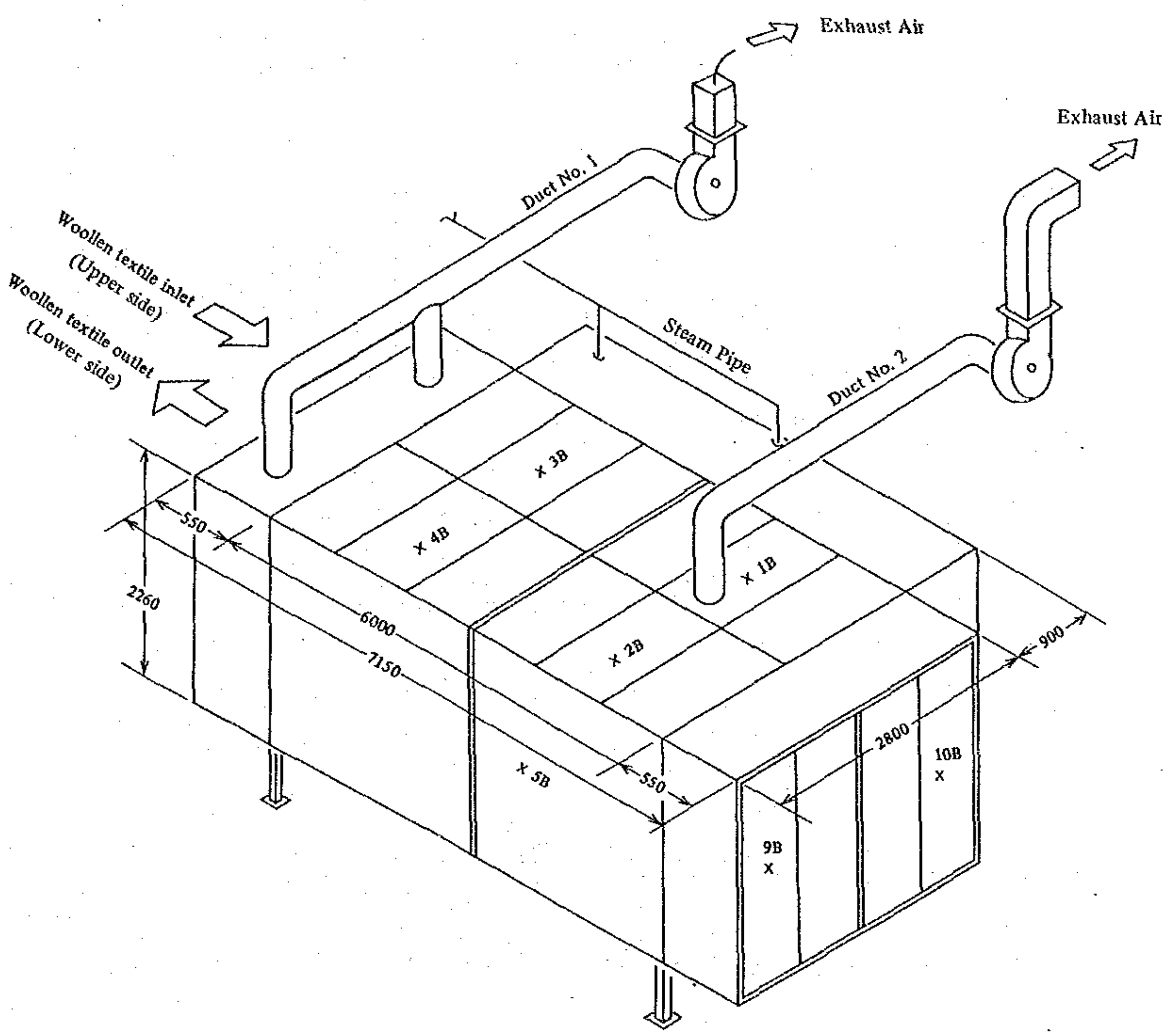


Figure 5–3–14 External View of Dryer and Surface Temperature Measuring Points

Table 5–3–15 Moisture Percentage Measuring Results

Sample No.	Before drying (%)	After drying (%)
1	29.93	0.25
2	28.32	0.36
3	32.47	0.02
4	28.60	0.01
5	28.91	0.12
Average	29.65	0.15

Note: All measured values are on a wet basis.

Table 5–3–16 Exhaust Air Measurement Results

			Exhaust Duct No. 1	Exhaust Duct No. 2	Inside room
Exhaust rate		m^3/h	451.2	903.50	–
Temperature	DB	°C	82.3	95.9	32.0
	WB	°C	42.8	42.0	21.4
Relative humidity	RH	%	–	–	38.3

Note: No. 1 fan stopped

Table 5–3–17 Surface Temperature of Dryer

Measuring point	ch. No.	Temperature (°C)	Measuring point	ch. No.	Temperature (°C)
Top	1 B	58.2	Right sidewall	5 B	32.8
	2 B	62.2	Rear chamber door	9 B	39.1
	3 B	66.4		10 B	37.9
	4 B	61.7		Average	38.5
	Average	62.1	Front chamber door	–	85.0
			Bottom plate	–	63.0

Note: Parts without ch No. were measured using a surface thermometer.

(C) Heat balance calculation

(a) Drying load

Wet textile weight per hour

$$G = 230 \times 80 \times 6 \times \frac{60}{38} \times \frac{1}{1000}$$

$$= 174.3 \text{ kg/h}$$

Average feed speed

$80 \times 6/38 = 12.63$ m/min

Absolute dry weight

$174.3 \times (1 - 0.2965) = 122.6$ kg/h

Evaporated water $\left(174.3 \times 0.2965\right) - \left(122.6 \times \frac{0.0015}{0.9985}\right) = 51.5$ kg/h

Residual water $122.6 \times \frac{0.0015}{0.9985} = 0.2$ kg/h

The quantity of heat required for drying is shown in Table 5–3–18.

(b) Water balance

Table 5–3–19 shows the inlet air and exhaust air humidity, and Table 5–3–20 the results of calculating the amount of water taken out through the exhaust duct.

The amount of water taken out through the exhaust duct was 28.9 kg/h, and there is a shortage of 22.6 kg/h of water comparing to the vaporization amount from the textile as follows:

$$\Delta W = 51.5 - 28.9 = 22.6 \text{ kg/h}$$

This shortage is considered to have been discharged from the dryer's textile inlet and the joint of the dryer body into the room.

If the humidity of leaking air is the average of the values for the ducts No. 1 and No. 2, the amount of air leaking into the room will be as follows:

$X = 0.036$ kg/kg

$V = 1.086$ m^3/kg

$$G = \frac{22.6}{0.036 - 0.012} = 941.7 \text{ kg/h } (1{,}023 \text{ m}^3/\text{h})$$

Water balance is:

Line No. 1:	12.0 kg/h	(23.3%)
Line No. 2:	16.9 kg/h	(32.8%)
Leak:	22.6 kg/h	(43.9%)
Total:	51.5 kg/h	(100.0%)

This means that about 44 percent is leaking into the room.

(c) Heat loss by exhaust air

The results of calculation are shown in Table 5–3–21.

(d) Radiation heat loss from dryer surfaces

Table 5–3–22 shows the radiation heat loss calculated from the surface temperature of the dryer shown in Table 5–3–17.

(D) Heat balance table

(a) A summary of effective heat and heat loss is shown in Table 5–3–23, which is based on the quantity of heat in a steady state of heat transfer.

Table 5–3–18 Heat Required for Drying

	Weight (kg/h)	Specific heat (kcal/kg °C)	Initial temperature (°C)	Final temperature (°C)	Quantity of heat (Kcal/h)	Percentage
Wool (65%)	79.7	0.325	21.4	149.6	3,320.7	9.1
Polyester (35%)	42.9	0.239	21.4	149.6	1,314.4	3.6
Vaporized water	51.5	1	21.4	(100 + 539)	31,806.4	87.2
Residual water	0.2	1	21.4	100	15.7	0.1
Total	174.3	–			36,457.2	100

Table 5-3-19 Basic Data on Air and Exhaust Air

Item \ Division			Exhaust air		Inside room
			No. 1	No. 2	
Dry bulb temperature	(DB)	°C	82.3	95.9	32.0
Wet bulb temperature	(WB)	°C	42.8	42.0	21.4
Absolute humidity	(X)	kg/kg'	0.040	0.032	0.0115
Specific volume	(V)	m^3/kg	1.070	1.100	0.880
Specific weight	(G)	kg/m^3	0.934	0.909	1.136

Note: Absolute humidity and specific volume were calculated from Mollier diagram.

Table 5-3-20 Water Taken Out through Exhaust Ducts

Duct \ Division	Exhaust Air			Air			Net amount of water taken out (W – Wo) kg/h
	Exhaust rate		Water taken out (W) kg/h	Air suction		Water taken in (Wo) kg/h	
	m^3/h	kg/h		m^3/h	kg/h		
No. 1	451.2	421.4	16.9	370.8	421.4	4.9	12.0
No. 2	903.0	820.8	26.3	721.9	820.4	9.4	16.9
Total	1,354.2	1,242.2	43.2	1,093.1	1,242.2	14.3	28.9

Table 5-3-21 Exhaust Heat Loss Calculation Results

		Exhaust rate	Exhaust temperature	Suction air temperature	Temperature difference	Exhaust heat loss
		kg/h	°C	°C	°C	kcal/h
Exhaust air	No. 1	421.4	95.9	32.0	63.9	6,516
	No. 2	820.8	82.3	32.0	60.3	9,991
Leak into room		941.7	89.1	32.0	67.1	15,292
Total		2,183.9				31,799

Note: Based on an exhaust air specific heat of 0.242 kcal/kg °C

Table 5–3–22 Heat Radiation Calculation Results

Part \ Item	Radiating surface: Area	Radiating surface: Temperature	Room temperature	Temperature difference	Heat transfer coefficient: αc	Heat transfer coefficient: αr	Heat transfer coefficient: α	Heat radiation
	m^2	°C	°C	°C	kcal/ $m^2h°C$	kcal/ $m^2h°C$	kcal/ $m^2h°C$	kcal/h
Top	20.02	77.7	32.0	45.7	5.72	5.53	11.25	10,293
Bottom	20.02	63.0	32.0	31.0	2.59	3.49	6.08	3,773
Rear chamber door	6.33	38.5	32.0	6.5	2.40	0.65	3.05	125
Left sidewall	17.30	32.8	32.0	0.8	1.42	0	1.42	19
Right sidewall	17.30	32.8	32.0	0.8	1.42	0	1.42	19
Front	6.33	85.0	32.0	53.0	4.05	6.64	10.69	5,380
Total	87.30	–	–	–	–	–	–	19,609

Note 1: Heat radiation was calculated using an ECC personal computer program.

Note 2: The emissivity of the radiating surfaces was assumed to be 0.8.

Table 5–3–23 Dryer Heat Balance

	Quantity of heat (kcal/h)	Ratio (%)
Heat required for drying	36,457	41.5
Exhaust loss	31,799	36.2
Radiation loss	19,609	22.3
Total	87,865	100

(b) Quantity of steam required for drying

Steam pressure: 7.2 kg/cm^2 G

Latent heat of vaporization: 488.6 kcal/kg

Required quantity of steam: $Gs = \frac{87,865}{488.6} = 180$ kg/h

(c) Thermal efficiency

$$\eta = \frac{36,457}{87,865} \times 100 = 41.5\%$$

(d) Steam consumption

Per unit dry textile weight $\frac{180}{174.3} = 1.03$ kg/kg–Tex

Per meter of textile $\frac{180 \times 38}{80 \times 6 \times 60} = 0.24$ kg/m

(E) Evaluation of heat balance table

(a) Heat required for drying

To reduce the largest load, that is, water vaporization heat, it is necessary to study the remainted percentage of water in textile in terms of energy conservation and product quality.

(b) Drying temperature

The possibility of lowering the present drying temperature of 150°C must be studied for not only energy but product quality.

(c) Exhaust Air

Large quantity of heat as much as nearly 90 percent of the water vaporization heat is discharged in the exhaust air, so it is important to reduce it. Also, 44 percent of the exhaust air is leaking from the dryer into room.

An appropriate exhaust system must be studied also for improving the working environment.

(d) Heat radiation from dryer itself.

The insulation is conducted in almost good condition.

(2) Improvement of dryer operation

To reduce drying energy, it is necessary

- o to decrease the drying load, and
- o to reduce heat loss by exhaust air, radiation, etc.

The steps to attain the above are described below.

(A) Decreasing the drying load

(a) Moisture at inlet

The moisture taken in by Tropical was at a satisfactory level of 30 percent on the average in our last survey.

This is considered due to the effect of vacuum dehydration after squeezing roller operation of the broad-width washer.

(b) Moisture after drying

Moisture after drying was extremely low as shown in Table 5–3–15.

Average	:	0.15%
Maximum	:	0.36%
Minimum	:	0.01%

These figures represent a state of nearly absolute driness. That is, the product textiles are extremely overdry.

As shown in Figure 5–3–15, woollen textiles in storage absorb or release moisture until their moisture reaches to equilibrium with the moisture of room air. Therefore, it is meaningless to dry woolen textiles over a certain level. Generally, 100% woolen textiles are dried to a water content of 10 percent, and woolen taxtiles with 35 percent polyester to a water content of 6 to 7 percent in most cases.

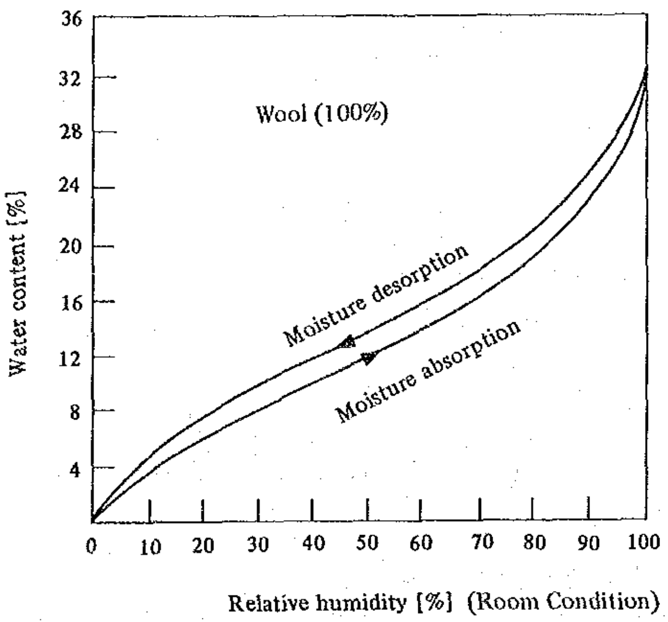


Figure 5–3–15 Relative Humidity and Water Content (Wool)

Because the textiles were dried to a state of nearly absolute dryness, the textile temperature after drying was about 150°C. Heating to a very high temperature will adversely affect the quality of wool fibers.

According to Table 5–3–24, wool fibers begin to decompose at 130°C or over. The textile temperature of 150°C exceeds this level.

Table 5–3–24 Change of Wool Fiber Quality by Heating

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

It is recommended for preventing overdryness that the dryer's temperature control target be gradually lowered from the present 150°C to 130°C ~ 140°C while paying attention to the relationship between the temperature and textile passing speed. A woollen textile with a weight of about 230 g/m is fed usually at about 30 m/minute average. An example of cloth temperature control system is shown in Figure 5–3–16.

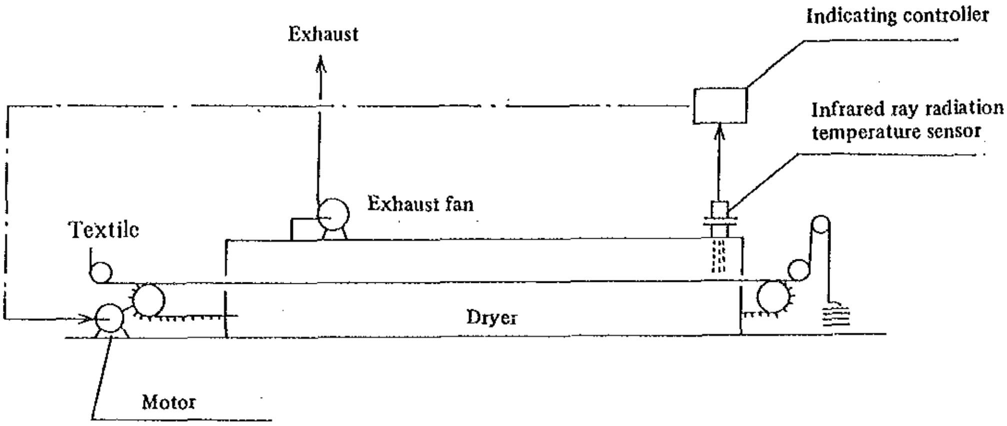


Figure 5–3–16 Dryer Cloth Temperature Control System

(B) Reducing exhaust loss

According to our survey results, exhaust air humidity was 0.032 to 0.040 kg/kg'-air as shown in Table 5–3–19.

The effect of humidity is small in high-temperature drying, so exhaust air is circulated to raise the heat efficiency even though drying speed may become a little lower due to increased humidity. Some textile factories operate at an increased exhaust humidity of about 0.1 to 0.12 kg/kg'-air.

The dryer in this factory is an energy conservation type using a circulation fan inside. The fact that the humidity was low despite of it indicates that fresh air leaked in so much as to increase the volume of exhaust.

The present state of air intake is shown in Figure 5–3–17 and Table 5–3–25. The results of measuring the temperature distribution inside the dryer are shown in Table 5–3–26. The No. 1 section showed a temperature difference of 6°C in the vertical directions, which was not so much. The No. 4 section, however, showed a large difference in temperature distribution with extremely low temperature in the lower part. The cause of it is that a large volume over the capacity of the steam heater of cold air was drawn in through the maintenance hatch which was kept out of place.

The air inlet on the side of the dryer has an opening enough for the required volume of air, so completely close the maintenance hatch and take in air from the air inlet only.

An example of humidity control method is shown in Figure 5–3–18. This method regulates the exhaust rate to keep the humidity inside at a constant level. Besides the method of fan speed control shown in the Fugure, exhaust rate may also be controlled by installing a damper in the exhaust duct. In this case, adjust the opening of the air inlet so that there will be neither hot air blast nor cold air suction through the opening in front.

If the exhaust humidity is raised by it from 0.036 kg/kg'-air to 0.060 kg/kg'-air and if the moisture of the dried woollen textiles from the present 0.15 percent to the normal moisture of 7 percent for wool-polyester textiles, the effect of reducing the required quantity of heat can be reduced about 28% as shown in Table 5–3–27.

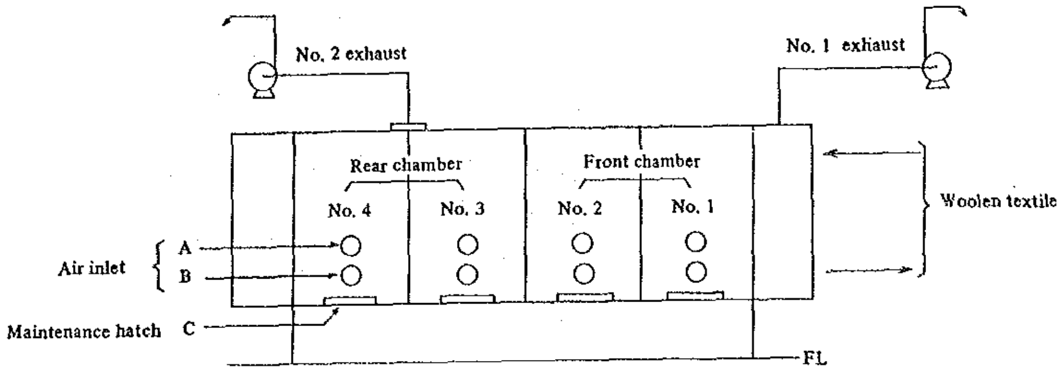


Figure 5–3–17 Air Suction and Exhaust System of Dryer

Table 5–3–25 Dryer Air Intake

Item	Part	Rear chamber		Front chamber		Remarks
		No. 4	No. 3	No. 2	No. 1	
Air inlet opening (mm)	A	3	15	10	5	Air inlet Opening
	B	10	5	0	10	
Maintenance hatch opening area (cm^2)	C	625	0	390	125	Total opening area
Suction static pressure (mm Aq)	A	17.5	19.2	17.0	21.0	Intake air temperature 32°C
	B	20.0	21.0	19.5	20.5	
Suction speed (m/s)	B	19	–	17	16.5	Reference value

Table 5–3–26 Temperature Distribution in Dryer

		Measuring point (over bottom plate)	Front chamber (No. 1) (A)	Rear chamber (No. 4) (B)	Temperature difference (A) – (B)
Height	Center	+ 1,200 mm	132 °C	115.0 °C	17.0 °C
	Lower level	+ 600	126	80.4	45.6
Temperature difference		–	6	34.6	–

Note: The temperatures of the front chamber (No. 1) are spot-measured values.

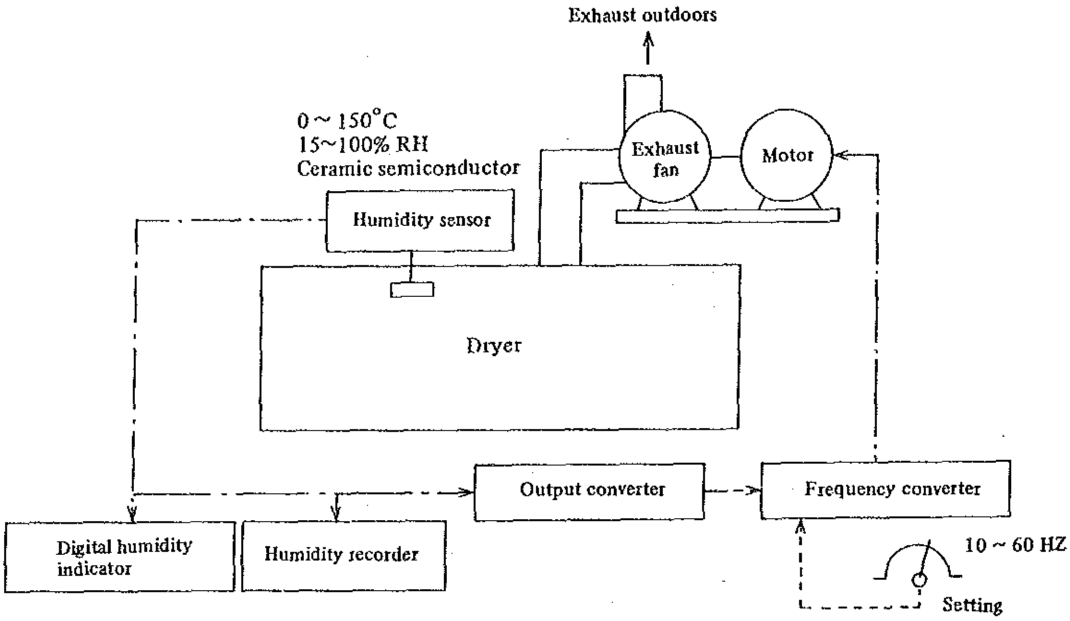


Figure 5–3–18 Dryer Humidity Control System

Table 5–3–27 Effect of Drying Condition Improvement

Preconditions:			
Specific heat of dry air	0.242 kcal/(kg. °C)		
Vaporization heat of water vapor	488.6 kcal/kg		
Reference temperature	32 °C		
Exhaust temperature	98 °C		
Room air humidity	0.012 kg/kg'-Air		
Drying speed	12.6 m/min		
Annual production	611.4 km/y		
Annual drying time	611.4 x 1,000/(12.6 x 60) = 809 h/y		
Decrease of exhaust loss			

	Before improvement	After improvement	Difference
Cloth moisture after drying Vaporized water	0.15% 51.5 kg/h	7% 122.6×(0.2965/0.7035-0.07/0.93) = 42.4 kg/h	9.1 kg/h
Exhaust air humidity Exhaust rate	0.036 kg/kg'-Air 51.5/(0.036-0.012) = 2,146 kg/h	0.060 kg/kg'-Air 42.4/(0.060-0.012) = 883 kg/h	1,263 kg/h
Heat of water vaporization	51.5 x 488.6 = 25,163 kcal/h	42.4 x 488.6 = 20,717 kcal/h	4,446 kcal/h
Sensible heat of exhaust air	2,146 x 0.242 x (98-32) = 34,276 kcal/h	883 x 0.242 x (98-32) = 14,103 kcal/h	20,173 kcal/h
Decrease of the quantity of heat			24,619 kcal/h

An annual saving of 24,619 X 809 = 19.9 X 10^6 kcal/y can be realized in the required quantity of heat.

Energy saving when converted in Fuel gas. $\frac{19.9 \times 10^6}{499.6 \times 1,000} \times 73.7 = 2,930\ Nm^3/y$

This will also keep the exhaust rate within the capacity of the exhaust fan so that there will be no leakage of hot air into the room. This also means improvement of the working environment.

(C) Improvement of the temperature control method

The present temperature control method is such that the circulation fan is manually switched on and off with steam kept on as shown in Table 5–3–28. Thus, temperature variation is considerable as shown in Figure 5–3–19, though it may due partly to cold air suction.

Because steam is kept on even during non-work hours, the internal temperature rises to about 170°C.

An improvement plan to prevent overdrying and stabilize temperature is shown in Figure 5–3–20. The proposed method keeps the circulation fan operating, but controls the temperature by regulating the rate of steam supply to the front and rear chambers. Thermal sensors will be installed in the No. 2 and No. 4 sections where the circulation fan will not be turned off even for non-work hours.

Table 5–3–28 Dryer Temperature Conditions and Operation Standard

	Unit	Product		Dryer turned off
		Thin	Thick	
Supply steam pressure	kg/cm^2	7.2	7.2	Continuous
Drying temperature	°C	Below 150°C	150 ~ 170	
Circulation fan	Temperature controlled by switching on and off No. 1 fan			Two fans in operation
Exhaust fan	Two fans kept in operation			Two fans in operation
Exhaust damper	Fixed			No operation
Cloth feed speed	As judged by operator			

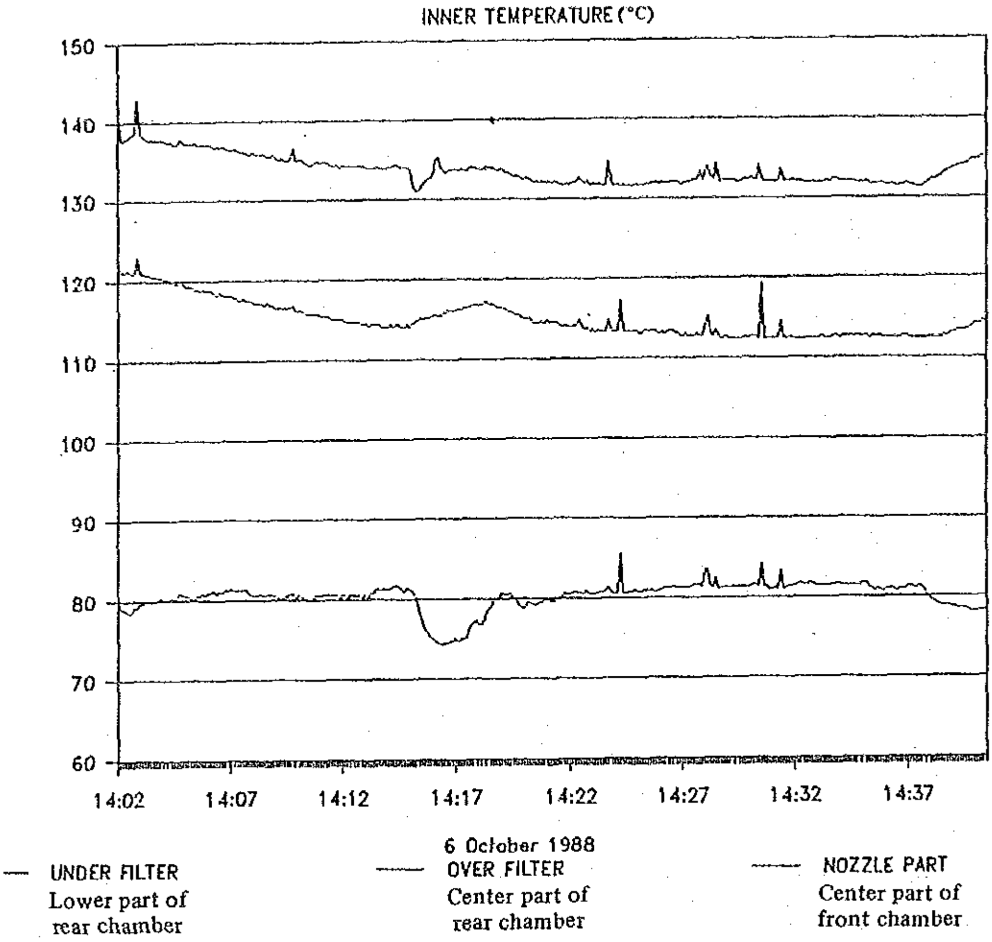
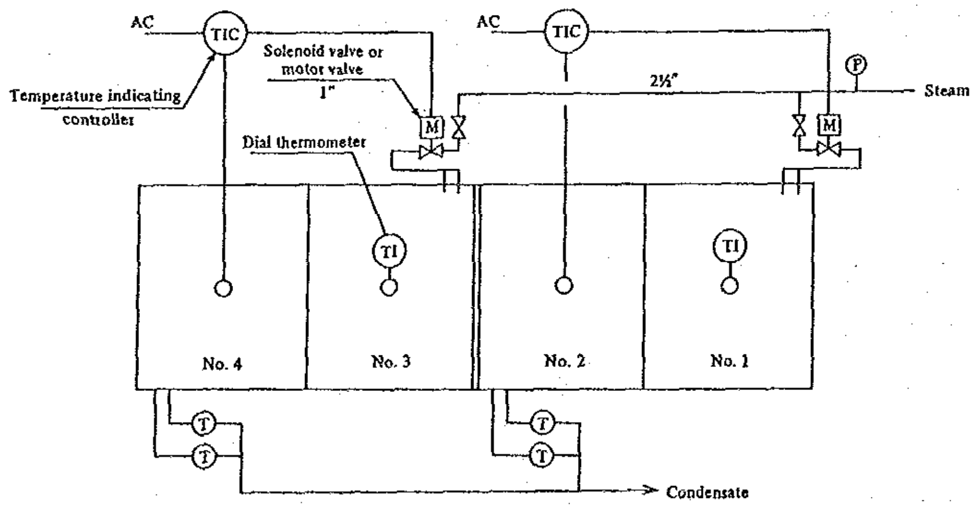


Figure 5-3-19 Inner Temperature



Note : Install thermal sensors in the sections No. 2 and No. 4 where the circulation fans will not be stopped when the dryer is not operating.

Figure 5-3-20 Temperature Control Method

(D) Stopping of exhaust fan for temporary work suspension

At present, the exhaust fan keeps operating even during waiting time in the drying process, discharging hot air outdoors.

Heat loss by keeping the exhaust fan operating is calculated as follows:

Preconditions

Specific heat of dry air	: 0.243 kcal/(kg°C)
Reference temperature	: 32°C
Exhaust air temperature	: 150°C
Exhaust rate	: 1,640 kg/h (Table 5–3–20, No. 2 fan X2)
Idle time	: 809 h (same as drying time)
Circulation fan	: No. 1 and No. 3 fans stopped

Heat loss

$0.243 \times (150 - 32) \times 1{,}640 \times 809 = 38.0 \times 10^6$ kcal/y

$38.0 \times 10^6/(500 \times 1{,}000) = 76.0$ t-Steam/y

When converted in Fuel gas.. $76.0 \times 73.7 = 5{,}600$ Nm^3/y

76 tons of steam can be saved annually if the exhaust fans are kept off during the idle time.

The operating ratio of the dryer appears low from the present level of production. It is advised, therefore, that a production plan that would allow continuous drying be prepared and that steam supply be stopped during a long suspension of operation.

5.3.3.3 Spinning Machines Winder

(1) Air conditioning and end breakage in the spinning process

(A) Present condition

In the spinning process, end breakage occurs due to many factors, such as the condition of air, the quality of the material, oiling, and machine maintenance. Of these factors, the effect of temperature and humidity of air particularly the latter, is large. In recent years, end breakage has been decreasing because oiling has suppressed static electricity generation even at low humidity.

In this factory, tow is humidified by a wall humidifier in the pre-spinning process, but temperature and humidity are left subject to ambient conditions in the fine spinning process which has no air conditioner.

The present temperature and humidity data for the fine spinning process of this factory are as follows:

Summer, average : 40°C, 45% RH

Winter, average : 25°C, 60% RH

Typical woollen textile factories in Japan control the temperature and humidity at 29°C to 30°C and 60% to 65% RH throughout the year. The humidity level of WELLS is a little lower in summer than shown in the Japanese data. End breakage in this factory occurs 100 times per hour per 1,000 spindles, compared with 20 to 30 times per hour per 1,000 spindles in Japanese woollen textile factories. This difference is due partly to the difference in temperature and humidity conditions between the WELLS factory and the Japanese factories.

(B) Study of the relationship between temperature and humidity conditions of air and end breakage

The number of occurrences of end breakage in the fine spinning process is in direct proportion to the amount of pneumafil waste, so it is suggested that the amount of pneumafil waste be weighed daily and that its relationship between the amount and the readings of the thermo-hydrometer installed on the wall of the fine spining process, checked daily at fixed times, be statistically studied.

(C) Temperature and humidity control improvement plan

The common method of controlling the temperature and humidity of air in a spinning room is to control the flow rate of saturated air at a constant temperature level. The average temperature of Buenos Aires in January, the hottest month of the year, is relatively low at 23.6°C, so an adiabatic cooling by outside air is assumed effective for improving temperature and humidity control.

The air supply rate and fresh air intake rate are obtained from the air diagram shown in Figure 5–3–21. If fresh air at point A is mixed with return air D from the fine spinning room into a mixture (point B), which is then humidified (point C) and supplied to the fine spinning room, it will be kept in condition D by the thermal load.

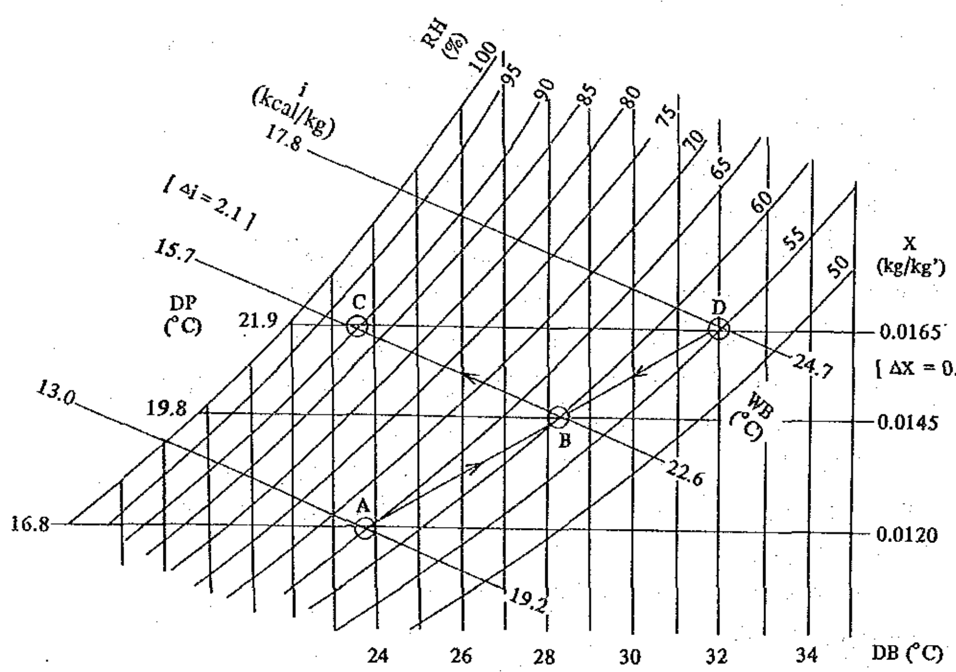


Figure 5–3–21 Case Study for Improvement of Temperature and Humidity Conditions for Fine Spinning Process

Point A	: Average outside conditions for January (23.6°C, 67% RH)
Point B	: Point where outside air and return air are mixed
Point C	: Air supply condition
Point D	: Temperature and humidity conditions of the fine spinning process (32°C, 55% RH)

Therefore,

Points A to B : Return intake ratio (55%)

Points B to D : Fresh air intake ratio (45%)

Points B to C : Humidifying rate at air conditioner (0.002 kg/kg')

The thermal load of the fine spinning process is mostly the heat generated by the fine spinning machines. Amount of heat generated by fine spinning machines.

860 x 15 (kw) x 0.8 x 7 (frame)

= 72,240 kcal/h

Required air flow,

$$\frac{72{,}240}{1.2 \times (17.8 - 15.6)}$$

= 28,670 m^3/h

(480 m^3/min)

provided that air density is 1.2 kg/m^3.

Fresh air intake rate

28,670 x 0.45

= 12,900 m^3/h

(215 m^3/min)

If the specifications of the air conditioner (UNI LUWA) in the dye finishing room meet the above conditions, it would be better to move the air conditioner to the fine spinning room where a large effect on production can be expected. In such a case, however, dampers for return air and fresh air and filters to remove fly must be newly installed.

The following effects can be expected from air conditioning the fine spinning process.

i) Reduction of end breakage to improve yield and product quality and lower energy consumption

ii) Decrease in the generation of fly

iii) Improvement of the working environment, possibly increasing the productivity.

(2) Plan to save blower power

(A) Saving the power of suction blowers for auto winder knotting

The results of measuring the suction pressures of the two suction blowers for knotting are shown in Table 5–3–29.

No difference was observed in their suction pressure despite the difference in the motor capacity.

The factors that affect the suction pressure include the following:

Air leakage into the suction system

Yarn dust collector filter clogged up with dust

Blower impeller with yarn waste sticking to it

Flow pass resistance in the blower discharge system

Table 5–3–29 Measured Suction Pressures of Auto Winders

(mm Aq)

	Blower (A)	Middle part	Out end (B)	Mean	ΔP (A) – (B)
No. 1 (15 kW)	1150	1060	1000	1070	150
No. 2 (11 kW)	1270	1050	1100	1140	170

Note: All the measured values shown above are static pressures in the main header measured with a digital manometer.

If the above-mentioned points are borne in mind during maintenance, the same size blower (11 kW) as the No. 2 machine can be used for the No. 1 auto winder.

Assuming that the suction blower load factor is 0.8 and that the operating ratio for production is 0.9, the amount of electric power that can be saved in a year is calculated as follows:

(15 – 11) kW x 0.8 x 16 h/d x 0.9 x 312 d/y
= 14,376 kWh/y

This can be calculated in terms of saving in electric charges as follows:

0.06 U$S/kWh x 14,376 kWh/y
= 862 U$S/y

If the purchase price of a impeller for 11 kW blower is assumed to be U$S1,500, this amount of investment can be recovered in two years.

(B) Improvement of pneumatic filter suction characteristics of fine spinning machines

The results of measuring the pneumatic filter suction pressures of the No. 5 to No. 7 fine spinning machines are shown in Table 5–3–30. These results indicate the following. The suction pressures at the gear end and intermediate part are low. If the suction pressure is less than 90 mmAq, suction of the end of a broken yarn will be difficult, and that yarn end may stick to an adjacent yarn to cause it to break. Suction pressures are generally controlled to be within the range of 100 to 130 mmAq.

To decrease the suction pressure gradient in the lengthwise direction, it is necessary to reduce the amount of suction air. The suction openings in this factory are 8 mm in diameter (50.2 mm^2), which is larger than those (7 mm in length x 4 mm in breadth = 23.7 mm^2) used in Japanese textile factories. It would be better to either replace the existing suction nozzles with ones smaller in diameter, or fit a plastic ring on the tips of the suction nozzles. This will decrease pressure fall in the suction tubes, and save the electric power consumed by the blowers.

The distances between the pneumatic nozzles and thread guides and deviations in their angles were also observed. Apart from these which are important items requiring daily management, attention must also be paid to the following.

Deposition of waste yarn in the pneumafil boxes
Contamination of the filters in the pneumafil boxes
Air leakage into the pneumafil ducts through joints
Entanglement of yarn waste with the blowers

It is recommended for the above maintenance that the suction pressures be measured with a U-tube manometer about once a month and record the readings to keep track of the trends.

Table 5–3–30 Measured Pneumatic Suction Pressures of Fine Spinning Machines

(mm Aq)

RF. No.	Part	Gear end (1)	Middle	Blower end (2)	Mean	(2) – (1) ΔP
No. 5	B	85.5	82.5	108.5	92.2	23
No. 6	A	86.5	93	120.5	100	34
	B	84	90.5	117	97.2	33
No. 7	A	86	89.2	113	96	27
	B	70	78	102.5	83.5	32.5

Suction nozzle diameter: ϕ8 mm X 432 sps/F
Yarn number count : 26's
Suction pressures were measured with a digital manometer.

5.3.3.4 Boiler

The steam supplied from the boilers is used as energy for the dyeing machine, dryer, etc. and thus plays an important role in the manufacturing process. This factory has two boilers. The 3-pass boiler on the left operates continuously 24 hours a day, while the 2-pass boiler on the right operates 17 hours a day, starting operation at 5 o'clock in the morning and stopping at 10 o'clock at night. The present study is made on the 3-pass boiler that is kept in continuous operation. There was no problem in particular about the method of boiler operation.

(1) Boiler specifications

Type : 3-pass, flue and smoke tube boiler
Evaporation : 4.5 t/h
Steam pressure : 10 kg/cm² G (rated)
Fuel : Natural gas

CH_4 = 94.32% i-C_4H_{10} = 0.06% n-C_5H_{12} = 0.03% N_2 = 0.96%
C_2H_6 = 2.49% n-C_4H_{10} = 0.11% C_6H_{14} = 0.05% CO_2 = 1.53%
C_3H_8 = 0.42% i-C_5H_{12} = 0.03%

Heating area : 104 m²
Date of manufacture : 1974
Structure : As shown in Figure 5–3–22

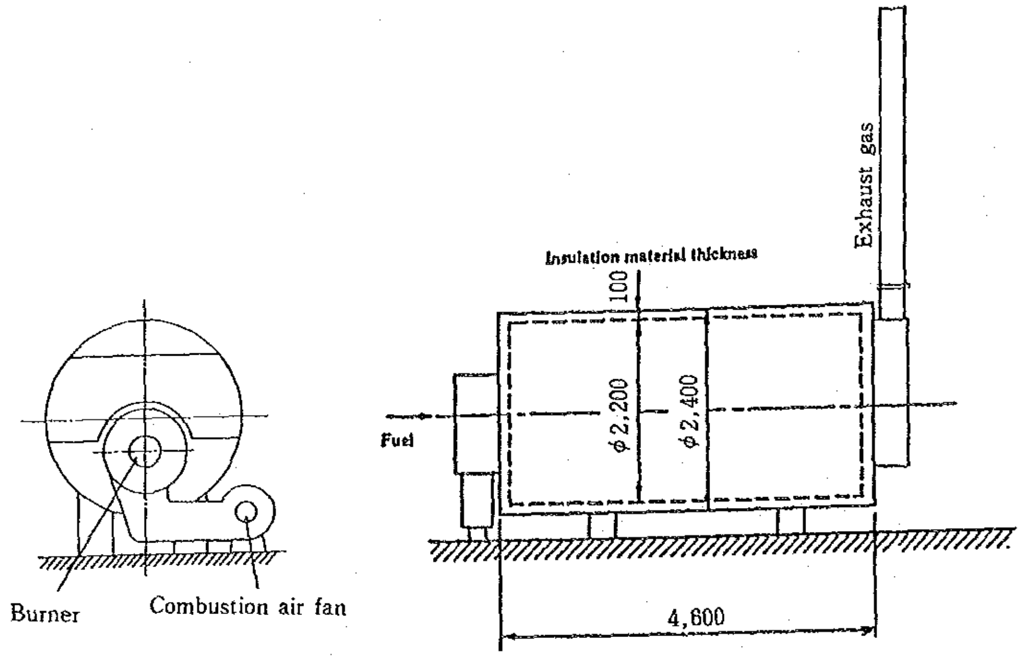


Figure 5−3−22 **Boiler Structure**

(2) Check items and collected data

The boiler was checked from October 3 to 7, 1988.

The measuring instruments brought by the study team were used to check the boiler, and its operating condition was observed visually.

(a) Data was gathered on the following items using the measuring instruments. The measuring points are shown in Figure 5-3-23.

1) Exhaust gas temperature and pressure; O_2%, CO_2%, and CO% in exhaust gas
2) Feed water temperature and flow rate
3) Fuel gas flow rate, temperature, and pressure
4) Furnace surface temperature
5) Ambient (reference) temperature
6) Steam pressure
7) Quality of feed water and boiler water

(b) The visually checked items are as follows:

1) Burning condition; smoke from the chimney
2) Control methods for combustion and water feed
3) Heat-insulation of boiler body and piping
4) Steam leakage
5) Equipment maintenance

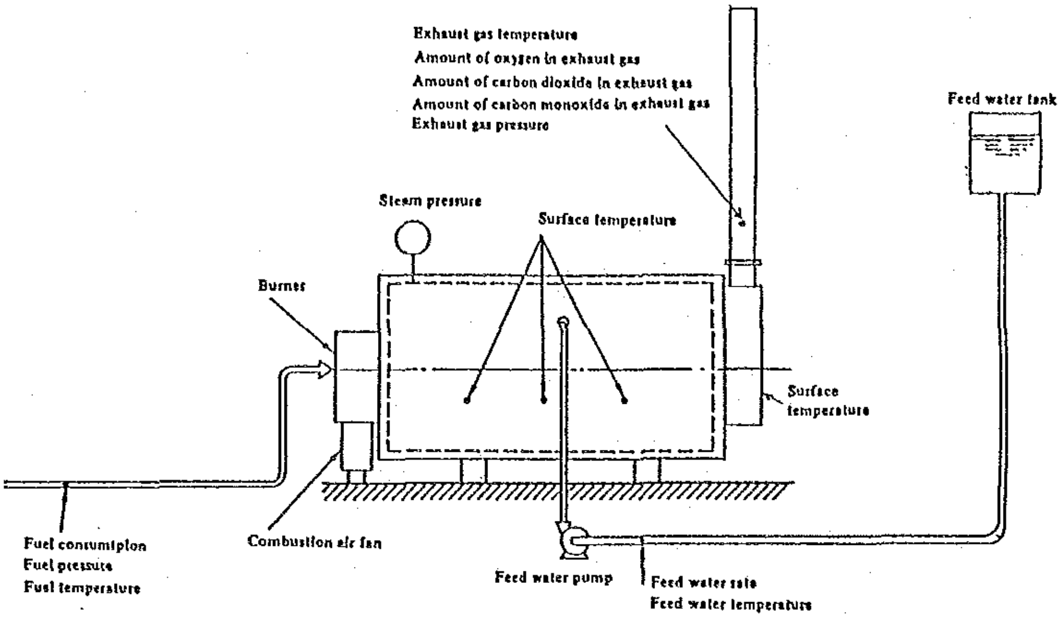


Figure 5−3−23 **Boiler Measuring Points**

(3) Heat balance of boiler

(a) The heat balance of the 3-pass boiler was calculated using the data collected from 14:00 to 15:00 on October 4. The details of the data are as follows:

1)	Kind of fuel		:	Natural gas
2)	Calorific value (low level)	(Hl)	:	8,632.3 kcal/Nm^3
3)	Specific gravity of fuel	(Sf)	:	0.767 kg/Nm^3
4)	Specific heat of fuel	(Cpf)	:	0.39 kcal/(Nm^3 °C)
5)	Fuel temperature	(Tf)	:	29.7°C
6)	Reference temperature	(To)	:	26.7°C
7)	Temperature of combustion air	(Ta)	:	26.7°C
8)	Specific heat of combustion air	(Cpa)	:	0.31 kcal/(Nm^3 °C)
9)	Theoretical amount of air	(Ao)	:	9.60 Nm^3/Nm^3-fuel
10)	Theoretical amount of wet exhaust gas	(Go)	:	10.62 Nm^3/Nm^3-fuel
11)	Fuel flow rate	(F)	:	162.00 Nm^3/h
12)	Exhaust gas temperature	(Tg)	:	193.1°C
13)	O_2% of dry waste gas	(O_2)	:	5.68%
14)	Air ratio	(m)	:	1.38
15)	Actual amount of combustion air	(A)	:	13.28 Nm^3/Nm^3-fuel
16)	Actual amount of wet exhaust gas	(G)	:	14.27 Nm^3/Nm^3-fuel
17)	Specific heat of exhaust gas	(Cpg)	:	0.33 kcal/(Nm^3 °C)
18)	Exhaust gas pressure	(Pg)	:	−0.67 mmH_2O
19)	Feed water flow rate (based on weight)	(Fw)	:	2,199 kg/h
20)	Feed water temperature	(Tw)	:	79.3°C
21)	Steam pressure	(Ps)	:	6.30 kg/cm^2 G
22)	Enthalpy of dry steam		:	659.91 kcal/kg

23) Enthalpy of saturated water : 167.43 kcal/kg

24) Dryness of steam : 0.98

25) Enthalpy of wet steam (h") : 650.06 kcal/kg

26) Enthalpy of feed water (h') : 78.991 kcal/kg

(b) Heat input

Heat input per Nm^3 of fuel is calculated.

1) Combustion heat of fuel (Hl)

$Hl = 8{,}632.30 \text{ kcal/Nm}^3$

2) Sensible heat of fuel (Qs)

$Qs = 0.39 \times (29.7 - 26.7) = 1.17 \text{ kcal/Nm}^3$

3) Sensible heat of combustion air (Qa)

$Qa = 0 \text{ kcal/Nm}^3$

4) Total heat input (Qi)

$Qi = Hl + Qs + Qa = 8{,}632.30 + 1.17 + 0 = 8{,}633.47 \text{ kcal/Nm}^3$

(c) Heat output

Heat output per Nm^3 of fuel is calculated.

1) Heat content of steam (Qv)

$$Qv = \frac{2{,}199}{162.00} \times (650.06 - 78.991) = 7{,}752.64 \text{ kcal/Nm}^3$$

2) Heat taken away by exhaust gas (Qg)

$Qg = 14.27 \times 0.33 \times (193.1 - 26.7) = 783.85 \text{ kcal/Nm}^3$

3) Heat radiation from boiler surface (Qr)

$$Qr = \frac{702 \times 4.52 + 231 \times 34.67 + 572 \times 4.52}{162.0} = 85.07 \text{ kcal/Nm}$$

Average temperature and surface area of front plate : 81.3°C, 4.52 m^2

Average temperature and surface area of shell plate : 48.5°C, 34.67 m^2

Average temperature and surface area of rear plate : 73.0°C, 4.52 m^2

4) Other heat loss (Qm)

$Qm = 11.91 \text{ kcal/Nm}^3$

5) Total heat output (Qo)

$Qo = Qv + Qg + Qr + Qm = 8{,}633.47 \text{ kcal/Nm}^3$

(d) Heat balance table

The data shown above are summarized in Table 5–3–31.

Table 5–3–31 Heat Balance of Boiler

Heat input			Heat output		
Item	$kcal/Nm^3$	%	Item	$kcal/Nm^3$	%
Fuel combustion heat	8,632.30	99.99	Heat of Steam	7,752.64	89.80
Sensible heat of fuel	1.17	0.01	Heat taken away by exhaust gas	783.85	9.08
Sensible heat of combustion air	0	0.00	Heat radiation from surface	85.07	0.99
			Other heat loss	11.91	0.14
Total	8,633.47	100.00	Total	8,633.47	100.00

(4) Problems and remedies

(a) Improving the air ratio to reduce the amount of heat taken away by exhaust gas

One of the ways of reducing the amount of heat taken away by exhaust gas is to reduce the amount of exhaust gas. This can be achieved by adjusting the amount of combustion air for the fuel to an appropriate level. The ratio of the actual amount of air for fuel combustion to the theoretically required amount of air for it is called the air radio, which can be calculated from the amount of oxygen in exhaust gas. The amount of oxygen in exhaust gas was 5.68% and the air ratio was 1.38, which are relatively satisfactory. It won't be difficult to reduce the amount of oxygen in exhaust gas to 4.5% by a little more careful adjustment of the air ratio, which will then be 1.27. The amount of exhaust gas will be reduced by about 8% as shown in Table 5–3–32.

Table 5–3–32 Reduction of the Amount of Heat Taken Away by Exhaust Gas by Improving the Air Ratio

No.	Item		Unit	Present	After improvement
1	Amount of oxygen in exhaust gas		%	5.68	4.5
2	Air ratio	m		1.38	1.27
3	Theoretical amount of air	Ao	Nm^3/Nm^3	9.60	9.60
4	Theoretical amount of exhaust gas	Go	Nm^3/Nm^3	10.62	10.62
5	Actual amount of air	A	Nm^3/Nm^3	13.28	12.19
6	Actual amount of exhaust gas	G	Nm^3/Nm^3	14.27	13.21
7	Exhaust gas temperature	tg	°C	193.1	193.1
8	Heat taken away by exhaust gas	Qg	$kcal/Nm^3$	783.85	725.39

The amount of air can reduced by adjusting the opening of the louver at the air suction port of the combustion air fan. No direct investment is necessary for this measure because no additional equipment is required.

The percentage of fuel saving (S) to be accomplished by lowering the air ratio can be calculated by the following equation.

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{8,633.47 - 783.85}{8,633.47 - 725.39} = 0.0074 = 0.74\%$$

where Hi: Heat input per Nm^3 of fuel ($kcal/Nm^3$);

Qga: Present amount of heat taken away by exhaust gas ($kcal/Nm^3$);

Qgi: Amount of heat taken away by exhaust gas after improvement ($kcal/Nm^3$).

Assuming that the annual consumption of fuel is 162.0 Nm^3/h X 24 h/d X 312 d/y = 1,213,056 Nm^3/y, the amount of annual saving can be calculated as follows:

1,213,056 Nm^3/y X 0.0074 X 0.08 U$S/$Nm^3$ = 718 U$S/y

(b) Boiler water quality control

The quality of feed water and boiler water was found to be as shown in Table 5–3–33.

Table 5-3-33 Quality of Feed Water and Boiler Water

Kind	Measured value			Reference		
	Temperature	pH	Electric conductivity	Temperature	pH	Electric conductivity
Well water	21.3 ℃ 21.7 ℃	7.57 7.55	1.327mS/cm 1.377mS/cm	–	–	–
Soft water	22.2 ℃ 22.2 ℃	7.91 7.72	1.381mS/cm 1.372mS/cm	–	–	–
Feed water	33.2 ℃ 37.3 ℃	9.06 8.87	0.988mS/cm 1.052mS/cm	25 ℃	7~ 9	–
Boiler water	33.4 ℃ 37.1 ℃	12.02 13.18	12.02 mS/cm 13.18 mS/cm	25 ℃	11~11.8	<4.5 mS/cm

Boiler water is controlled by bottom blow of boiler water. Bottom blow, lasting about 2 minutes, is done 4 or 5 times a day. Boiler water is checked for solids twice or three times daily, and bottom blow is done when the content of solids exceeds 4,000 mg/ℓ.

The boiler water showed extremely high electric conductivity according to our study results. This means that the boiler water contains a large amount of impurities, which cause to shorten boiler life. To regulate the quality of boiler water by blow only, a continuous blow of about 29% will be necessary as expressed by the following equation. Such a blow will result in a big loss.

$$Fb = Fc/(Bc - Fc) \times 100$$
$$= 1.02/(4.5 - 1.02) \times 100$$
$$\doteqdot 29.31\%$$

where Fb : Blow ratio (%);

Fc : Electric conductivity of feed water;

Bc : Electric conductivity of boiler water.

The quality of feed water can be improved as described below.

1) Judging from the feed water temperature, the percentage of condensate recovery is assumed to be nearly 80%, however, electric conductivity has not fallen to about 400 mS/cm as it should have. It is necessary to check whether steam was leaking from a faulty trap to raise the feed water temperature and lower the actual percentage of condensate recovery, and whether the condensate is contaminated.

2) To lower the concentration of salts in raw water (well water) by treating part of it with a reverse osmosis device, and thus improve the quality of feed water.

3) If the present softening process is changed to a de-alkali softening process, most of the M-alkalinity in the raw water can be eliminated (remaining 5 to 15 mg/liter) so that the salt content of the soft water can be slightly lowered.

4) If it is not possible to take the above measures, corrosion may accelerate due to chloric ions, etc. and therefore deoxidation must be enforced thoroughly.

(c) Maintenance problems

Satisfactory maintenance of the boilers is necessary to ensure safe, secure operation. The following points were found to be in need of repair or improvement by our study.

1) The boiler room smelled foul, raising suspicions of gas leakage. It is necessary to check for gas leaks and repair them.

2) One of the two boiler water level meters was broken. Both level meters are necessary for the safe operation of the boilers. Repair the defective meter as soon as possible.

3) The flow recorder that records the steam generated by the boilers was left out of order. Repair it.

4) The high-temperature feed water tank located on the roof and the piping from that tank to the boilers were not heat-insulated. It is recommended that they be heat-insulated hopefully soon.

5.3.3.5 Steam system

(1) Steam piping heat-insulation and prevention of leakage

Figure 5–3–24 shows the bare parts and steam leaking points of the steam pipelines.

The amount of heat radiation from the bare parts of the steam lines and the effect of insulating them with mineral wool 25 mm are shown in Table 5–3–34.

Table 5–3–34 Radiation Heat Loss and Insulation Effect

Line	Equipment	Bare Area m^2	Radiation heat loss kcal/h		
			Present	Insulated	Effect
4″–1	Dyeing, washing	5.6	12,321	1,424	10,897
4″–2	Decatizer, autoclave	4.6	10,005	943	9,062
4″– Br.	Dyeing	15.8	35,130	4,454	30,676
4″– Br.	Washing	2.5	6,525	876	5,649
4″– Br.	Ironing	0.9	1,684	241	1,443
4″– Br.	Drying	2.1	4,973	598	4,375
2″–1	Decatizer	1.3	3,467	465	3,001
2″–2	Heat setter, autoclave	4.0	9,196	1,152	8,045
	Boiler room	5.6	12,494	1,449	11,044
Total			95,794	11,603	84,192

Parts	Radiation heat loss kcal/h		
	Present	Insulated	Effect
Ball valve	35,091	4,243	30,848
Reducing valve	3,682	487	3,194
Flange	14,274	1,583	12,691
Pipe	42,747	5,289	37,458
Total	95,794	11,603	84,192

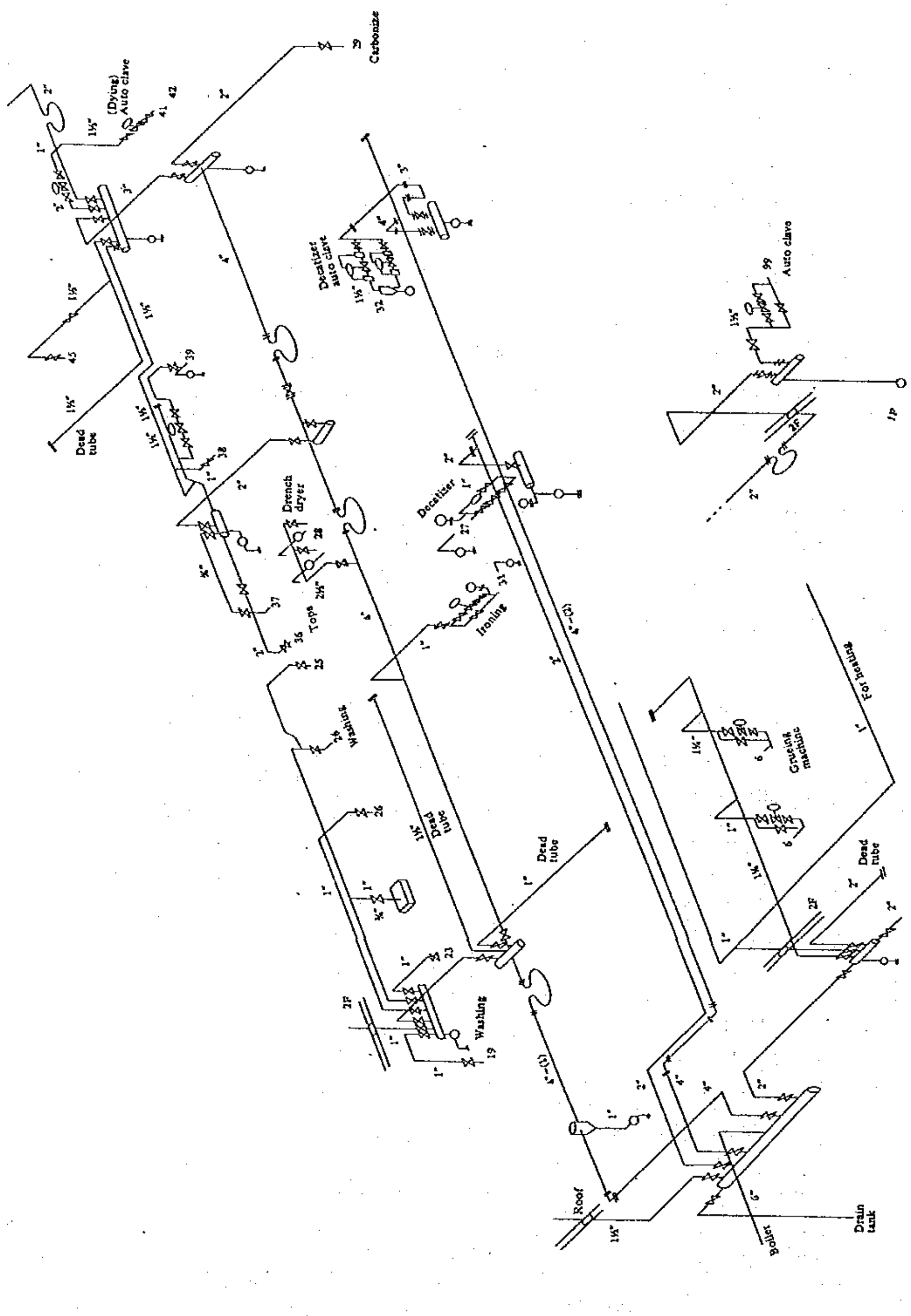


Figure 5–3–24 Wells Steam Line

The 4-inch branch lines for dyeing and washing had large bare areas, that were mainly pipes and valves. Heat radiation can be reduced by about 88 percent by insulating these bare parts.

Of these, the valves can be heat-insulated by the factory workers. The large valves may be enclosed in a wooden crate, which may then be filled with mineral wool. The small valves and flanges may be wound with mineral wool, and then wrapped with jute cloth.

The expenses required for insulating the pipes are shown in Table 5–3–35.

Table 5–3–35 Insulation Expenditure

Pipe dia.	Length m	@ U$S/m	Insulation expenditure U$S
6"	3	36.75	110.2
4"	8.5	24.03	204.3
3"	2	21.40	42.8
2½"	4	20.20	80.8
2"	31	18.15	562.6
1½"	35	16.65	582.8
1"	16	14.90	238.4
Total			1,821.9

Insulating the pipes will bring about the following saving in steam.

37458/489.5 = 76.5 kg/h

76.5 kg/h x 4,992 hy = 382 t/y

Since the fuel required to generate 1 ton of steam is 73.7 Nm^3, the saving in fuel will amount to:

382 x 73.7 x 0.08 = 2,252 U$S/y

The insulation expenditure is recoverable in 0.8 years.

If the steam leaking parts are left as they are, erosion will rapidly progress, causing increased leakage and repair expenses. Therefore, the leaking parts must be repaired soon. Attach a tag to each steam leaking point, and record the dates of finding leakage and repairing it in a ledger, thus preventing a delay in repairing leaking parts.

(2) Selection and maintenance of steam traps

(A) Operating condition of steam traps

The operating condition of the steam traps was checked using the diagnostic measuring instruments that had been brought from Japan as well as with the eyes and hands. The results of this check are shown in Table 5–3–36. Of the 21 steam traps checked, 43 percent were defective.

Table 5–3–36 Inspection Result of Steam Trap

Type	Good	No good
Disk	4	8
Float	8	1
Total	12	9 (43%)
Blowing		3
Leak		6

(B) Type of steam trap suited to condensate recovery

As shown in Table 5–3–36, the disk type traps in particular were found defective more than the other types. The main reasons are that the disk type traps are used for condensate recovery and are not properly cared. There are the following limitations on disk type trap adoption.

(a) Back pressure on steam traps must be not more than 50 percent of inlet pressure. If back pressure is gradually increased while maintaining inlet pressure constant, steam will leak from the trap or the trap will keep blowing.

(b) In the case of low pressure, the pressure difference between inlet and outlet must be more than 0.3 kg/cm^2. The thermodynamic trap other than dish type is neither suited to the recovery of condensate.

Thermostatic traps such as bellows type, bimetal type, etc. are also unsuited to condensate recovery. One type of thermostatic trap tends to accumulate condensate as back pressure increases to push the valve, while another type of thermostatic trap tends to let steam leak or keep blowing as back pressure rises.

Mechanical traps, such as the float type and bucket type, are suited as steam traps to be mounted at points where they are subject to the effect of back pressure. It is recommended that the existing traps be replaced by degrees with mechanical traps.

Replacing the steam traps with the best suited type of uniform size will facilitate management of the steam traps.

(C) Method of maintenance and management of steam traps

The person in charge of the management of steam traps must keep the steam traps in satisfactory condition at all times to maintain the steam using equipment operating at high efficiency, and to minimize steam loss while trying to reduce labor and cost to the lowest possible level.

(a) Inspection

Whenever making an inspection round of the factory, be sure to check the operating condition of the steam traps. The steam traps deteriorate with the time of use. If the percentage of defective traps is high, check them at least twice a year. If the defect percentage falls to less than 10 percent, an accurate check is recommended once a year. It is advised that a ledger be prepared to record the history of the individual traps and their inspection results. This will facilitate trap management as to trouble prediction and trends of trap deterioration.

(b) Inspection and maintenance methods

There are three kinds of steam trap trouble: Blow, faulty discharge, and steam leakage. The methods of checking and maintaining the steam traps to detect such defects early and take remedial steps are described below.

1) Visual method

If the steam trap to be checked has a sight glass at the outlet, its operation can be directly checked with the eyes. Since this is the surest method, it would be better to install a sight glass on the condensate recovery piping at the necessary points. Some of the existing sight glasses cannot be checked for internal operation because of improper care. It is necessary to periodically clean them.

The condensate recovery piping is laid in the ditch, so it is wet and loses heat. It is recommended that the condensate recovery piping be laid on or above the ground at a suitable time in the future.

2) Hearing method

Listen to the operating sound with a stethoscope and identify trouble.

3) Method by touch

Wear gloves, grip the steam trap inlet and outlet pipes, and feel the difference between their temperatures to determine whether the steam trap is properly operating.

4) Instrumental method

Use an ultrasonic instrument to check the operating sound of steam traps. A recently developed instrument checks the operating sound, surface temperature, etc. of a steam trap to automatically determine whether the steam trap is good or not referring to the trap type and steam pressure.

5) Maintenance

Disassemble and clean the strainers and sight glasses at each periodic inpsection time.

If any steam trap is found faulty, replace or repair it.

(D) Effect predictions

The amount of steam leakage from the steam traps was calculated as shown in Table 5–3–37. The annual amount of steam leakage amounts to 329 tons as shown.

Annual steam leakage

$65.9\ kg/h \times 16\ h/d \times 312\ d/y = 329\ t/y$

Steam leakage were obtained from the following equation

Blowing (kg (kg/h) = $0.4 \times P \times d^2$

d : Equivalent orifice dia. (2.6 mm for 1" trap)

p : Absolute pressure

Leakage = 1/10 Blowing

By repairing the leaking steam traps, the fuel can be saved by

$329 \times 73.7 \times 0.08 = 1{,}940$ U$S/y.

Table 5–3–37 Steam Leakage Through Steam Traps

Type	no.	Condition	Press kg/cm² g	Leakage per trap kg/h	Total leakage kg/h
Disk	3	Blowing	6	18.9	56.7
Disk	4	Leakage	6	1.9	7.6
Disk	1	Leakage	2	0.8	0.8
Float	1	Leakage	6	0.8	0.8
					Total 65.9

5.3.3.6 Power Receiving and Distributing and Other Electrical Facilities

(1) Outline of power receiving equipment

Electric power is received through the 13.2-kV underground cable, and supply meters, that is, an integrating wattmeter and an integrating reactive power meter, are installed at the power receiving point, which is connected to the switches in the transformer room in the factory through a cable. There are two 3-phase, 800-kVA transformers in the transformer room, where the received power is stepped down to 380 V and connected to the distribution board.

The distribution board distributes the power to the 12 sections for driving the machines and lighting (the lighting feeders are not shown in the one-line diagram of Figure 5–3–5).

A 230-kVar condenser is connected to the bus of the distribution board. The condenser is kept on from 6:00 through 22:00 to maintein the power factor above 90 percent.

(2) Measurements

Watt-power factor mèter (PFM-1000, PFMA-5210, PFM-1000P), AC clip-on power meter, and 12-point recorder were used to measure the following.

(a) No. 1 transformer secondary (Figure 5–3–25)

(b) No. 2 transformer secondary (Figure 5–3–26)

(c) Weaving (Teji dos)

(d) Drying (Acabado Humedo)

(e) Boiler (Usina)

(f) Spinning (Hilanderia)

(g) Finishing (Acabado Seco)

(h) Twisting (Retorcido Enconado)

(3) Power consumption

The factory's overall load condition is shown in Figure 5–3–25, 26. The load was steady at about 550 kW during the operating hours (6:00 to 22:00). The power factor was maintained at over 90 percent during the operating hours. The load on each feeder was also nearly steady during the work hours as shown in Table 5–3–38.

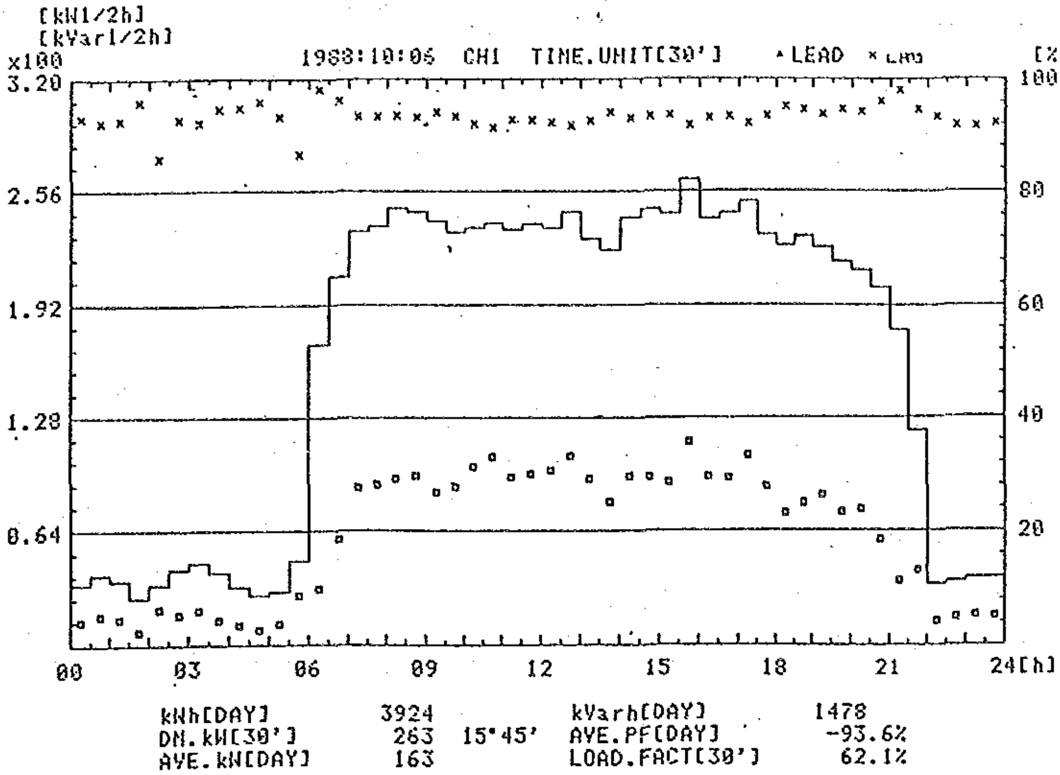


Figure 5–3–25 No. 1 Transformer Secondary

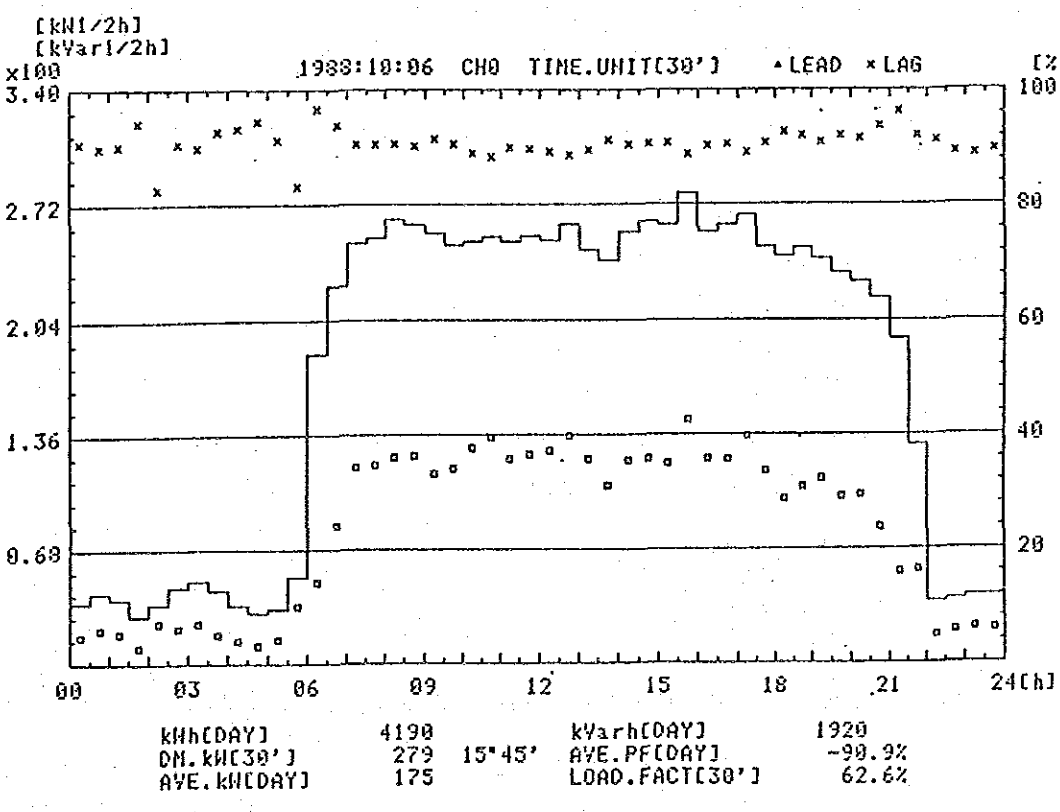


Figure 5–3–26 No. 2 Transformer Secondary

Table 5–3–38 Load of each Section

Section	Consumption kWh/d	Demand kW	Power factor %	Remarks
Weaving (Tejidos)	807	55	56	0 kW in night
Drying (Acabado humedo)	1,013	78	64	
Boiler (Usina)	895	51	70	
Spinning (Hilanderia)	1,970	143	60	0 kW in night
Finishing (Acabado seco)	312	28	67	0 kW in night
Twisting (Retorcido enconado)	1,366	97	79	0 kW in night

(4) Improvement of transformer operation

(A) The factory has two 800-kVA transformers, both of which must be kept in operation during the daytime work hours. However, the load is about 90 kW during the nighttime and days off, so it is suggested that only one of them be operated during the low-load hours to reduce transformer loss.

(B) Characteristics of 800 kVA transformers of 6.6-kV/400-V class

No-load loss : 3.2 kW

Load loss : 10.6 kW

Operation time operative with a single transformer

8 h X 312 d + 24 h X (365 d – 312 d) = 3,768 h/h

The load in kVA during nighttime and days off is:

$$\sqrt{(91)^2 + (74)^2} = 117 \text{ kVA}$$

When one of the transformers is put out of operation, the load loss of the operating transformer will increase as calculated below.

$$10.6 \times \left\{ \left(\frac{117}{800}\right)^2 - \left(\frac{59}{800}\right)^2 \times 2 \right\}$$

$$= 10.6 \text{ kW} \times (0.022 - 0.011)$$

$$= 0.1 \text{ kW}$$

Thus, the annual saving from operating one transformer in light load time will amount to:

$$3,768 \times (3.2 - 0.1) = 11,681 \text{ kWh/y}$$

When putting one of the two transformers out of operation, both the primary and secondary of the transformer must be disconnected.

(5) Lighting in the factory

The lighting load in the factory had been originally about 70 kW, but was reduced to about 10 kW in 1985, when the lights were relocated close to the work benches as an energy conservation measure. The luminance at the work benches was 250 to 500 lux, which satisfies the standard luminance of 300 to 750 lux for ordinary visual work. The overall luminance in the factory, however, was much lower at 60 to 130 lux. It is recommended, therefore, that sodium lamps be installed at points where luminance is insufficient to raise the luminance to 100 lux or over.

5.3.3.7 Summary

The following are the effects of the aforementioned improvement that can be estimated quantitatively.

Item		Possible annual amount of saving	%
Decrease of evaporation loss of atmospheric dyeing vat	Gas	14,900 Nm^3	1.2
Heat insulation of atmospheric dyeing vat		1,100	0.1
Heat recovery of dyeing waste liquor		23,200	1.9
Improvement of operation of drying machine		3,000	0.2
Prevention of idle running of dryer fan		5,600	0.5
Improvement of boiler air ratio		9,000	0.7
Heat insulation of steam pipe		28,200	2.3
Repair of steam trap		24,200	2.0
Total		109,200	9.0
Cut off of transformer at night and holidays	Electric power	11,700 kWh	0.5
Replacement of winder blower impeller		14,400 kWh	0.7
Total		26,100	1.2

5.4 Results of Survey of Paper and Pulp Factory

5. Survey of the Use of Energy in Model Factories

5.4 Results of Survey of Paper and Pulp Factory

5.4.1 Outline of the Factory

(1) Name of the factory : ANSABO S.C.A.

(2) Type of product : Paper and pulp production

(3) Location of the factory : Isidoro Iriarte 1257, Villa La Florida (1881), Prov. de Buenos Aires

(4) History of factory

This factory produces 6,900 tons of cardboard paper a year using only waste paper as material. It is a small one among the 15 paper and pulp companies in the country, and holds a market share of only about 2 percent. There are 36 corrugated board making machines in Argentina with an average capacity of 10,650 tons/year. Therefore, the actual capacity of this factory corresponds to about one half of the average capacity of those machines.

ANSABO acquired a factory 28 years ago, and has since been expanding the production facilities, building a new pulp process, updating the formation processes of the paper making machines, and undertaking other measures for modernization. ANSABO has only two engineers: the superintendent and quality control engineer. Operation is not continuous. Apart from one-month shutdown during summer, the factory has a day off weekly.

The energy conservation measures that have been taken so far include installation of hood on a paper machine, installation of condensers to improve the powe factor, and recovery of steam condensate.

Boiler fuel was changed from heavy oil to natural gas at the beginning of 1988.

(5) Number of employees : 66, including 2 engineers

(6) Survey period : October 11 to 14, 1988

(7) Survey members

Name	Position/assignment
Mitsuo Iguchi	Chief
Akira Koizumi	Paper and pulp process
Takashige Taniguchi	Heat management
Genzo Ema	Heat management
Teruo Nakagawa	Heat management
Toshio Iimori	Electrical management
INTI Members	
Mr. Jorge A. Fiora	Chief
Mr. Marcelo A. Silvosa	Unit operation, process
Mr. Alberto Berset	Heat using equipment
Mr. Anibal A. Monzon	Heat using equipment, mobile unit driver
Mr. Miguel A. Bermejo	Electric receiving and distributing equipment
Mr. Arturo D. Verghelet	Electric receiving and distributing equipment
Mr. Ignacio F. Cozza	Heat using equipment

Mrs. Beatriz R. Martinez — Heat using equipment

(8) Interviewed

Ing. Julio M. Angeletti — President

Ing. Ricardo Angeletti — Factory manager

Ing. Jose Dania — Quality control

(9) Production

Table 5-4-1 Production

Year	1983	1984	1985	1986	1987
Paper (t)	5390	5894	5712	8074	6888

(10) Energy consumption

Table 5-4-2 Energy Consumption

Year		1983	1984	1985	1986	1987
Oil	kl	960	1080	1200	1496	1579
Elect. power	MWh	1987.3	2258.7	2493.8	2997.6	3278.5
Energy/Product						
Oil	Gcal/t	1.75	1.80	2.06	1.82	2.25
Power	kWh/t	368.7	363.2	436.6	371.3	476.0

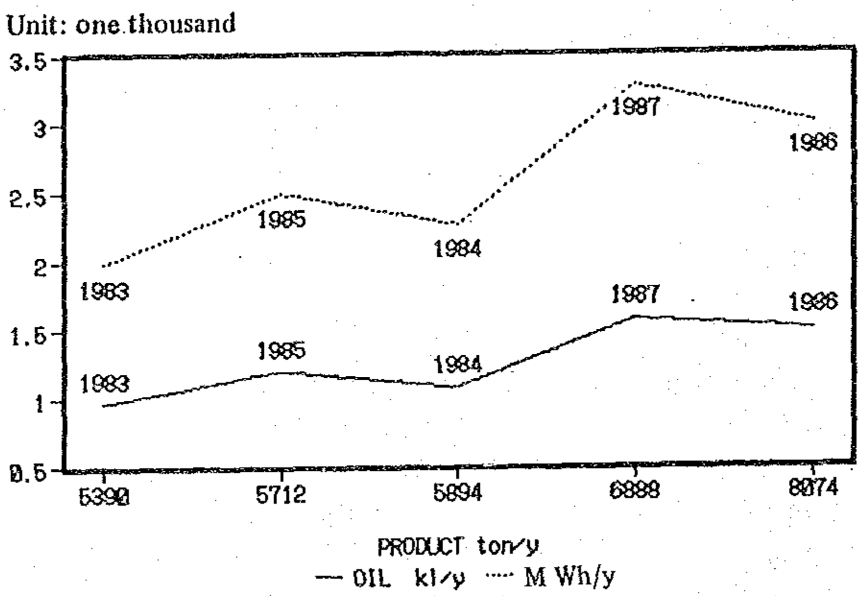
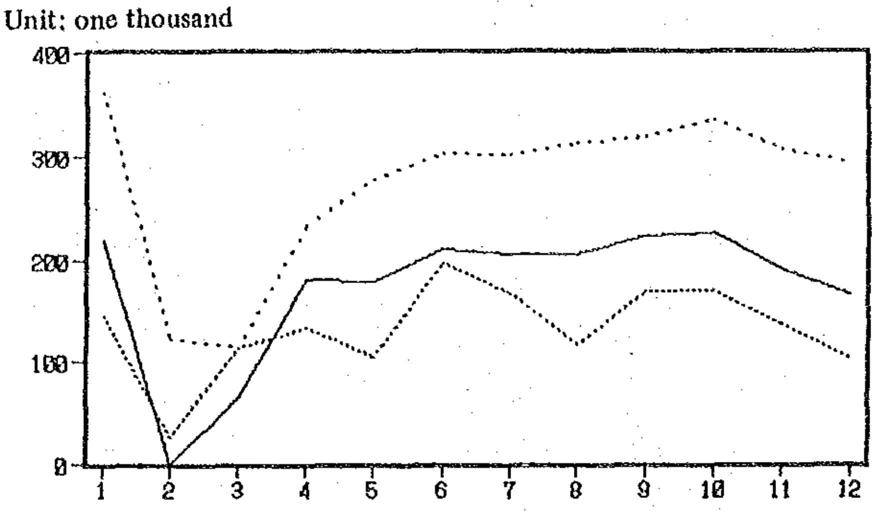


Figure 5-4-1 Production and Energy Consumption



—— PRODUCT (t) 300 . . . OIL kg . . . ELECTRIC POWER

Figure 5-4-2 Monthly Production and Energy Consumption

Electric power unit price : 0.06U$S/ kWh
Natural gas unit price : 0.09U$S/$Nm^3$.

(11) Factory layout

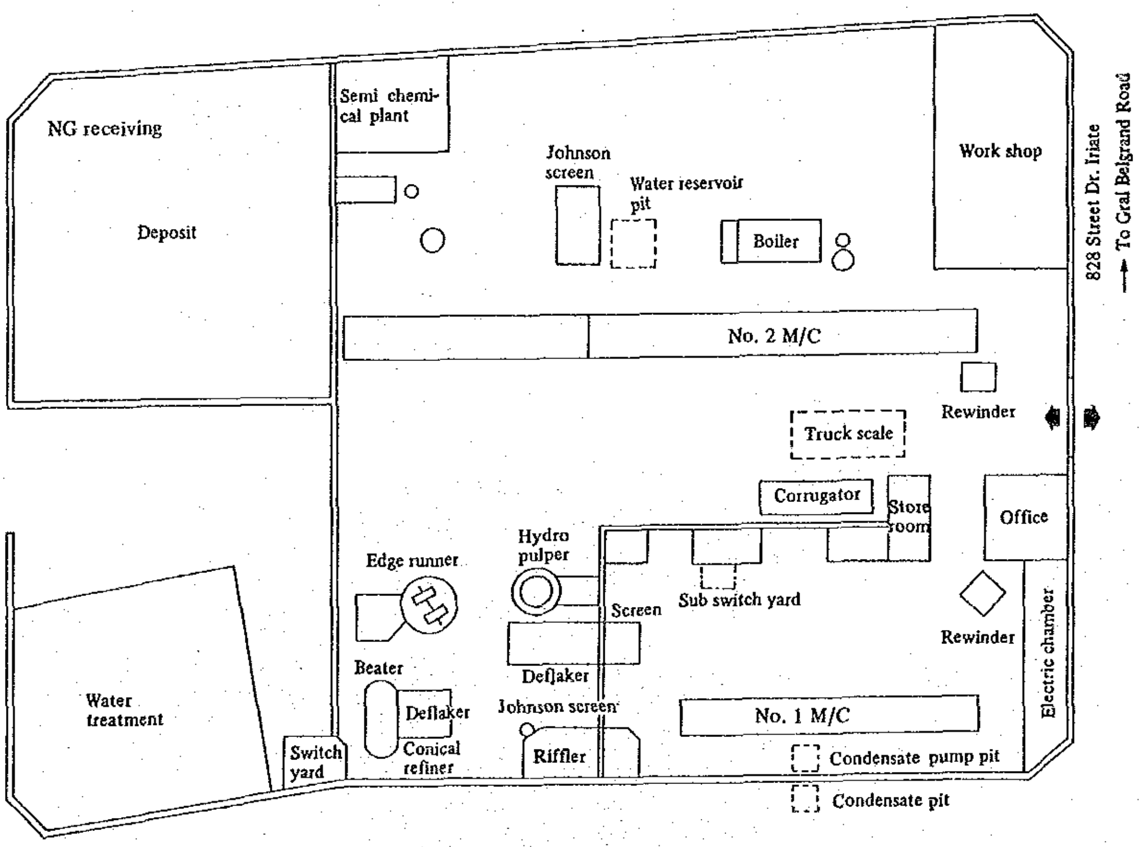
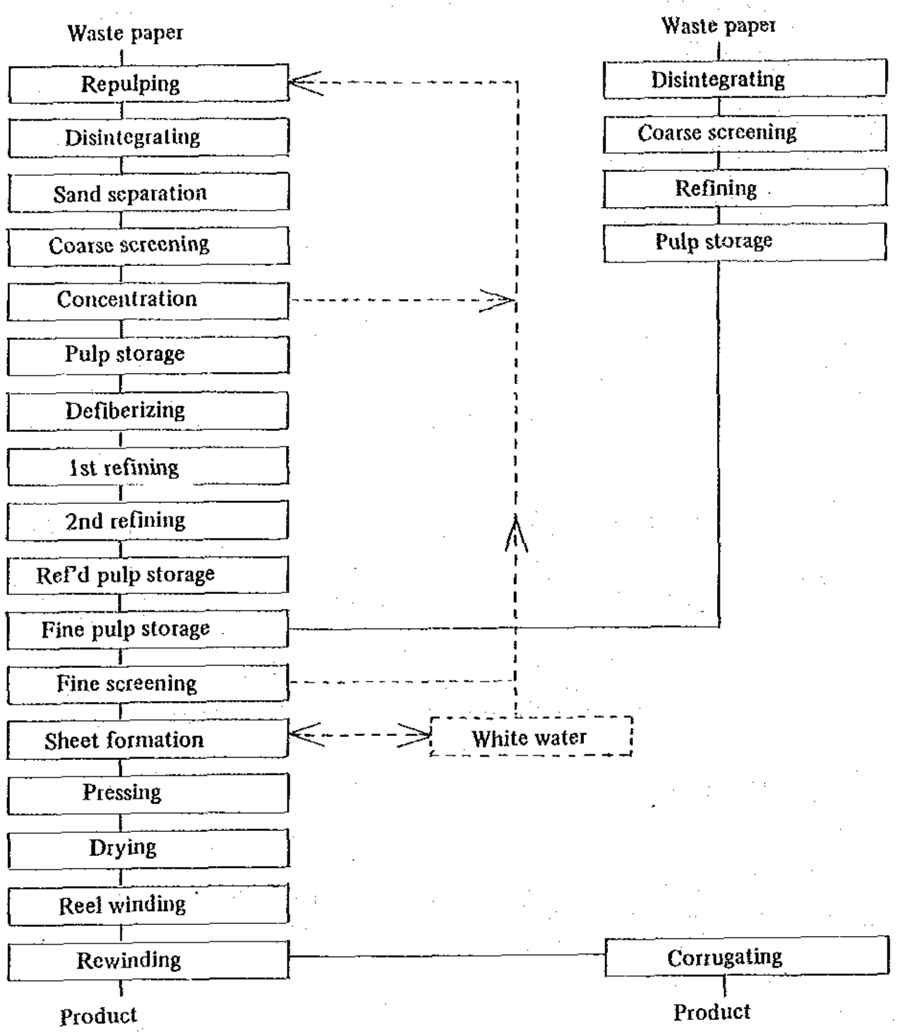


Figure 5-4-3 Factory Layout

(12) Production process



(13) One line diagram

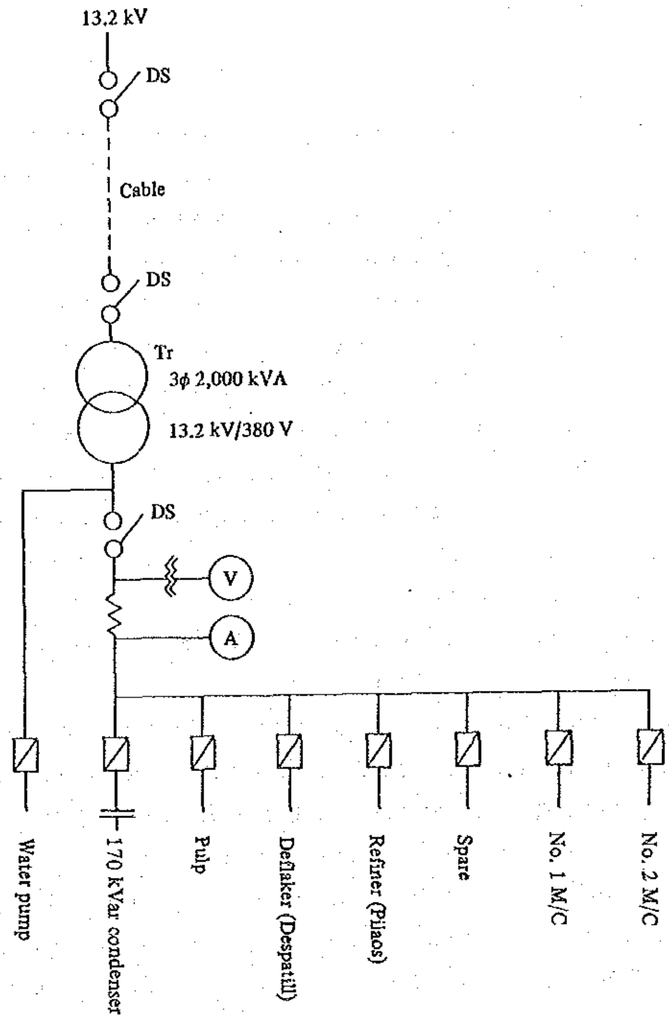


Figure 5-4-5 One Line Diagram

(14) Outline of main equipment

Table 5-4-3 Major Energy Consuming Equipment

Name	Number	Specifications
Boiler	1	4.4 t/h 8 kg/cm²
		Flue and smoke tube type
Pulper	1	100 Hp
Predeflaker	1	100 Hp
Deflaker	2	100 Hp
Refiner	4	Conical disc (2) 60 Hp + 70 Hp
		Disc (2) 150 Hp + 160 Hp
Paper machine	2	Cylinder's multidryer
		1.5 t/h, 1,700mm W.
		2.0 t/h, 1,900mm W.

(15) Factory operating time

24 h/d X 290 d/y = 6,960 h/y

5.4.2 Energy Management

(1) Energy conservation target

The responsible persons of the factory have interest in energy conservation but have neither a set target for energy conservation nor a concrete plan for improvement.

Paper mills use large amounts of water in which fibers are suspended at a low concentration level, and must remove the water from those fibers by pressing or heating evaporation. Therefore, their operation is essentially based on large consumption of energy.

The energy consumption of ANSABO is about an average for this type of factory, but should not be left as it is because more energy will be required in the event that there arises a need for further improvement of paper quality in the future. The ratio of the energy expenses to the sales of this factory is about 20 percent. Energy conservation must be systematically promoted because it not only conforms to the national policy but is an effective means of cost reduction. It is necessary first of all for that purpose to set an energy conservation target or energy consumption rate target for each process to show the direction for all the employees to follow and arouse their interest.

(2) Determining energy consumption

To reduce energy consumption and raise productivity and quality, their data and operating conditions must be recorded daily so that the actual conditions of plant operation can be accurately determined and compared. If variations are found in the recorded data, or if differences occur between planned or design values and actual data, the cause may be identified and a remedial step be taken to deal with the problem at once.

It is good practice in this factory that the gas meters are read from time to time and their readings of fuel gas consumption are reported to the foremen. Such a practice will automatically lead to a saving action.

Because data is not recorded daily, however, it is not possible to determine whether the present level of energy consumption is appropriate to the operating conditions, or collect information to trace the causes of variations in energy consumption. Electric power consumption is not checked daily, but only monthly from the bills of the electric power company. If something unusual occurs in energy consumption, it can be found only later, and it is not possible to identify the cause or take an appropriate remedial step while watching the subsequent trend. It is strongly suggested that energy consumption be checked and recorded daily.

Thermal energy is consumed in the form of steam in this plant, so install a feed water integrating meter on the boiler feed water pipeline and, if possible, a steam flowmeter on each machine, and record their readings every hour. This enables to determine the trends of steam consumption, and compare the readings with equipment operating conditions and production, and thus identify the causes of generating losses. If the daily totals of feed water and fuel gas consumption are recorded in the boiler journal, and are compared from day to day, changes in boiler efficiency can be assumed. Total feed water consumption divided by total fuel gas consumption is called the evaporation ratio, which should be at least 12 kg/m^3.

If a boiler journal is kept, cleaning intervals can be determined by assuming the dirtiness of the heat transfer surface from changes in exhaust gas temperature, or variations in the amount of recovered condensate can be determined from feed water temperature. It will make it possible to check long term changes, and is effective for not only saving energy, but also maintenance of the equipment. A boiler journal should be prepared by all means.

As regards electric power, read the supply meters daily and record the readings of daily consumption.

(3) Education and training

Even if the employees are willing to make improvements, they won't be able to take actual steps for improvement unless they know how. It is important, therefore, to educate the employees by means of training courses.

According to their story, there are few engineer training courses or few visits to other factories operating in the same industry. It is recommended that an official organ, such as INTI, promote training programs in the future.

There is no training course for the employees in the factory. It is important to start training them as to the prevention of motor idling, repairs for steam leakage, observation of the work standard, and other problems close to factory operation, so that the employees will have an awareness of the necessity of energy conservation.

(4) Equipment management

The paper making industry is liable to contamination of and damage to the equipment, and therefore the importance of maintaining the equipment in good order is high. ANSABO uses half a day or a day weekly for periodic repairs. As mentioned later, it is desirable for the paper making industry to keep continuous operations in point of energy, quality, and productivity. Operating the factory on Sundays is something that must be determined in view of the working conditions. If that becomes possible, however, periodic repairs can be made monthly on schedule.

It was observed that repairs were made speedily, but some steam leaks, faulty steam traps, and switch boxes not properly maintained were found. It is necessary to assign serial numbers to all the valves and traps, record their defects and repairs in the management book, and periodically service them.

The factory did not have design calculation data, drawings, and modification recordings of the main equipment, nor one line diagrams. These must be prepared and kept in file for use in drawing up improvement plans or speedily dealing with accidents.

It is desirable that a liquid level meter be installed for the chest and a thermometer for hood exhaust air.

5.4.3 Problems with Use of Energy and Remedial Meawures

5.4.3.1 Management of Waste Paper

This factory produces liners and corrugating medium for cardboards. These paper products are in the category of lowest prices so that energy expenses account for a large percentage of the production cost. Therefore, energy saving must be an object of great concern. Producing paper by reusing waste paper is significant not only from the standpoint of conservation of timber resources but also for energy conservation because, compared with the case of an integrated paper mill which processes timber into pulp and then into paper, the factory does not need any energy for producing pulp and thus consumes only about a half of the total energy of heat and electricity consumed by the latter. However, waste paper varies greatly in quality so that the quality of the material in the process and of the finished product tends to vary, and so does energy consumption.

Quality variations can be reduced by using waste kraft bags, or application of screening and refining, but it is important to purchase waste paper of high quality, prevent the waste paper in storage from deteriorating in quality, and take other steps to ensure satisfactory management of waste paper.

(1) Receiving waste paper

While waste paper is in storage, it becomes oxidized and its fibers grow brittle. If it is exposed to sunlight, winds, and rains, waste paper further deteriorates, and sandy dust may get into it. If waste paper quality lowers, yield will fall and electric consumption for converting it into pulp will increase.

(A) Acceptance quality standard

It is assumed that ANSABO has its own standard for the purchase of waste paper, but such a standard can hardly be applied to trade between a paper mill and individual waste paper dealers. It is suggested that a quality standard be established by the paper industry as in Japan.

(B) Acceptance inspection

Acceptance inspection is necessary at least one or twice a year. Waste paper should be checked for water, sand, plastics, film, stitches, adhesive tape, etc., and determine the percentages of these substances contained in the waste paper. Such a step will lead to a quality improvement effort on the part of the waste paper dealers, and provide data on waste paper quality up to date on the part of the factory to help take remedial measures for the equipment and operating processes in the future.

(2) Storing waste paper

The following steps must be taken for the storage of waste paper.

(A) Properly drain the waste paper yard so that there will not be water pools in the yard.

(B) Store waste paper by kind and quality. (Piling)

(C) Store waste paper by piling on pallets to prevent it from direct contact with the floor.

(D) Cover each pile of waste paper with old blankets or canvas.

5.4.3.2 Preventing Operation Interruption

The continuous operation is are essential to energy conservation in a paper mill once its equipment starts operation to produce paper.

If operation is interrupted,

(A) Products of faulty quality tend to increase at restart.

(B) If paper breaks, energy loss will occur because the material pulp and white water must be kept circulating.

(C) Loss will occur at the start of dryer heatup.

The factory stops its operation in the following cases:

Weekly day off

Half a day per week for periodic repairs and blanket cleaning

Twice or thrice a day when paper breaks.

Intermediate blanket cleaning

A well-managed cardboard factory makes periodic repairs for about 4 consecutive days once a month, and may have about twice or thrice of interruption per month due to paper breaks.

The following steps are recommended to reduce or prevent interruption of plant operation.

(1) Preventing paper from breaking

The following are necessary to reduce or eliminate paper breaks.

(A) Produce wet sheets free of dust and other foreign matter. For this purpose, it is necessary to reinforce waste paper management as mentioned above and screening as mentioned later.

(B) Use washed clean blankets. Refer to the subsequent section on the press.

(C) Make uniform the pressure applied by the press.

(D) Regulate the cylinder rpm (revolutions per minute) so that the paper won't shrink and be too tense in the drying process.

(E) Prevent dust and water from dropping from the hood top, etc.

(F) Completely remove adhesive matter from the cylinder surface using doctor knife to prevent holes from being made in the paper.

(G) Prevent paper quality from lowering due to overdrying.

Everyone should know all of these, which, however, were left ignored as matters of fact. It is important for preventing paper breaks to take steps that have been ignored but are necessary.

(2) Preventing stoppage due to failure

Stoppage of operation may be caused by equipment damage such as failures in the electrical system, steam system, or water system; breakage of rotary parts; and by inferior quality of paper making instruments, like breakage of the wire nets or blankets. The equipment and instruments must be thoroughly checked, repaired, washed, and cleaned at periodic maintenance times. The workers engaged in production and maintenance must cooperate with one another toward the common target of continuous operation.

The factory now has a day off each week. If this way of suspending operation weekly is replaced by a few consecutive days a month of suspension for repairs, paper making efficiency, yield, and thermal efficiency can be improved, and product quality will be constant.

5.4.3.3 White Water Circulation

The factory consumes about 50 tons of water per ton of paper, which is a satisfactory figure. This indicates the great concern that the factory has about white water circulation. If white water circulation is satisfactory with a low rate of supply of fresh water, the pulp temperature will rise, dehydration in the formation process and squeezing in the press part will improve so that the drying heat load will decrease and steam consumption will be reduced. White water circulation also help to improve the yield through recovery of fibers that might have been lost otherwise, and reduce waste water to contribute to environmental protection.

An increased rate of white water circulation, however, will accelerate contamination of the paper making equipment and instruments so that added caution must be exercised in the maintenance and management of white water.

(1) Pulp water temperature in each part

The results of measuring the temperatures of the main parts from the pulp process to the No. 2 paper machine are shown in Table 5–4–4. It was found by comparing the temperature of industrial water with the machine chest water of the high temperature that there was a temperature difference of 12.2°C (that is, 32.7°C – 20.5°C). The temperature increased to 32.7°C because the electric power used for refining, stirring in the chest, and pumping up was transformed into thermal energy and accumulated as such. There was a report showing an instance of a temperature rise in inverse proportion to decreased use of fresh water in which the temperature increased to 40°C from fresh water of 21°C. This instance had an added advantage that the high temperature totally prevented slime generation and helped stabilize quality. As shown in Table 5–4–4, the temperature fell in the paper machine because of fresh water for the wire cleaning shower, deckle shower, and blanket cleaning shower. Fresh water consumption can be reduced by improving the deckle shower as mentioned later. If the water for blanket cleaning is heated by recovered heat, it will help raise the white water temperature.

(2) Reducing fresh water

It is necessary to reduce the supply rate of fresh water in order to raise the white water temperature. Table 5–4–5 shows the results of measuring all the fresh water used in the No. 1 and No. 2 machines for shower. Pressurized fresh water is used for cleaning the wire meshes of the cylinder, deckle shower, and blanket cleaning. The fresh water for cleaning the cylinder wire nets cannot be dispensed with, but for the deckle shower sometimes white water is applicable because pressure is not necessary so high.

The method of attaching a very smooth, separable adhesive tape is increasing to serve as a deckle. Be sure to try it. Only a small amount of running water is sufficient for the purpose.

Table 5-4-4 Temperature and Consistency of Main Process

Process Name	Temperature (°C)	Consistency (%)	Reference	
			PH	Freeness
Before deflaker (After pulping)	25.3	1.47	7.63	–
Inlet of Johnson screen	25.4	1.17	7.67	–
Outlet of extractor	24.3	5.50	7.71	–
Paper machine chest (No. 2 M/C)	32.7	9.96	7.33	S.R. 48°
Before fine screen (No. 2 M/C)	25.6	0.9	7.80	–
1st cylinder moulder vat	23.6	0.2	8.18	–
Mill water (Laboratory)	20.5	–	–	–

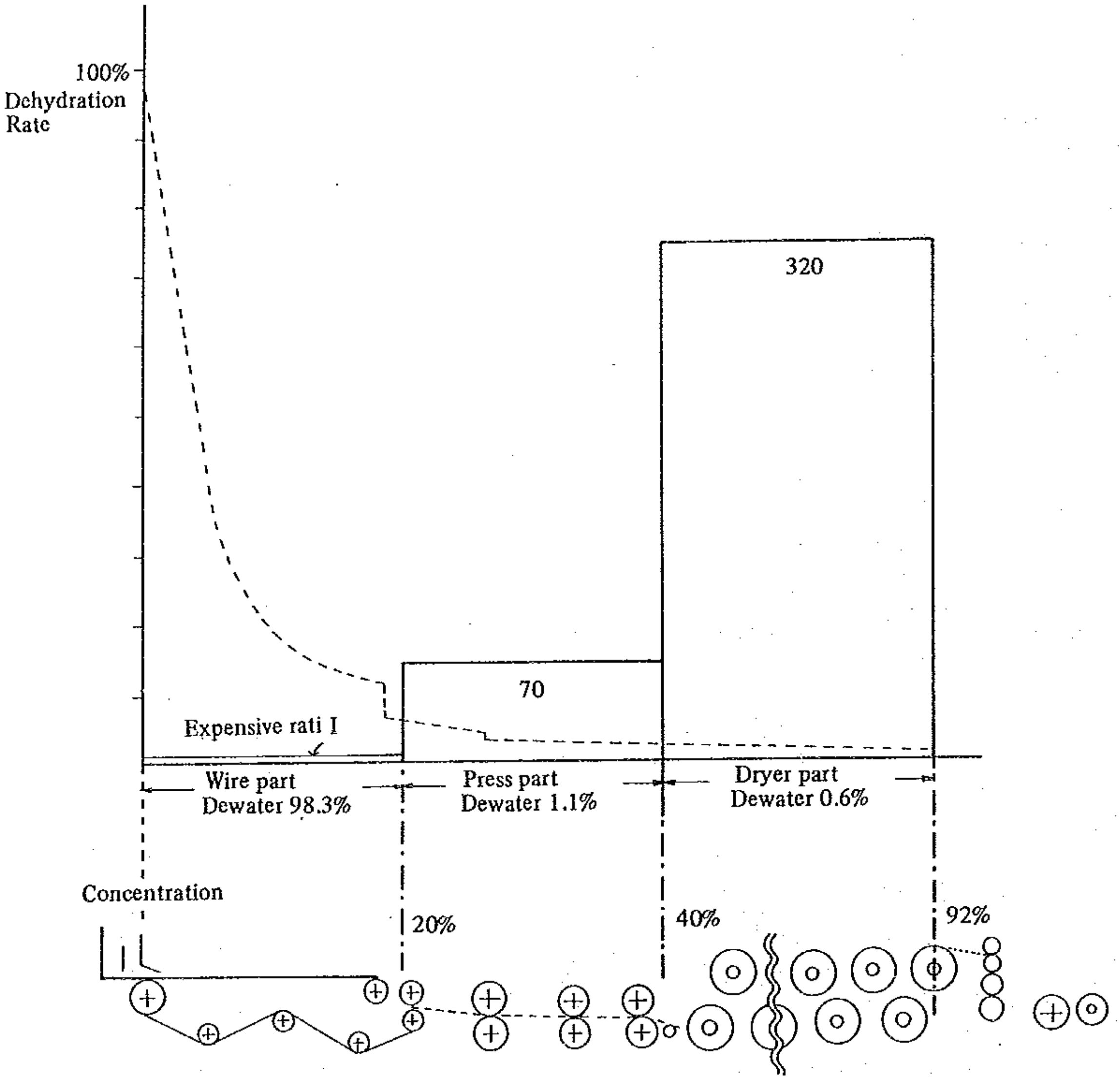
Sampling: Oct. 12th '88 A.M. 10:30 – 11:55
Measurement: INTI Cellulose & Paper Labo. ANSABO-Mill Labo.

Table 5-4-5 Fresh Water Flow

	Flow	User for
High pressure water	9.37 m^3/h	No. 1 M/C and No. 2 M/C Cylinder mould wire 1st blanket
Low pressure water	15.2 m^3/h	No. 1 M/C Cylinder mould deckel shower and 2nd blanket shower
	14.7 m^3/h	No. 2 M/C Cylinder mould deckel shower and 2nd, 3rd blanket shower

5.4.3.4 Press Part

The cost of drying wet paper by heat is 5 times as much as the mechanical dehydration cost of the press part. It is therefore necessary to minimize the water content of wet paper before entering the dryer part. Figure 5–4–6 shows a comparison of the dehydration rates and costs of the individual parts in making uncoated paper.



Reference Book: The paper maker, Dec. 1970 "new feature in press part design of fine paper machine."

Figure 5-4-6 Dehydration Rate, Concentration and Expensive Ratio of Fine Paper Machine

(1) Function of press part

1) Far less costly than thermal drying that uses steam or other source of energy.

2) Wet paper strength increases as sheet density increases simultaneously with squeezing so that there will be less paper breaks at the press or dryer part.

3) Wet paper surface is smooth and strong at the same time.

4) If there is much water at the dryer inlet, fibers tend to stick to the dryer cylinder, preventing the cylinder surface temperature, particularly at points close to the wet end, from rising enough.

5) If wet paper contains much water, it becomes loose and wrinkled at the open draw point, resulting in a faulty product or paper breakage.

(2) No. 2 machine press part dehydration

Of all the No. 2 machine equipment, the press part was well equipped. It consists of three presses, and can dehydrate about 57 percent. As shown in Table 5–4–6, there is a water content difference of 4.3 percent after pressing between the No. 1 machine and No. 2 machine, and there is a much larger difference of about 21 percent between them in terms of the amount of water evaporation. The amounts of water before and after pressing at the No. 2 machine and at the dry end shown in Table 5–4–6 are diagramatically shown in Figure 5–4–7. Water content samples were taken from the front, center, and back equally divided in the width direction.

Table 5-4-6 Moisture of Each Wet End and Each Dry End

	Part of cross direction	Front side	Center	Back side	Average
No. 1 M/C	Before pressing wet sheet moisture (%)	64.49	65.31	69.52	66.43
	After pressing wet end sheet moisture (%)	61.09	61.51	62.06	61.5
	Dry end paper moisture (%)	4.63	4.89	5.41	4.68
No. 2 M/C	Before pressing wet sheet moisture (%)	69.9	65.2	63.7	66.27
	After pressing wet end sheet moisture (%)	55.8	57.3	58.6	57.23
	Dry end paper moisture (%)	0.9	1.22	1.3	1.14

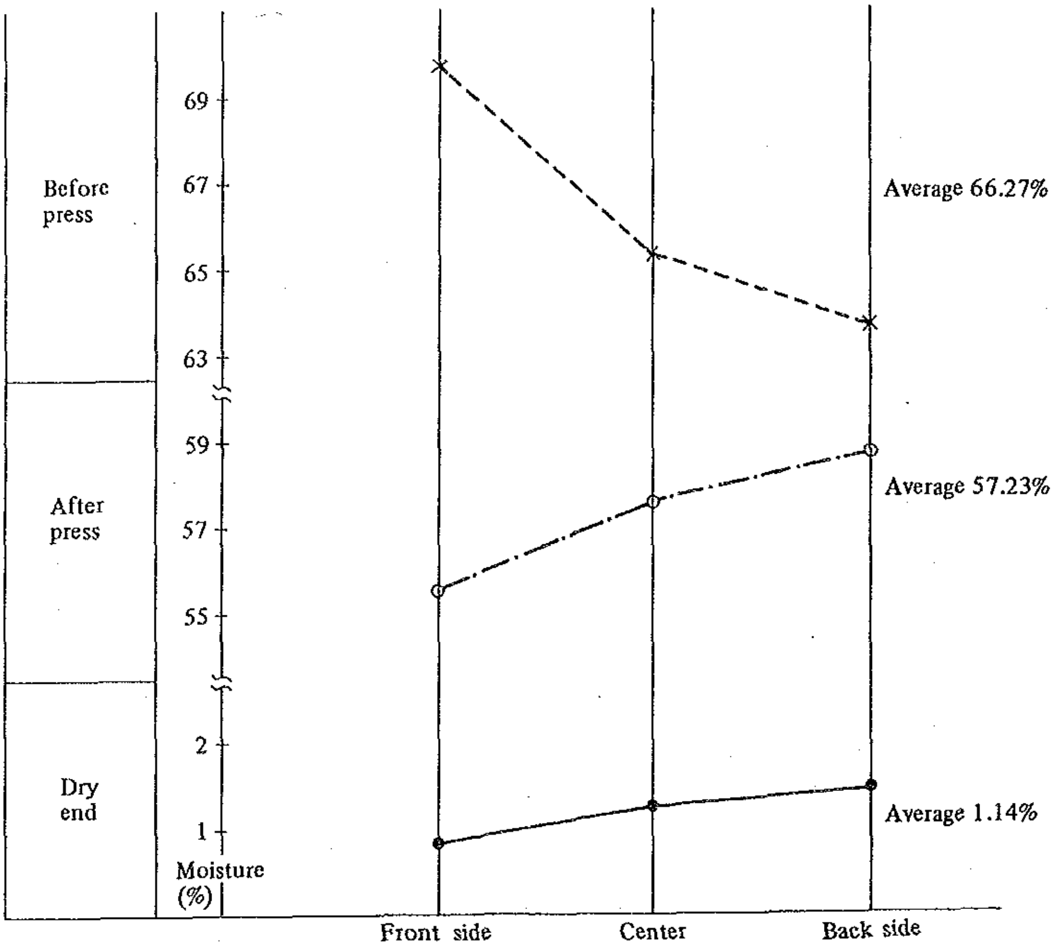


Figure 5-4-7 Change of Moisture on No. 2 M/C

Before the press part (that is, after the wire part), the front piece showed an abnormally high water content, presumably because the blanket was dirty or the suction function in front of the suction box was faulty. There was a difference of 2.8 percent between the front piece and rear piece after pressing perhaps because the presses applied an uneven linear pressure, not a uniform pressure. This effect continued to the dry end.

The infrared ray thermal picture in Figure 5–4–8 shows a high temperature in front, and a low temperature in back. This was partly due to the effect of air currents running from the back to the front of the machine as mentioned later, and partly due to the insufficient pressing of the back leaving much water. Perhaps, the front has higher density than the back, and is different in thickness from the back. The real thickness appears different between the right and left in the picture, indicating what has been mentioned above.

The front dries more quickly than the back because it contains less water at the dryer inlet. The front tends to overdry if an attempt is made to adjust the water content of the back to that of the finished product.