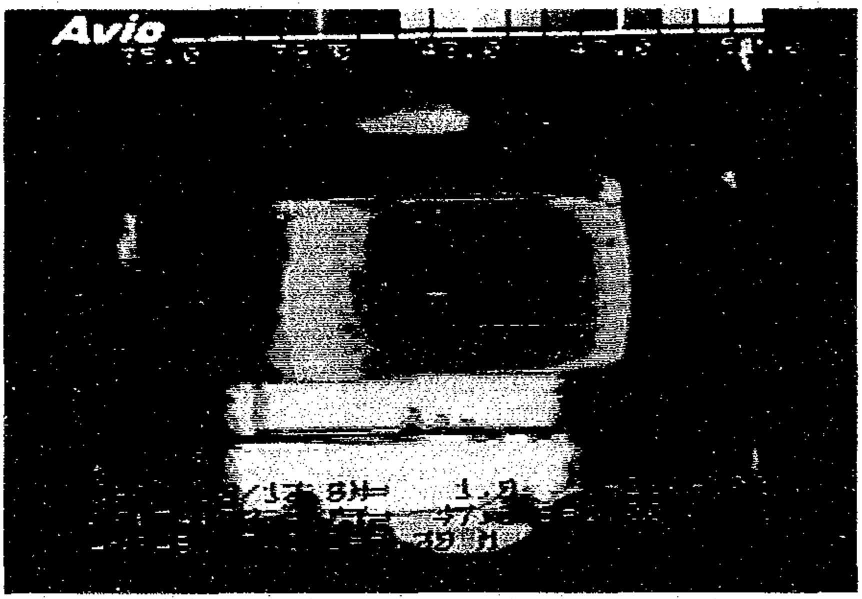

Figure 5-4-8 Surface Temprature of Dry End Reel

(3) Wet end water content and evaporation quantity

The quantity of steam required for drying decreases and so does the cost as wet end water content (after pressing) decreases. If water content is decreased 1 percent by pressing, evaporating water decreases about 4 percent shown below.

Wet end water content after pressing : Xi%

Dry end water content after dryer : Xo%

Under the above conditions, the quantity of pulp at the dry end will be (100 – Xo)%, and the quantity of pulp at the wet end (100 – Xi)%.

The balance of water for 1 kilogram of paper absolutely dry will be as follows:

Water entering the dryer . . . . $\frac{Xi}{100 - Xi}$ kg

Water going out of the dryer . . . . $\frac{Xo}{100 - Xo}$ kg

Water evaporating . . . . $\left(\frac{Xi}{100 - Xi} - \frac{Xo}{100 - Xo}\right)$ kg

Quantity of evaporating water from 1 kilogram of paper with water content of Xo% will be:

$$W = (100 - Xo)\left(\frac{Xi}{100 - Xi} - \frac{Xo}{100 - Xo}\right) \times \frac{1}{100} = \frac{Xi - Xo}{100 - Xi}$$

The water content of paper at the dry end is generally set to somewhere between 5 and 10 percent.

Suppose that paper containing 58 and 59 percent water at the wet end (before entering the dryer) is processed into 1 kilogram of paper with a water content of 7 percent.

If $Xi = 58\%$, $W_{58} = \frac{58 - 7}{100 - 58} = 1.214$ (kg)

If $Xi = 59\%$, $W_{59} = \frac{59 - 7}{100 - 59} = 1.268$ (kg)

A 1 percent increase in water content after press part increases water evaporation by 0.054 kg, per kiloggram of paper or about 4.4 percent.

(4) Uniform pressing

To increase dehyration from the present level, first check whether the linear pressure of the press rolls is uniform over the full width as shown in Table 5–4–6 and Figure 5–4–7. There are two methods of checking it. One is to use slightly embossed aluminum foil, and the other is to use non-carbon paper between the rolls. (Refer to the Guideline.)

High pressure is of course preferable, but it is important to check the strength of the equipment and reinforce it if necessary before applying pressure.

Also check the rolls for the crown condition, and the rubber rolls for hardness. Make sure that the equipment is in satisfactory condition beforehand.

(5) Blanket

1) Blanket quality

The blankets for the presses must be elastic, and easily absorb and discharge water. In selecting blankets of such quality, check their dehydration rate, contamination, ease of cleaning, life, etc. by actual use and discussions with the blanket manufacturer so that the selected blankets will have a quality suited to paper making machines.

2) Blanket cleaning equipment

Both the No. 1 and No. 2 paper machines need improvement of their blanket cleaning equipment, which should include showers, whippers, squeeze rolls, and suction boxes. The blanket cleaning equipment pours water on the blankets, strikes them, rubs them, and squeezes them. The combination of these components must be so selected that cleaning will be effective, dehydration rate will increase, and uniformity of pressure can be achieved. This factory is equipped with showers and suction boxes alone, which are not sufficient. It is recommended that whippers or squeeze rolls be added to the present equipment.

The blankets run from a height of 3 meters to floor level at the same speed as paper, and requires attention to safety in the same way as the belts. It is suggested that a footing be built to permit safe checking and monitoring of the operating condition of the blanket cleaning equipment. The detergent tank and pump for cleaning the blankets must be set at a fixed point to ensure safety and speed of operation.

3) Cleaning with hot water

The blankets are cleaned by forcing high-pressure water into them, rubbing, striking, and squeezing them. Hot water is clearly more effective than cold water for cleaning, thus improving their elasticity and raising the dehydration rate of wet sheets, which maintain higher temperature than when cold water is used for cleaning. Thus, the dryer load will decrease and steam will be saved. There are instances in which blanket cleaning water is heat-exchanged with dryer condensate.

5.4.3.5 Examination of No. 2 Paper Machine Drainage System

(1) Drying pattern of paper machine

The drying curve for a dryer varies to some extent with the type of paper. It can be divided into parts for the preheating period, constant rate dryings period, anf falling rate drying period.

A typical drying pattern is shown in Figure 5–4–9. (A standard diagram of paper making at 350 g/m^2 at a certain cardboard plant) The target steam pressure and cylinder surface temperature of each cylinder group are changed as occasion demands according to the quality requirements (smoothness, paper form, stretch/shrink, etc.) or the need for decreasing steam consumption.

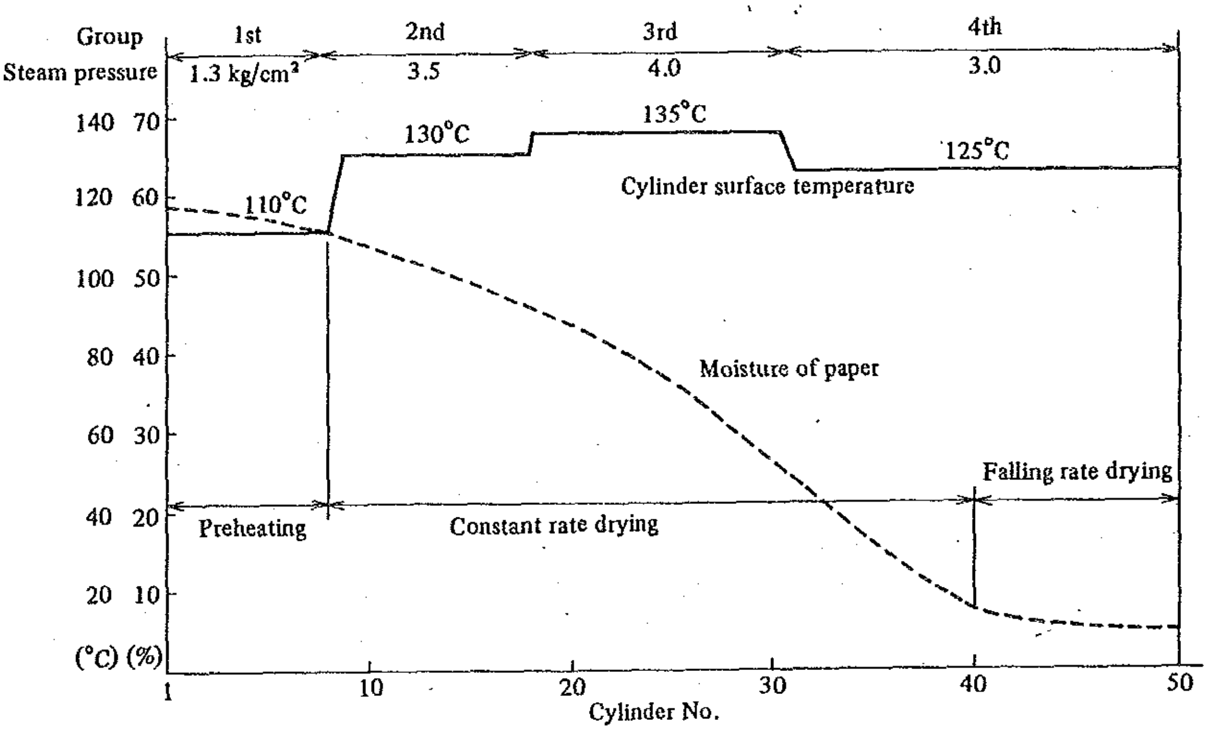

Figure 5-4-9 Typical Drying Pattern

(2) Temperature distribution of No. 2 paper machine

The side temperature of the No. 2 paper machine cylinder and the temperature of the paper across the running width are shown in Figure 5–4–10.

These temperatures were measured using a radiation pyrometer. The No. 2 paper machine has 14 dryer cylinders and one Yankee cylinder.

Wet paper from the press contacts the No. 1 cylinder which is relatively low in temperature, and then No. 2 to No. 10 cylinders whose surface temperature is over 100°C.

It then contacts the No. 11 Yankee dryer with a surface temperature of 60 to 70°C, and is heated high again at the No. 12 to No. 14 cylinders. The final No. 15 cylinder has a surface temperature of about 60°C, at which the drying process ends.

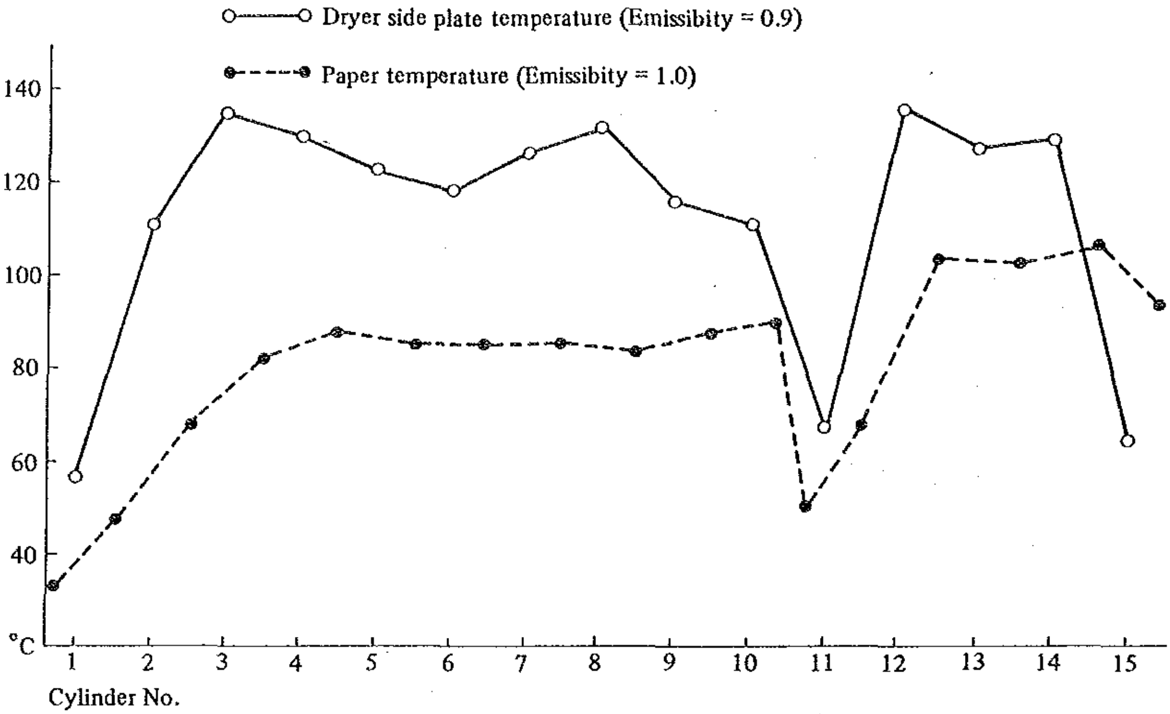

Figure 5-4-10 Temperature of Dryer Surface Paper of No. 2 M/C

(3) Steam consumption at 3 kg/cm^2 system and 1.3 kg/cm^2 system

Steam of 3 kg/cm^2 G is supplied parallel to the 14 cylinders, while steam of 1.3 kg/cm^2 G is supplied to the single Yankee cylinder. The resultant condensate is collected by a single header, from which it is returned to the boiler feed water tank.

The No. 2 paper machine consumes about 2.1 tons of steam per hour. The distribution of this steam to the 3 kg/cm^{2}G line and 1.3 kg/cm^{2}G line should be determined from the evaporation rate by sampling sheets running from cylinder to cylinder and measuring their water content. Because it is very difficult to sample the running sheets, steam consumption is assumed from the heat transfer area as follows.

Cylinder heat transfer area receiving 3 kg/cm^2 steam.

$1.2 \text{ m} \times \pi \times 1.8 \times 14 = 95.0 \text{ m}^2$

Cylinder heat transfer area receiving 1.3 kg/cm^2 steam

$3.2 \times \pi \times 1.8 \times 1 = 18.1 \text{ m}^2$

If steam consumption is divided between the 3 kg/cm^2 line and 1.3 kg/cm^2 line based on the above heat transfer areas,

$$2.1 \text{ t/h} \times \frac{95.1}{95.0 + 18.1} = 1.8 \text{ t/h}$$

$$2.1 \text{ t/h} \times \frac{18.1}{95.0 + 18.1} = 0.3 \text{ t/h}$$

(4) Calculation of drainage system effect

A plan was drawn up as shown in Figure 5–4–11, under which the existing facilities would be utilized to the maximum extent to supply the flash steam of the 3 kg/cm^2 line to the 1.3 kg/cm^2 line.

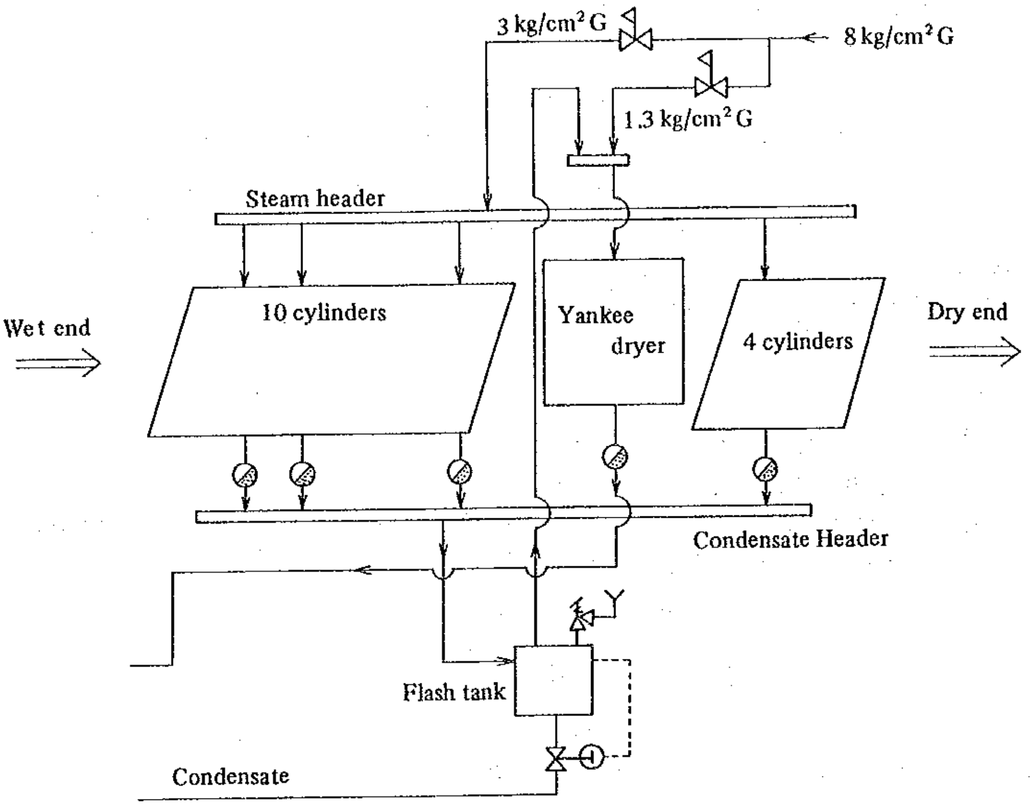

Fig 5-4-11 An Example of Drainage System

The amount of steam that can be supplied to the 1.3 kg/cm² line is calculated as follows.

Saturated water sensible heat at 3 kg/cm² G : 144 kcal/kg

Saturated water sensible heat at 1.3 kg/cm² G : 124 kcal/kg

Evaporation latent heat at 1.3 kg/cm² G : 523 kcal/kg

$$1.3\ \text{kg/cm}^2\ \text{G generated steam:}\ \frac{(144 - 124)\ \text{kcal/kg}}{523\ \text{kcal/kg}} \times 1.800\ \text{kg/h} = 69\ \text{kg/h}$$

$$\text{Steam saving rate will be:}\ \frac{69\ \text{kg/h}}{2100\ \text{kg/h}} \times 100 = 3.3\%$$

The flash tank and instruments are main components of the equipment. The flash tank capacity can be calculated from Table 6–8 of the Guideline.

In this case, it comes out to be 8" in diameter and 940 mm in height with some dimensional allowance. The condensate pipes for the inlet and outlet should have same diameter (2-1/2") as the collecting tube, while the flash steam pipe should be 3" so that the fluid velocity will be less than 15 m/s.

The necessary control equipment includes a liquid level controller to maintain liquid level in the flash tank, and relief valve to control the upper limit of pressure.

The total cost required for the above-mentioned equipment will be less than $20,000, while the resultant energy saving will be:

$69 \times 6{,}960 \times \frac{92.9}{1{,}000} \times 0.09 = 4{,}015$ U$S/y because the amount natural gas required to generate steam of 1 ton is $\frac{328.05}{3.53} = 92.9\ \text{Nm}^3/\text{t}$.

5.4.3.6 No. 2 Paper Machine Dryer Ventilation

Appropriate ventilation is necessary to effectively dry wet paper with a limited amount of heat and thus produce paper of constant quality.

The No. 1 paper machine is an open dryer type, though it will be equipped with a semi-closed hood in the near future. The No. 2 paper machine which already has a semi-closed hood was checked whether its function was effective measures for improving it were also examined.

(1) Preconditions (Measurements made on October 13 except for water content which was measured on October 12)

1) Weight : Corrugating medium 135 g/m^2
2) Paper making speed : 50.8 m/min
3) Trim width : 1,650 mm
4) Paper production : 135 g/m^2 x 50.8 m/min x 1.65 m x 60 = 680 kg/h
5) Wet end water content : 57.2%
6) Dry end water content : 1.16%
7) Evaporating water : $\frac{57.2 - 1.16}{100 - 57.2} \times 680 = 900$ kg/h

(2) Dryer evaporation rate

Evaporating water ÷ Cylinder drying area

$$= 0.9 \text{ tons/h} \div (\underset{\text{Cylinder diameter}}{1.2 \text{ m})} \times \pi \times \underset{\text{Width}}{1.8 \text{ m}} \times \underset{\text{No. of cylinder}}{14} + \underset{\text{Yankee diameter}}{3.2 \text{ m}} \times \pi \times \underset{\text{Width}}{1.8 \text{ m}})$$

$$= \frac{900 \text{ kg/h}}{95.0 \text{ m}^2 + 18.1 \text{ m}^2} = 8 \text{ kg/(m}^2\cdot\text{h)}$$

The evaporation rate in a case where about 150 g/m^2 of paper is processed using a semi-closed hood dryer is about 15 $kg/(m^2 \cdot h)$ according to the Tappi data sheet, which is based on the use of PV (pocket ventilation) roll and plastic canvas, against the former value of about 8 $kg/(m^2 \cdot h)$. The evaporation rate of the No. 2 paper machine may be said to be about the average for that time because it does not have PV rolls.

(3) Results of measurement of air temperature and humidity

The results of measuring air temperature and humidity under the hood are shown in Figure 5–4–12. As shown, the humidity was higher in front than in back, indicating that air was flowing from back to front.

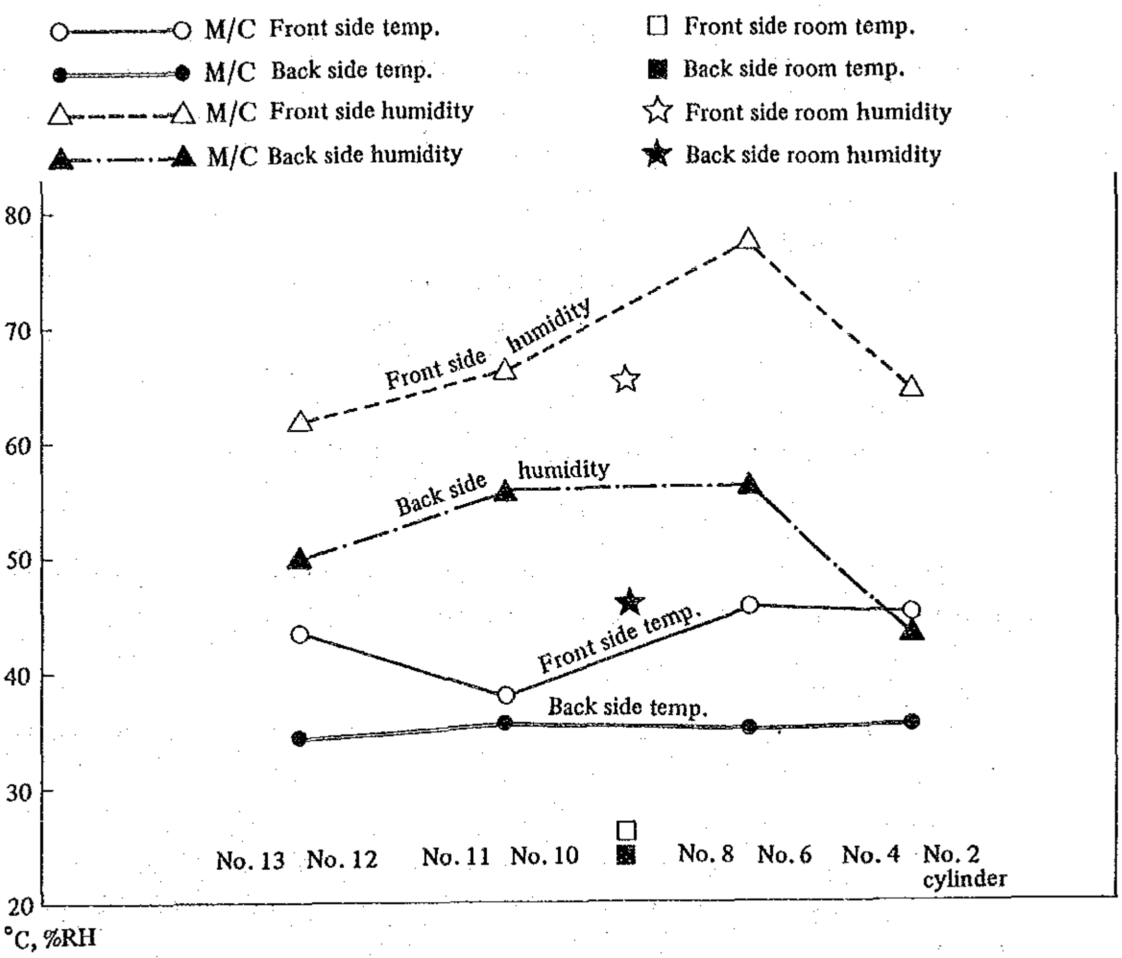

Figure 5-4-12 Temperature and Humidity in Dryer Hood (No. 2 M/C)

(4) Evaporated water balance in dryer part

The water content of the air supplied to the hood

The air conditions for the rear part under the hood are used.

Temperature : 25°C
Relative humidity : 55%
Absolute humidity : 0.010 kg/kg –dry air
Specific volume : 0.86 m³/kg – dry air

The water content of the air in the duct over the hood : 45°C saturated

Temperature : 45°C
Relative humidity : 100%
Absolute humidity : 0.065 kg/kg – dry air
Specific volume : 0.99 m³/kg – dry air

Amount of air passing through the duct over the hood

From Table 5–4–7

$0.63^2 \times \pi/4 \times (4.2 + 2.6) \times 3{,}600 = 7{,}630\ \mathrm{m^3/h}$

$7{,}630/0.99 = 7{,}700$ kg – dry air/h

Amount of water taken out through the hood

$7{,}700 \times (0.065 - 0.010) = 420$ kg/h

The water evaporation rate in the paper drying process is 900 kg/h as shown in the preconditions specified in item (1) above, about 480 kg/h of water is assumed to have been carried away by the air running from the back of the machine to the front.

The water content of the air in front under the hood

Temperature : 44°C
Relative humidity : 68%
Absolute humidity : 0.041 kg/kg – dry air
Specific volume : 0.96 m^3/kg – dry air

The amount of air passing from back to front of the machine

$$480/(0.041 - 0.010) = 15{,}500 \text{ kg – dry air/h}$$

If the area of air passing is assumed to be 25 m^2, air velocity will be:

$$15{,}500 \times 0.96 \times \frac{1}{3{,}600} \times \frac{1}{25} = 0.2 \text{ m/s}$$

If all the evaporating water from the wet paper is assumed to be discharged from top of the hood, it is theoretically necessary to pass air at the rate specified below.

$$\frac{900}{0.065 - 0.010} = 16{,}000 \text{ kg/h}$$

The amount of air normally required per ton of paper in the case of an open hood is 50 to 60 tons.

$$0.68 \times 60 = 41{,}000 \text{ kg/h}$$

Therefore, the amount of air to be discharged from the hood will be about 5 times as much as is discharged at present so that one or two additional ducts will have to be installed.

Table 5-4-7 No. 2 M/C Hood Exhaust

	Diameter (mm)	Exhaust speed (m/sec)	Exhaust temp. (°C)	Exhaust capa. (m^3/min)
No. 1 duct	630	4.2	44	78.5
No. 2 duct	630	2.6	48	48.6
			Weighted average 45.5	Total 127.1

(5) Remedies for No. 2 paper machine ventilation

As mentioned above, the dryer is cooled from the back with air currents from the entrance to the plant. In order to make even the degree of drying paper between front and back side by controlling fresh air passing and to reduce radiating heat from dissipating, it is recommended that a curtain of polyethylene film or like in front side and a curtain of old canvas or like in back side so as not disturbing driving gear operation, maintenance or patrol.

Now, regarding the damper adjusting method, the method of observing water drops in the hood and adjusting damper tends to occur, oversupply of air and electricity loss and heat loss can also occur. It is suggested that the damper be adjusted as discharging air to be the standard temperatures of 45°C for winter and 50°C for summer approximately.

It is desirable that a thermometer be installed on each duct so that the duct damper be opened or closed while checking the temperature in front of the machine.

There is an instance of damper control with an automatic controller, in which steam was saved by 2 percent and electric power by 10 percent.

5.4.3.7 Preventing Overdrying and Dust Removal

The normal water content of corrugating medium is 5 to 6 percent. The paper water content of 1.14 percent shown in Table 5–4–6 clearly indicates that the paper was overdry. Overdry means not only waste of energy but also quality deterioration. Particularly, tear strength, elongation, and folding endurance will decrease, causing the paper to be brittle. This will also lower yield by about 4 percent.

There are two main causes of overdrying.

1) Non-uniformity of thickness and density in width direction
2) Much dust

As the cause (1) has already been discussed in 5.4.3.4 on the press part, the effect of dust will be dealt with here.

Parts of paper where the base is faulty or where dust is present cannot be fully dehydrated, possibly leaving stain. Shives and other similar dust stand out as black stain such as fish tail, seriously degradating the apparent quality of the product. Such spots gradually disappear if the water content of such parts decreases to less than 10 percent. It is when the water content is about 5 percent that such spots disappear completely. The remaining part of paper must have a water content of about 2 to 3 percent at that time.

The most effective means of reducing dust is to reinforce the screen before the formation part. The present Johnson screen can hardly be improved. A type of screen which has as little differential pressure, ensures mild separation inside the liquid, and permits adjustment of the reject rate is desirable. It is suggested the present Johnson screen be replaced with a Lamort screen or the like.

5.4.3.8 Heat Insulation of Dryer

The drying area of the Yankee dryer is 3.2 m x π x 1.8 m = 18.1 m^2, while the area of the dryer sides (both sides) is (3.2 m/2)^2 x π x 2 = 16.1 m^2.

It accounts for as much as 47 percent of the total surface area, and heat is radiated without being used for drying. These sides should of course be heat-insulated, but are often left uninsulated because, for one thing, the dryer is a rotary object; for another, it is liable to breakage in paper connecting and other dryer operations; and for another, dust may get into sheets of paper due to damage to the insulating material. Recently, the dryer cylinder sides are often covered with steel sheets to heat-insulate them with an air layer. Divided steel sheets are used so that they can be easily removed by hand even in narrow space when checking the inside of cylinders. Not only the Yankee dryer but also the ordinary cylinders is similarly heat-insulated.

If the two Yankee dryers (for the No. 1 and No. 2 machines) in this plant are heat-insulated, steam consumption by the dryers can be saved by about 4 percent.

The fuel gas that can be saved is 0.3 t/h x 2 x 0.04 x 6,960 x 92.9 = 15,512 Nm^3/h.

5.4.3.9 Yankee Dryer

(1) Measures to prevent paper temperature from falling

As shown in Figure 5–4–10, the paper temperature abruptly falls before the paper enters the Yankee dryer. This is presumably because the run from the No. 10 cylinder to the Yankee dryer is too long, the space is too wide to receive the peripheral radiating heat, and there is excessive inflow of fresh air. As mentioned in the section on ventilation, it will be effective to install a curtain from the hood in front and back of the paper machine to prevent direct contact with fresh air, apart from shortening the paper run.

(2) Yankee dryer, canvas

Wet sheets in the Yankee dryer are mostly held by the canvas during contact with the dryer. When the steam evaporating from the sheets is held in the texture of the canvas, the steam is blocked. After sheets stick to the dryer, the canvas is not necessary at that point of time. It would be better to make the canvas move away before the peak is reached.

5.4.3.10 Management of Cylinder Surface at Dryer Inlet

Plans are under way to change the cylinder type of the No. 2 machine to a Fourdrinier machine. If speed is raised by it, the temperature must be raised to make full use of the dryer capacity. If the inlet dryer temperature is raised, the resin, etc. contained in the waste paper tend to stick to the surface, causing heat conduction to lower, paper breaks, and production or quality trouble.

It is desirable that the adhesive be always removed using a doctor knife. The cylinders should be kept at high temperature to facilitate removal of the adhesive, and doctor knife material, angle, and blade width suited to the actual conditions should be selected.

If the adhesive sticks hard to the dryer surface together with paper dust, for example, it is necessary to remove it using a solvent or scraper on a repair day, and thus keep the surface clean.

5.4.3.11 Boiler

The steam supplied from the boiler is used as energy for the dryer, etc. and thus plays an important role in the manufacturing process. Since the beginning of 1988 the fuel for boiler has been changed from heavy oil to natural gas.

It was observed that the combustion state of the natural gas burner was very bad, and black smoke was exhausted from the stack. In addition, there were such problems in maintenance as the steam leakage from the safety valve, water gauge and steam pressure gauge, the crack of heat insulation of boiler caused by burn, and the lack of heat insulation of the feed water tank, feed water pipe and steam pipe. The recovering of steam condensate for feed water is considered as a good measure.

(1) Boiler specifications

Type : 3-pass, flue and Smoke tube boiler
Evaporation : 4.5 h
Steam pressure : 10 kg/cm^{2}G (rated)
Fuel : Natural gas (Hl = 8,792.48 kcal/Nm^3)

CH_4 = 94.70% $i\text{-}C_4H_{10}$ = 0.34% $n\text{-}C_5H_{12}$ = 0.01% N_2 = 1.38%
C_2H_6 = 2.19% $n\text{-}C_4H_{10}$ = 0.48% C_6H_{14} = 0.01% CO_2 = 0.41%
C_3H_8 = 0.45% $i\text{-}C_5H_{12}$ = 0.03%

Heating surface : 104 m^2
Date of manufacture : 1980
Structure : As shown in Figure 5–4–13

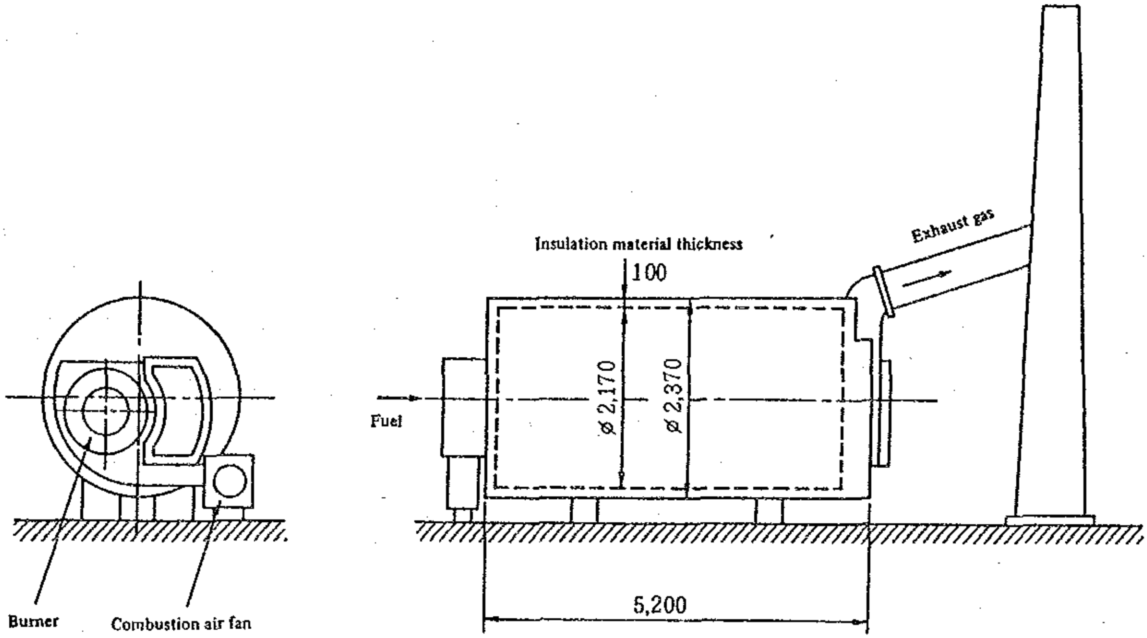

Figure 5–4–13 Boiler Structure

(2) Survey items and collected data

The boiler was surveyed on October 12, 1988.

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

a) Data was gathered on the following items using the measuring instruments. The measuring points are shown in Figure 5–4–14 "Boiler Measuring Points."

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 visual observation items are as follows:

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

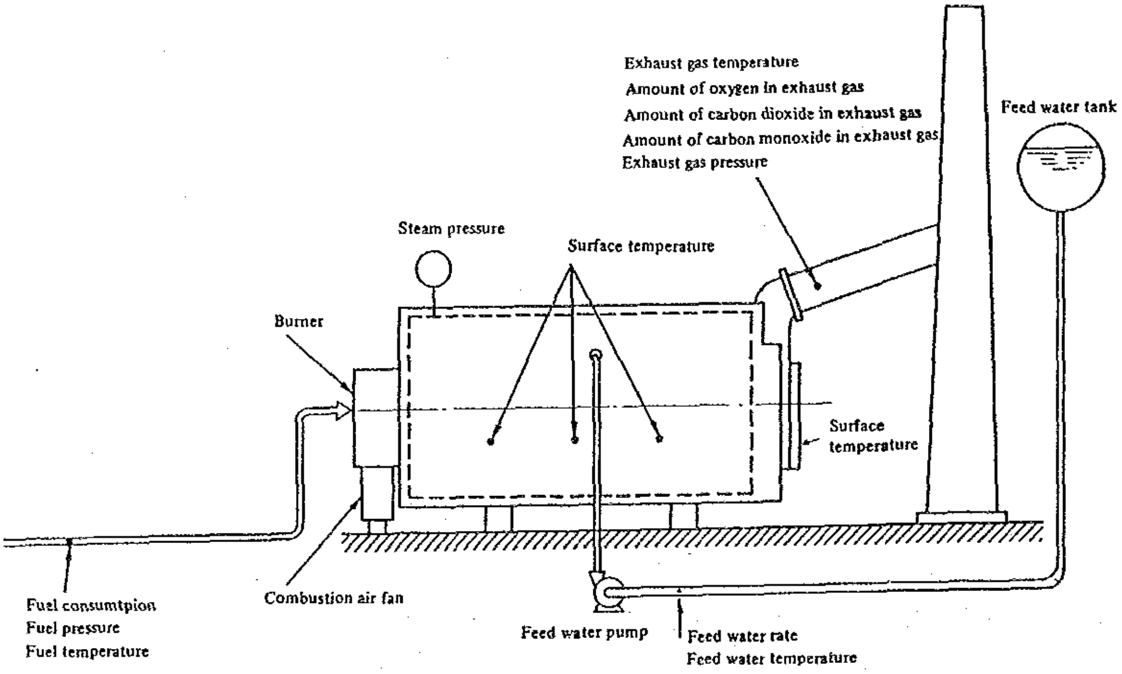

Figure 5–4–14 Boiler Measuring Point

(3) Heat balance of boiler

a) The heat balance of the boiler was calculated using the data collected from 15:00 to 16:00 on October 12. The details of the data are as follows:

1)	Kind of fuel		: Natural gas
2)	Calorific value (low level)	(Hl)	: 8,792.48 kcal/Nm^3
3)	Specific gravity of fuel	(Sf)	: 0.7646 kg/Nm^3
4)	Specific heat of fuel	(Cpf)	: 0.39 kcal/(Nm^3°C)
5)	Fuel temperature	(Tf)	: 24.7°C
6)	Reference temperature	(To)	: 22.8°C
7)	Temperature of combustion air	(Ta)	: 28.6°C
8)	Specific heat of combustion air	(Cpa)	: 0.31 kcal/(Nm^3°C)
9)	Theoretical amount of air	(Ao)	: 9.76 Nm^3/Nm^3-fuel
10)	Theoretical amount of wet exhaust gas	(Go)	: 10.79 Nm^3/Nm^3-fuel
11)	Fuel flow rate	(F)	: 328.05 Nm^3/h
12)	Exhaust gas temperature	(Tg)	: 290.6°C
13)	O_2% of dry waste gas	(O_2)	: 2.30%
14)	Air ratio	(m)	: 1.13

15) Actual amount of combustion air (A) : 11.03 Nm^3/Nm^3-fuel
16) Actual amount of wet exhaust gas (G) : 12.06 Nm^3/Nm^3-fuel
17) Specific heat of exhaust gas (Cpg) : 0.33 kcal/(Nm^3°C)
18) Exhaust gas pressure (Pg) : -4.89 mmH_2O
19) Feed water flow rate (based on weight) (Fw) : 3,530 kg/h
20) Feed water temperature (Tw) : 72.3°C
21) Steam pressure (Ps) : 7.98 kg/cm^2 G
22) Enthalpy of dry steam : 661.93 kcal/kg
23) Enthalpy of saturated water : 176.51 kcal/kg
24) Dryness of steam : 0.98
25) Enthalpy of wet steam : 652.22 kcal/kg
26) Enthalpy of feed water (h′) : 71.978 kcal/kg

b) Heat input

Heat input per Nm^3 of fuel is calculated.

1) Combustion heat of fuel (Hl)

$$Hl = 8{,}792.48 \text{ kcal/Nm}^3$$

2) Sensible heat of fuel (Qs)

$$Qs = 0.39 \times (24.7 - 22.8) = 0.74 \text{ kcal/Nm}^3$$

3) Sensible heat of combustion air (Qa)

$$Qa = 11.03 \times 0.31 \times (28.6 - 22.8) = 19.83 \text{ kcal/Nm}^3$$

4) Total heat input (Qi)

$$Qi = Hl + Qs + Qa = 8{,}792.48 + 0.74 + 19.83 = 8{,}813.05 \text{ kcal/Nm}^3$$

c) Heat output

Heat output per Nm^3 of fuel is calculated.

1) Heat content of steam (Qv)

$$Qv = \frac{3{,}530}{328.05} \times (652.22 - 71.978) = 6{,}243.73 \text{ kcal/Nm}^3$$

2) Heat taken away by exhaust gas (Qg)

$$Qg = 12.06 \times 0.33 \times (290.6 - 22.8) = 1{,}065.79 \text{ kcal/Nm}^3$$

3) Heat radiation from boiler surface (Qr)

$$Qr = \frac{2{,}124 \times 4.41 + 233 \times 38.70 + 1{,}221 \times 4.41}{328.05} = 72.40 \text{ kcal/Nm}^3$$

Average temperature and surface area of front plate : 149.8°C, 4.41 m^2
Average temperature and surface area of shell plate : 45.1°C, 38.70 m^2
Average temperature and surface area of rear plate : 107.8°C, 4.41 m^2

4) Other heat loss (Qm)

$$Qm = 1{,}431.13 \text{ kcal/Nm}^3$$

5) Total heat output (Qo)

$$Qo = Qv + Qg + Qr + Qm = 8{,}813.05 \text{ kcal/Nm}^3$$

d) Heat balance table

The data shown above are summarized in Table 5–4–8.

Table 5–4–8 Heat Balance of Boiler

Heat input			Heat output		
Item	kcal/Nm³	%	Item	kcal/Nm³	%
Fuel combustion heat	8,792.48	99.77	Heat Possessed by Steam	6,243.73	70.85
Sensible heat of fuel	0.74	0.01	Heat taken away by exhaust gas	1,065.79	12.09
Sensible heat of combustion air	19.83	0.23	Heat radiation from surface	72.40	0.82
			Other heat loss	1,431.13	16.24
Total	8,813.05	100.00	Total	8,813.05	100.00

(4) Problems and remedies

a) Reduction of other heat loss by the improvement of combustion state

The combustion of this boiler was made by the three-position (high, low and stop) control method. At the time of high combustion black smoke from the stack was observed, and the incomplete combustion was perceived by the red flame color of the burner. Oxygen of 5 – 7% was detected in the exhaust gas at the time of low combustion, but the oxygen content reduced to 0% at the time of high combustion.

It is said that the above phenomenon occured after the beginning of 1988 when the fuel for boiler was changed from heavy oil to natural gas. However, it was not possible to clearly find the cause because there was no chance to inspect the inside of the boiler during the period of study. Since it is assumed to be ascribable to the air supply system such as burner, damper or combustion blower from the fact that the oxygen in exhaust gas was not detected at the time of high combustion as shown in Figure 5–4–15 and the flame color of the burner became red, it is recommended to ask the boiler manufacturer and burner manufacturer to clear up the cause

In addition, it is also necessary to compare the maximum capacity of the combustion blower and the amount of air actually required since the comparison of the theoretical air amount for the same evapolation volume between heavy oil and natural gas indicates that the air amount required for natural gas exceeds that for heavy oil by 6.3%.

If the cause for the incomplete combustion is cleared up and the normal combustion is made, a part of other heat loss will be reduced. Although the heat loss due to the incomplete combustion is not calculated concretely, if 30% of other heat loss is improved not to be losed, the fuel conservation rate (S) obtained by it can be calculated by the following equation.

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{8{,}813.05 - 1{,}431.13}{8{,}813.05 - 1{,}000.00} = 0.0552 = 5.52\%$$

where Hi : Heat input per Nm³ of fuel (kcal/Nm³);

Qga : Present amount of heat taken away by exhaust gas (kcal/Nm³);

Qgi : Amount of heat taken away by exhaust gas after improvement (kcal/Nm³)

Assuming that the annual consumption of fuel is 328.05 Nm³/h X 24 h/d X 290 d/y = 2,283,228 Nm³/y, the amount of annual saving can be calculated as follows: 2,283,228 m³/y X 0.0552 X 0.09 US$/m³ = 11,343 US$/y

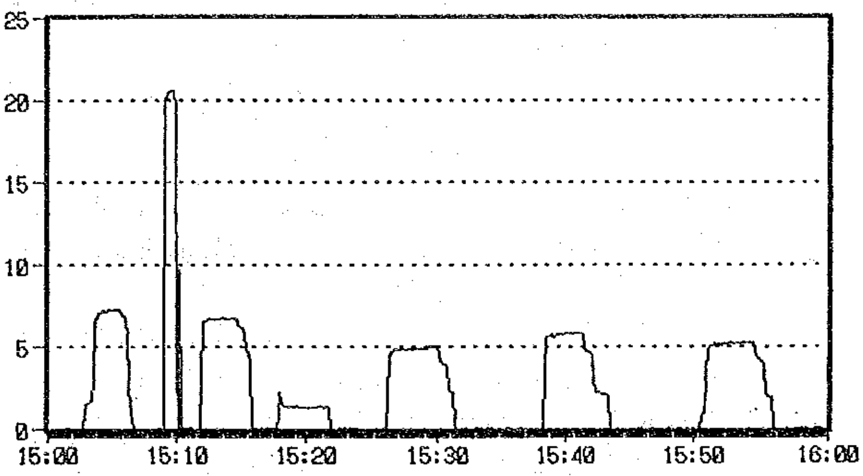

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Figure 5–4–15 Oxygen Contents in Exhaust Gas (%)

b) 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 ratio, which can be calculated from the amount of oxygen in exhaust gas. At the time of low combustion the oxygen content in exhaust was about 6%, and the air ratio was 1.41. However, at the time of high combustion the oxygen content was zero due to the incomplete combustion. If the air ratio is carefully adjusted at the time of low combustion, it will not be difficult to reduce the oxygen content to 4.5%. As a result, the air ratio will be 1.27, and the amount of exhaust gas will be reduced by about 8%.

The amount of air can be 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.

Table 5–4–9 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		%	6.00	4.5
2	Air ratio	m		1.41	1.27
3	Theoretical amount of air	Ao	Nm^3/Nm^3	9.76	9.76
4	Theoretical amount of exhaust gas	Go	Nm^3/Nm^3	10.79	10.79
5	Actual amount of air	A	Nm^3/Nm^3	13.76	12.40
6	Actual amount of exhaust gas	G	Nm^3/Nm^3	14.79	13.43
7	Exhaust gas temperature	tg	°C	290.6	290.6
8	Heat taken away by exhaust gas	Qg	$kcal/Nm^3$	1,307.05	1,186.86

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

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{8{,}813.05 - 1{,}307.05}{8{,}813.05 - 1{,}186.86} = 0.0158 = 1.58\%$$

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 328.05 $Nm^3/h \times 24\ h/d \times 290\ d/y = 2{,}283{,}228\ Nm^3$ and the proportion of low combustion as ¼, the amount of annual saving can be calculated as follows:

$$2{,}283{,}228\ m^3/y \times 1/4 \times 0.0158 \times 0.09\ US\$/m^3 = 812\ US\$/year$$

c) Reduction of exhaust gas loss due to the lowering of exhaust gas temperature

As the incomplete combustion was caused at the time of high combustion and the exhaust of black smoke from the stack was observed, it is suspected that the heating surface of the boiler is covered with soot. It so, the heat transfer efficiency from the combustion gas to the boiler water will be lowered, and the exhaust gas temperature will rise with the worsening of the boiler efficiency.

The exhaust gas temperature of this boiler is 290.6°C, about 50°C – 100°C higher than the case of ordinary boiler. Therefore, to cope with such problems, first prevent the incomplete combustion, and then clean the heating surface of the boiler. This boiler has not been overhauled and cleaned at all after it was newly installed, but it is necessary to clean the heating surface at least once a year. If the staining of the heating surface is left as it is, its partial corrosion will progress, cause local heating and incur the danger of explosion. If the heat transfer efficiency is recovered by the cleaning of the heating surface and the exhaust gas temperature is lowered from 290.6°C to 250°C, the exhaust gas loss will be reduced as shown below.

Table 5–4–10 Decrease of Heat Taken Away by Exhaust Gas in Cleaning of Heat Transfer Surface

№	Item		Unit	Present	After improvement
1	Exhaust gas temperature	tg	℃	290.6	250.0
2	Reference Temperature	ta	℃	22.8	22.8
3	Air ratio	m		1.41	1.27
4	Theoretical amount air	Ao	Nm^3/Nm^3	9.61	9.76
5	Theoretical amount of exhaust gas	Go	Nm^3/Nm^3	10.79	10.79
6	Actual amount of exhaust gas	G	Nm^3/Nm^3	14.79	13.43
7	Heat taken away by exhaust gas	Qg	$kcal/Nm^3$	1,307.05	1,006.93

The percentage of fuel conservation (S) to be accomplished by lowering the exhaust gas temperature can be calculated by the following equation.

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{8{,}813.05 - 1{,}307.05}{8{,}813.05 - 1{,}006.93} = 0.0384 = 3.84\%$$

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 328.05 Nm^3/h X 24 h/d X 290 d/y = 2,283,228 Nm^3/y, the amount of annaul saving can be calculated as follows:

2,283,228 Nm^3/y X 0.038 X 0.09 U$S/$Nm^3$ = 7,891 U$S/y

d) Boiler water quality control

The quality of feed water and boiler water was found to be as shown in Table 5–4–11.

Table 5–4–11 Quality of Feed Water and Boiler Water

kind	Measured value			Reference		
	Temperature	pH	Electric conductivity	Temperature	pH	Electric conductivity
Well water	23.0 ℃	7.38	1.150mS/cm	–	–	–
Feed water	29.9 ℃	8.04	1.236mS/cm	25 ℃	7～9	–
Boiler water	35.2 ℃ 37.1 ℃	12.12 12.11	16.50 mS/cm 14.96 mS/cm	25 ℃	11～11.8	<4.5mS/cm

The boiler water quality control is conducted by the surface continuous blow and bottom blow of the boiler water. The bottom blow is executed three times a day, for two or three minutes each time. The boiler water is inspected once a week by the company staff, and the water quality inspection is entrusted to a professional inspection company once a month.

As a result of the study, the electrical conductivity of the boiler water is found to have an extremely high value. This means that much impurities are contained in the boiler water, and that it not only hinders the heat transfer but also shortens the life of the boiler. If the quality control of the boiler water is conducted by blow alone, the continuous blow of about 29% will be required as indicated by the following equation. Since it is not a realistic plan causing great loss, it is necessary to improve the water quality of the boiler water.

$$Fb = Fc/(Bc - Fc) \times 100$$
$$= 1.236/(4.5 - 1.236) \times 100$$
$$= 37.87\%$$

where

Fb : Blow rate (%)

Fc : Electrical conductivity of feed water

Bc : Electrical conductivity of boiler water

According to the measurement of electrical conductivity, the electrical conductivity is same for well water and feed water despite the recovering of condensate, and pH also rises. This means that the condensate is stained. First of all, it is necessary to prevent the condensate from staining by the measures explained separately. To lower salt concentration, the following methods can be used.

(1) The quality of the feed water is improved by lowering the salt concentration of a part of raw water (well water) by using a unit for reverse osmosis.

(2) The salt in soft water can be reduced slightly because a large part of M alkali in raw water can be removed (residue: 5 – 15 mg/l) by changing the currently used softener to the dealkali softener.

(3) In case the above mentioned measures cannot be taken, the deoxydization processing must be conducted completely because the corrosion due to chlorine ion is likely to be accelerated.

5.4.3.12 Steam System

(1) Preventing steam leakage

The results of checking steam leaking points are as follows:
(See the steam system schematic diagram Figure 5–4–16.)

i) Slight steam leaks were found at the glands of four steam valves on the main header and sub-header.

ii) Steam leaks were found at the steam injection rotary joints to the cylinders for the No. 2 paper machine. Slight steam leaks were also found at the No. 1 paper machine.

Because the velocity of steam passing through leaking clearances is similar to the velocity of sound, even slight steam leaks will accelerate wear and erosion, enlarging the clearances and sharply increasing the volume of leaking steam.

If worn valves or flanges are left as they are, expenses to repair them will increase more than necessary.

Therefore, prevention of steam leaks should be included in the daily schedule of work, and detect and repair them as soon as possible.

Conduct a periodic check (at weekends, for example) for steam leaks while the plant is in operation. If steam leaks are found, mark them with a piece of red cloth, for example, to make sure that they will be repaired later on.

It is difficult to accurately determine the volume of steam leaking from the clearance on the piping using a simple method, but it can be assumed from experience as follows:

i) Assume the diameter of each hole where steam is leaking.

ii) Calculate the volume of leaking steam by the following equation.

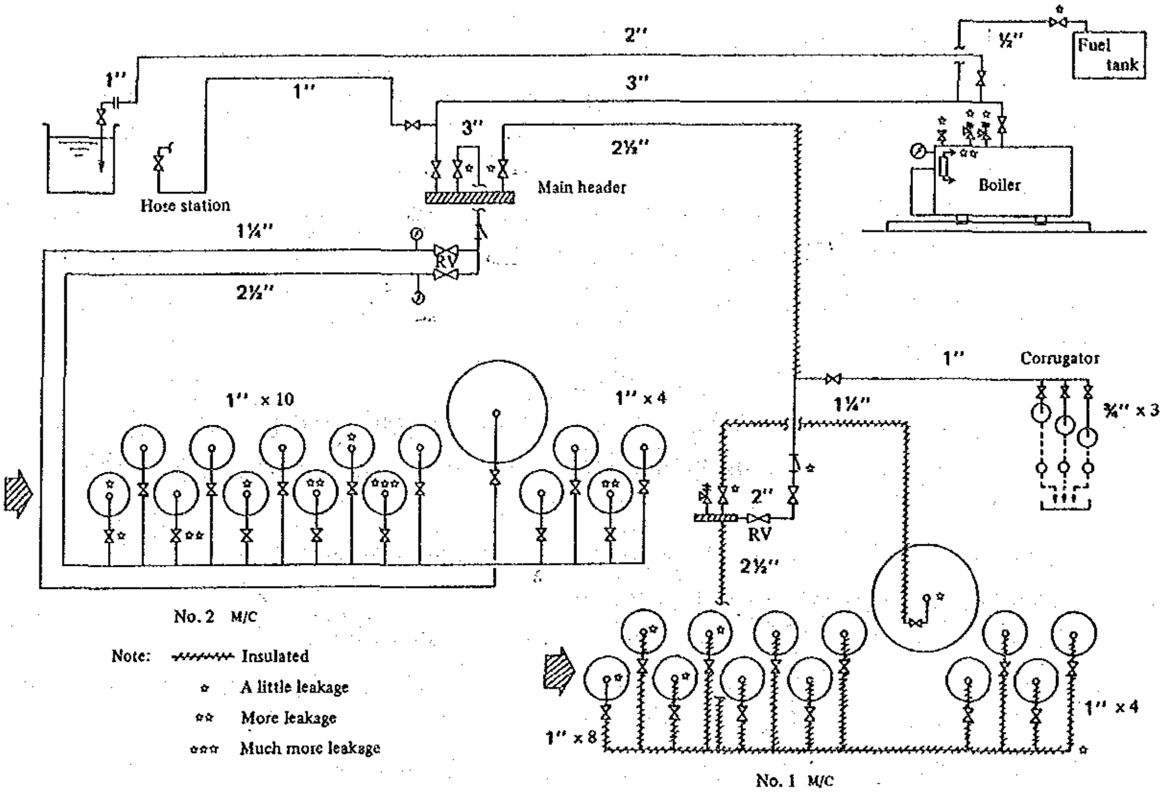


Fig 5-4-16 Steam Line Flow Sheet

- o Equation to calculate leaking steam loss

$$G = 0.5484 \times A \times P^{0.97} \times f$$

where G = Leaking steam volume (kg/h);
A = Hole area (mm^2);
P = Steam pressure (absolute) (kg/cm^2 ata)
f = Coefficient of blow (generally from 0.65 to 0.97; 0.8 for leaks from piping valves)

iii) The survey results are shown in Table 5−4−12.

o The volume of steam lost by leakage can be expressed in value as follows:

o Volume of Natural Gas loss per annum (Nm^3/y)

$$0.648 \times 6{,}960 \times \frac{92.9}{1{,}000} = 419 \ Nm^3/y$$

o Economic loss per annual (U$ S/y)

$0.09 \times 419 = 37.7$ U$W/y

(2) Heat insulation of steam piping

(a) Heat insulation at present

The heat insulation of the steam piping at present is shown in the piping diagram (Figure 5–4–16).

The main steam piping downstream of the boiler and the piping around the No. 2 paper machine are not heat-insulated at all.

None of the steam valves and flanges were insulated despite their relatively large surface area.

(b) Dissipating heat from bare surfaces

The heat dissipated from the bare parts of each line and the volume of heat that can be prevented from dissipating by heat insulation were calculated as shown in Table 5–4–13.

Here, the boiler and condensate recovery piping were excepted from the calculation and evaluation of their heat insulation.

The following conclusions can be drawn from this Table 5–4–13.

i) The dissipating heat can be reduced by 87 percent if the bare radiating surfaces are covered with rock wool 25 mm thick.

ii) The main piping and the No. 2 paper machine line account for 72 percent of the total heat dissipation.

iii) The heat dissipation ratio of piping to valves is 76 to 24 percent. Heat dissipation by valve size is as follows:

15.6 percent for valves 2" or more in diameter

8.4 percent for valves 1½" or less in diameter

If all the pipes and all the valves and flanges 2" or more in diameter are heat-insulated, therefore, 91 percent of the total heat radiation can be covered.

(c) Economic effect by heat insulation

The economic effect of heat insulation within the scope specified in iii) above is evaluated as follows:

In this case, the total economic effect of heat insulation is 52,249 kcal/h. If the value is divided by the corresponding steam evaporation latent heat and converted into the amount of steam, it is 105 kg/h.

Amount of fuel saved

$$105 \times 6{,}960 \times \frac{92.9}{1{,}000} \times 0.09 = 6{,}110 \text{ U\$S/y}$$

Table 5–4–12 Results of Checking Leaking Steam

Leaking position	Degree of leakage	No. of leaking points	Leaking part		Steam pressure ($kg/cm^2 G$)	Volume of leaking steam (kg/h)	Total volume of leaking steam
			Equivalent hole diameter (mmϕ)	Equivalent area (mm^2)			
No.1 M/C	☆	5	0.1	7.85×10^{-3}	3	0.013	0.081
		2	0.1	7.85×10^{-3}	1.3	0.008	
No.2 M/C	☆	5	0.1	7.85×10^{-3}	3	0.013	290
	☆☆	2	0.2	3.14×10^{-2}	3	0.053	
	☆☆☆	1	0.3	7.06×10^{-2}	3	0.119	
Main piping	☆	5	0.1	7.85×10^{-3}	8.5	0.031	0.277
	☆☆	1	0.2	3.14×10^{-2}	8.5	0.122	
						Total	0.648

Degree of leakage : ☆ Slight

☆☆ Medium (Sound is heard.)

☆☆☆ Much (Sharp sound is heard.)

The calculated volume of leaking steam was multiplied by the coefficient of blow (0.8).

Table 5-4-13 Heat Radiation from Bare Steam Piping and Heat Insulation Fffect

(unit: kcal/h)

Process	Heat radiation from bare part	Heat radiation after insulation	Insulation effect	Percentage	Remarks
Main piping	21, 612	2, 632	18, 980	33. 5	Except piping around boiler
No. 1 M/C	3, 796	524	3, 272	5. 8	Except condensate piping
No. 2 M/C	24, 746	3, 209	21, 537	38. 0	Except condensate piping
Others	14, 721	1, 885	12, 836	22. 7	Except the three above
Total	64, 875	8, 250	56, 625	100%	

Note: Heat radiation was calculated using a personal computer program of the Energy Conservation Center.

- o The cost of heat insulation by pipe size is shown in Table 5–4–14.
  The heat insulation costs for the valves and flanges were based on the corresponding ratio to pipe in Japan.
- o Investment paid back period

$$\frac{\text{Investment}}{\text{Profit from fuel saving}} = \frac{2{,}684.76\ (\text{U\$S})}{6{,}110\ (\text{U\$S/y})} = 0.44\ \text{y}$$

Table 5-4-14 **Piping Insulation Expenses**

Classification	Size	Quantity	Insulation unit price U$S/m	Insulation cost	Remarks
Pipe	1"	40 m	14.90	596.00	• Rock wool wound a single layer 25 mm thick • Exterior: Aluminum sheet lagging 0.7 mm
	1¼"	21	15.60	327.60	
	2"	16	18.15	290.40	
	2½"	56	20.20	1,131.20	
	Subtotal	–	–	2,345.20	
Globe valve	2"	1	18.15	18.15	• Cost for valves, reducing valves, and strainers were considered as corresponding to 1 meter of pipe. • Flanges were considered as corresponding to 0.75 m of piping. • Insulation specifications are the same as those of piping.
	3"	3	21.40	64.20	
	6"	1	30.31	30.31	
	Subtotal	–	–	112.66	
Reducing valve	2"	1	18.15	18.15	
	4"	1	24.03	24.03	
	Subtotal	–	–	42.18	
Strainer	2"	2	18.15	36.30	
Flange	2"	2	13.61	27.22	
	2½"	8	15.15	121.20	
	Subtotal	–	–	148.42	
			Total	2,684.76	

(3) Steam trap management

(A) Steam trap operating condition

The steam traps were checked using the diagnostic instruments that had been taken along from Japan, as well as the senses of vision and touch. The results of this check are shown in Table 5–4–15. Of 26 operating traps 38% have inner leakage.

(B) Type of steam trap suited to recovery of condensate

Mechanical traps (float type or bucket type, for example) are suited to the recovery of condensate.

Mechanical traps operate accurately regardless of change in back pressure, and therefore are suited to the recovery of condensate. The traps used in this factory are a bucket type, and therefore have no problem.

Table 5–4–15 Result of Steam Trap Inspection

No. of traps inspected	28
Working	26
Good	16
Not good	10
Failure rate	38%
Leakage	10
Steam press.	3.0 kg/cm^{2}g
Trap type	Bucket

(C) Steam trap maintenance method

The person assigned to take care of the steam traps must keep them in satisfactory condition at all times to maintain the steam using equipment in highly efficient operation and minimize steam loss, with minimum maintenance labor and cost.

(a) Inspection

It is necessary to check the steam traps operating condition wherever a regular round of inspection is made. The steam traps are deteriorate with time, and must be periodically checked at least twice a year while there is a high percentage of faulty traps. When that rate falls to less than 10 percent, a periodic minute inspection of once a year will be sufficient.

Prepare a trap history ledger and be sure to record inspection results in it. This will facilitate management of the traps particularly as to trouble prediction and trends of deterioration.

(b) Inspection and maintenance methods

There are three kinds of steam trap trouble: Blow, faulty discharge, and steam leakage. Steam trap faults and abnormalities can be detected early and remedied using the following methods.

1) Visual check

If the steam trap to be checked discharges condensate into the atmosphere at a point nearby, or has a sight glass at its outlet, steam trap operation can be directly checked with the eyes.

This is the surest method, and it is recommended that a sight glass be mounted on the condensate recovery piping,at each of the necessary points without fail.

2) Hearing method

Listen to the operating sound of the steam trap with a stethoscope, and determine whether it is faulty.

3) Touching method

Wear gloves, grip the steam trap inlet pipe and outlet pipe to find if there is a temperature difference between them, and determine whether the steam trap is properly operating.

4) Instrumental method

Check the operating sound of the steam trap with an ultrasonic instrument. Particularly, use one of those recently developed instruments that automatically check steam trap operation from its operating sound, surface temperature, type of trap, steam pressure, etc.

5) Maintenance

During periodic inspection, disassemble and clean the strainers and sight glasses. Replace or repair traps that are not operating properly.

(c) Effect of repairing steam traps

Leaking amounts can be estimated by the following equations.

Amount of leak kg/h = $0.4 \times P \times d^2 \times 0.1$

where P : Absolute pressure (kg/cm^2)

d : Corresponding orifice diameter (mm).

Amount of leak = $0.4 \times 4 \times 2.6^2 \times 0.1 \times 10$ (traps) = 10.8 kg/h.

Annual amount of leak = 10.8 kg/h x 6,960 h/y = 75.2 t/y.

Thus, the amount of fuel saving by repairing steam traps will be:

75.2 x 92.9 x 0.09 = 629 U$S/y

(D) Problems of trap mounting piping

There must be not steam clogging in the piping connected to the steam trap inlet in order to the condensate continuously generated in the cylinder dryer is to flow and reach the steam trap. If the condensate encloses the steam in the steam trap inlet piping and thus blocks the passage, the steam trap will not operate no matter how much condensate remains inside the cylinder dryer until the enclosed steam becomes cool and condensed. This phenomenon is called steam locking. If it occurs, the heating effect of the cylinder dryer falls sharply.

Before feeding steam to the steam using equipment, the air that fills the piping and equipment must be discharged. In the case of trap without an air venting function open the vent first and purge air. The valve stay closing if air remains inside. This phenomenon is called air binding.

Steam trouble and air trouble are caused by the piping from the equipment to the steam trap inlet except by the steam traps themselves. A piping which is liable to steam trouble is also liable to air trouble. Such a piping has a point steam or air is hardly replaced by condensate. In the case of this paper machine, the piping rises to the steam traps as shown in Figure 5–4–17 so that steam or air is hardly replaced by condensate. The following improvements are necessary.

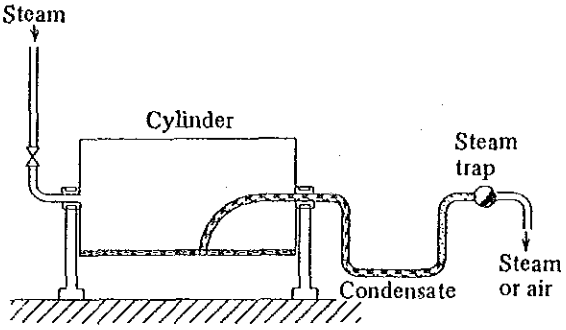


Fig 5-4-17 Existing Riser Pipe

1) Riser pipes must be replaced by down-inclined pipes that allow natural fall of condensate.
2) Use pipes of sufficient size.
3) Use pipes as short as possible.

The present state and our proposed plan for improvement are shown in Figure 5–4–18.

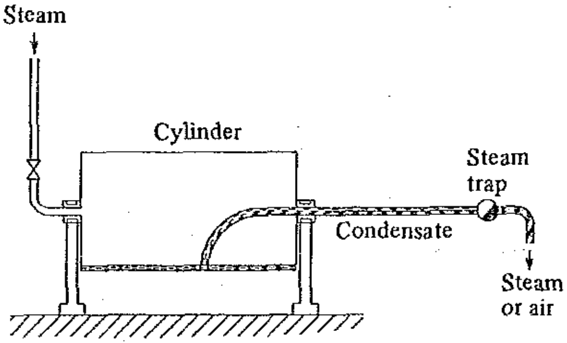


Figure 5-4-18 Improved Arrangement

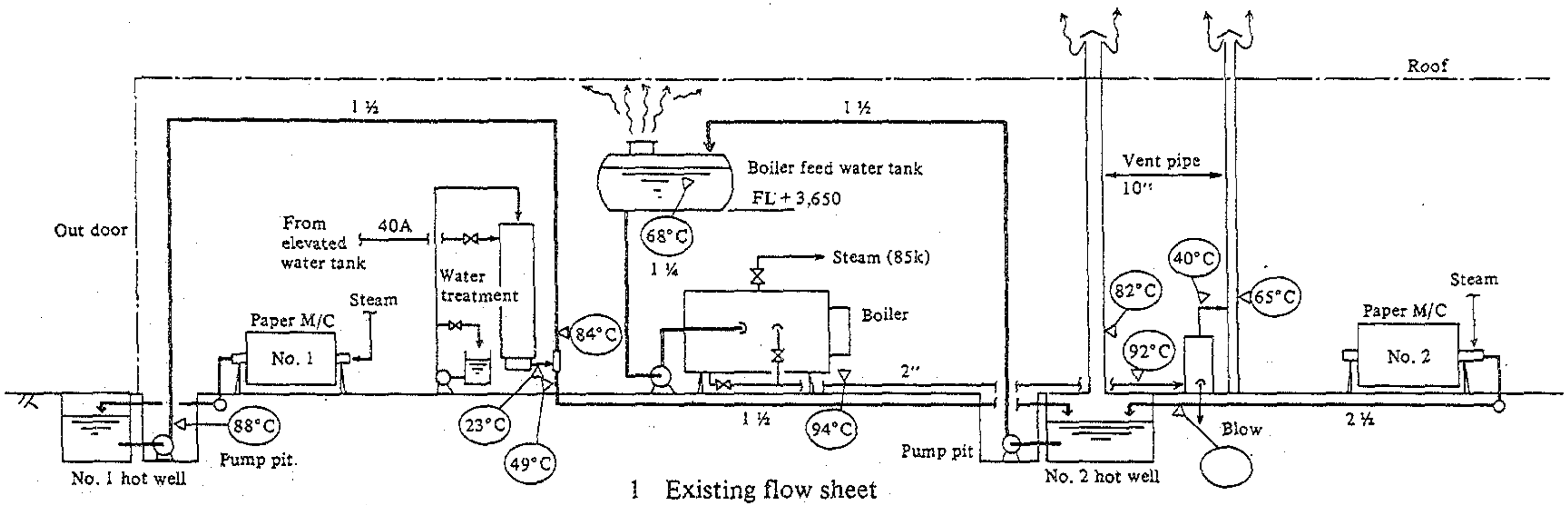
(E) Improvement of steam quality

It is necessary for the high-efficiency operation of the cylinder dryer to feed dry saturated steam of high quality. The steam piping to the cylinder dryers for the No. 1 paper machine, for example, runs from a high point to a low point, and branch pipes rise to the individual cylinder dryers from the steam header at the low point. Because this low steam header does not have a steam trap, wet steam flows into the cylinder dryers.

Raise the steam header about 30 cm higher than present, then install steam traps on both sides of the steam header to discharge condensate.

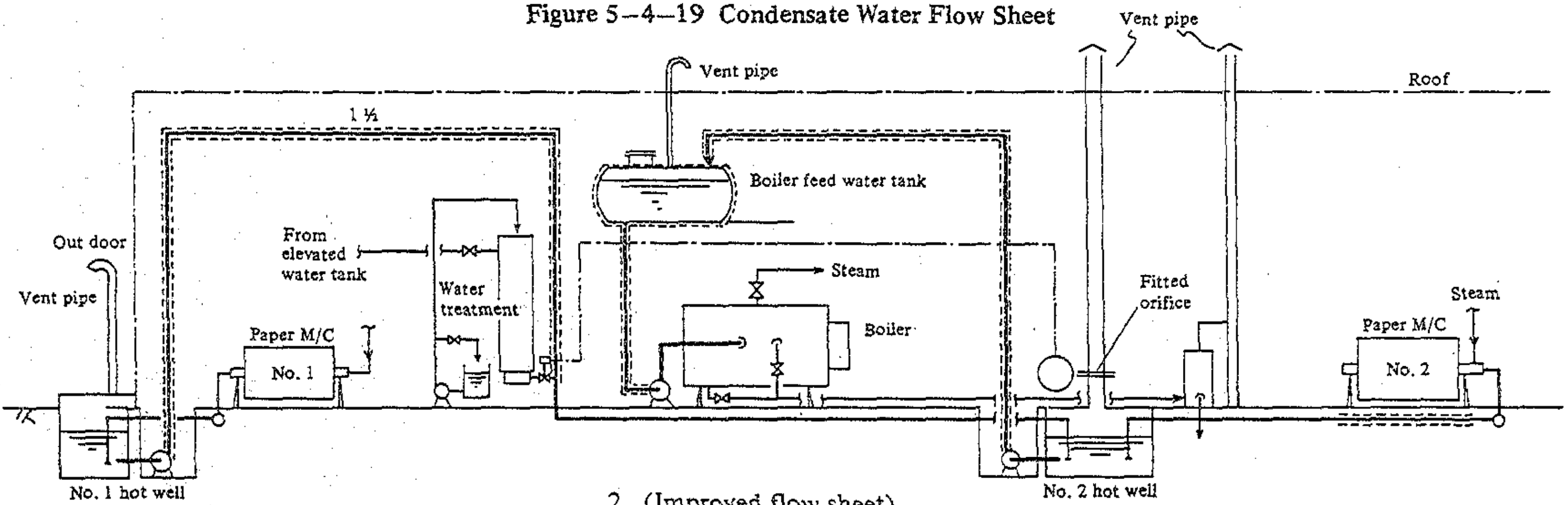
If possible, install a cyclone separator on the steam pipe to the cylinder dryer inlet to remove waterdrops contained in the steam. This will make it possible to supply dry saturated steam of highest quality.

(4) Improvement of condensate system (See Figure 5–4–19)



1 Existing flow sheet

Figure 5–4–19 Condensate Water Flow Sheet



2 (Improved flow sheet)
(Range of insulation work)

Figure 5–4–23 Condensate Flow Sheet

A) Existing problems

a. Because the upper end of the side wall of the hot well for recovering condensate installed at the outside of No. 1 paper machine is lower than the ground level and does not have a cover, the recovered condensate is cooled by the air and stained by the rain water and earth and sand flowing in it. Much impurities are floating in the hot well.

b. The condensate recovery pipe crossing No. 2 paper machine is wetted with the paper machine washing water. Therefore, the high temperature condensate is cooled.

c. The whole exposed portion of the condensate recovery pipe is not heat insulated. The temperature of the condensate recovered from No. 1 paper machine reduces by about 4°C.

d. The surface temperature of the boiler feed water tank is about 70°C, but it is not heat insulated. In addition, the upper manhole of the boiler feed water tank is kept open. It produces flash steam to accelerate the corrosion of the iron portion of the building structure considerably.

e. The flash steam is discharged to the outdoor from the hot well provided under the ground. The surface temperature of the hot well exhaust pipe is 82°C, and its inside temperature seems to be much higher.

f. As the liquid level in the hot well is not controlled, there is a possibility that the high temperature condensate overflows to be lost.

B) Improvement of condensate recovery system

a. Improvement of the outdoor hot well for No. 1 paper machine

To extend upward the concrete wall of the hot well to prevent earth and sand and rain water from flowing in it from the ground level. (See Figure 5–4–20).

To make the upper opening portion of the hot well as a closed structure and fit the necessary manhole and air vent to it so that the heat radiated from the condensate in the hot well can be restricted. (See Figure 5–4–20).

At the time of taking the above measures, completely clean the inside of the hot well and check the outflow of condensate from the hot well as well as the inflow of underground water. In addition, the condensate recovery pipe is improved to be discharged in the liquid as shown in Figure 5–4–20.

b. Improvement of the indoor underground hot well

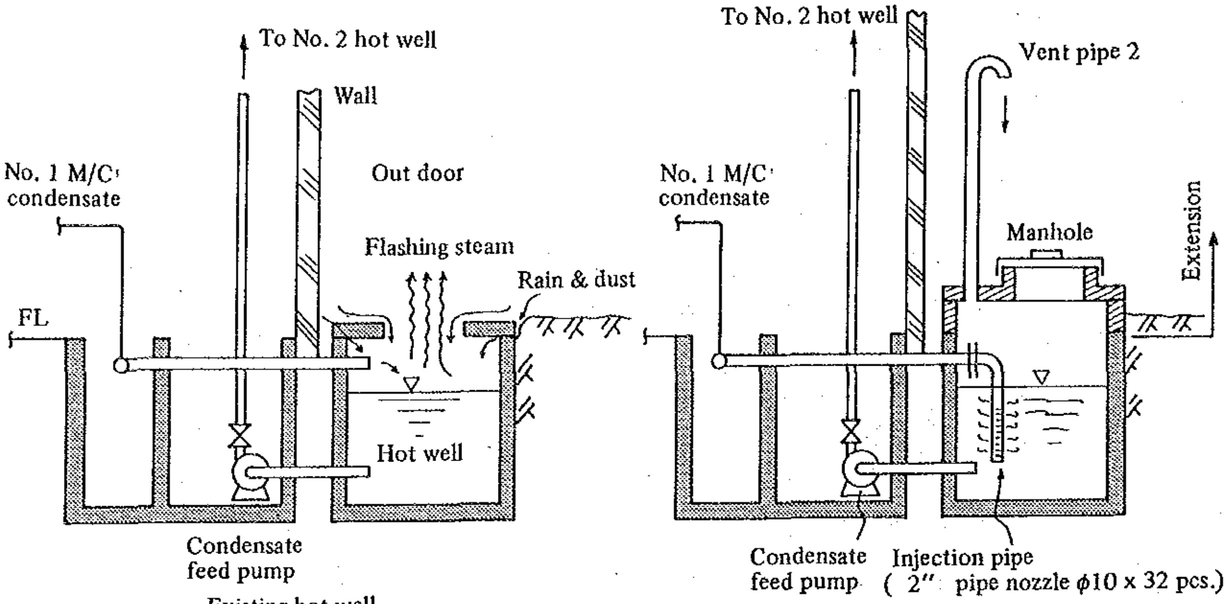
i) Measures for restricting flash steam

The improvement measures are shown in Figure 5–4–21. For these measures, attention must be given to the following points.

o Insert the tip of the condensate recovery pipe under the liquid surface of hot well.

o As the hot well discharge pipe has an extreme diameter of 10", an orifice (diameter of about 3") is inserted into the flange for the prevention of natural draft in the exhaust pipe and negative pressure in the hot well.

ii) Figure 5–4–22 shows the water level control system to effectively use all the condensate recovered in the hot well by preventing its overflow.



Existing hot well

Remodelled hot well

Figure 5-4-20 Improved Outdoor Hot Well

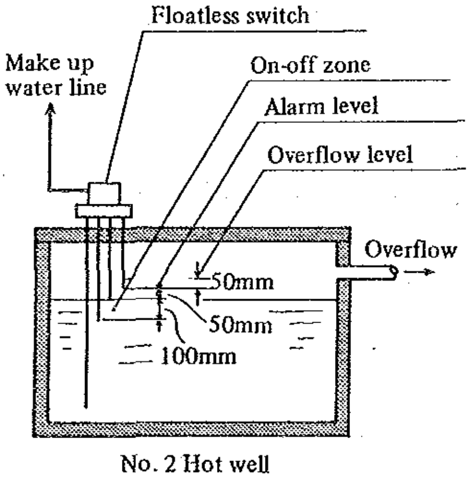


Figure 5-4-22 Water Level Control System

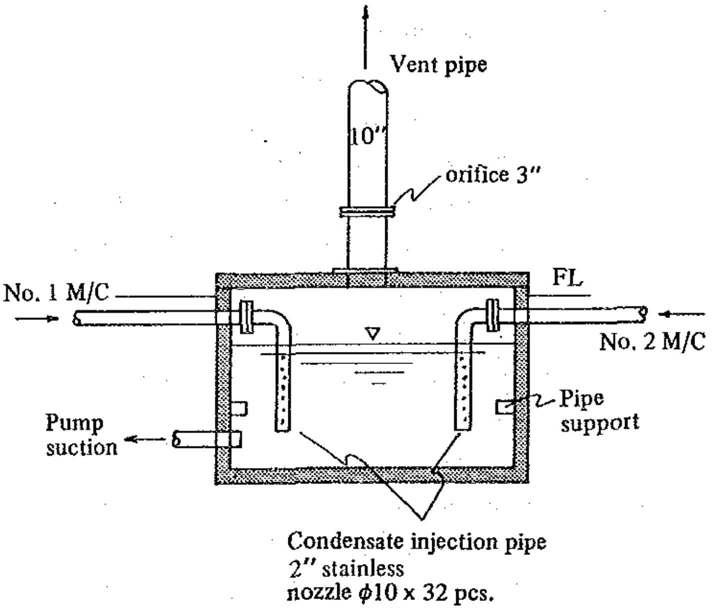


Figure 5-4-21 Improved Indoor Hot Well

c. Heat insulation of the heat radiation portion

The range of portions requiring heat insulation (See Figure 5–4–23) is as mentioned below.

- o The condensate recovery pipe extending from No. 1 hot well to the connection of the water treatment tower
- o The wet portion of the recovery pipe that crosses No. 2 paper machine
- o The recovery pipe portion that crosses the pump pit located on this side of No. 2 hot well.

- The outer surface of the tank located at a high position for feeding water to the boiler and the pipe attached to it

d. Measure to prevent the dispersion of flash steam of the tank located at a high position for feeding water to the boiler

i) The manhole is closed and vent to the outside of the building by the exclusive exhaust pipe. Inverted U type pipe is used for the end of the outdoor exhaust pipe.

ii) The end of the feed water pipe extending from No. 2 hot well can restrict the flash steam generated in the tank when it is put in the tank liquid.

iii) It is desirable to conduct such maintenance works as the cleaning and inspection of the tank inside at the time of piping work.

C) Forecasted effect and economical evaluation

a. Prevention of the loss of flash steam in No. 2 hot well

- Actually measured value of 106°C for the surface temperature of the dryer cylinder side plate is considered as the condensate temperature.
- Saturation pressure at 106°C: 0.25 kg/cm^{2}G
- Enthalpy at 0.25 kg/cm^{2}G

Saturated water:	106.1 kcal/kg
Steam:	641.4 kcal/kg

- The average steam leakage rate of the steam trap is set at 5%.

The amount of flash steam ($x$kg) for condensate of 1 kg after opening in the air is calculated as follows:

$$106.1 + 641.4 \times 0.05 = 100.1 \times (1.05 - x) + 639.2x$$

$$x = 0.061 \text{ kg}$$

The ratio to the amount of heat input is obtained by the following equation.

$$h = \frac{639.2 \times 0.061}{138.2} \times 100 = 28.2\%$$

The following amount of dispersed steam is obtained from the actually measured value of No. 1 machine condensate, 670 kg/h (676 ℓ/h).

Amount of dispersed steam = 670 x 0.061 = 40.9 kg/h

If it is possible to prevent 70% of steam from dispersion, the heat is utilized for the rise of the boiler feed water temperature.

$$\text{Fuel saving rate} = \frac{40.9 \times 0.7 \times 639.2}{328.05\ (8{,}813.05 - 1{,}065.79)} = 0.72\%$$

Saved amount = 328.05 x 6,960 x 0.0072 x 0.09 = 1,480 U\$S/y

b. Heat insulation

Changes of the amount of radiated heat due to the heat insulation of bare heat radiated portion are shown in Table 5–4–16.

Table 5–4–16 Heat Radiation and Insulation Effect

(Unit: kcal/h)

Process	Heat radiation	Heat radiated after insulation	Insulation effect	Remarks
Condensate recovery piping	7,249	1,038	6,211	Total of No. 1 and 2 systems
Boiler feed water tank	7,280	995	6,285	
Total	14,529	2,033	12,496	

For the submerged sections, calculation was made on condition that the sections were waterproofed. Under the submerged condition, the heat loss reaches 51,415 kcal/h.

As with the case of a)

$$\text{Fuel saving rate} = \frac{12{,}496}{328.05\ (8{,}813.05\ -\ 1{,}065.79)} = 0.49\%$$

Saved amount = 328.05 x 6,960 x 0.0049 x 0.09 = 1,007 U$S/y

c. Calculation of the heat insulation investment recovering period

Heat insulation expenses are shown in Table 5–4–17.

Investment recovering period:

$$\frac{2{,}065.6}{1{,}007} = 2.1 \text{ years}$$

Table 5–4–17 Insulation Work Expenses

(Unit: U$S)

Classification	Size	Quantity	Insulation unit cost U$S/m · m²	Insulation work expenses	Remarks
Pipe	1-½	50 m	16.65	832.50	Conditions are same as the case steam piping.
	2-½	5.5 m	20.20	111.10	
	Sub total			943.60	
Feed water tank		18.7 m²	60.00	1,122.00	1.55 ϕ X 3.06 m
Total				2,065.60	–

Note: The basis of the calculation of the insulation unit cost for feed water tank is the cost handbook of chemical equipment. The calculation was made from the ratio of 8" pipe insulation unit cost to the tank and other plane unit cost.

5.4.3.13 Power Receiving and Distributing and Electrical Facilities

(1) Outline of power receiving facilities

A supply integrating wattmeter and integrating reactive wattmeter are installed at the point where power is received from the 13.2-kV aerial line.

The receiving voltage was raised from 380 V to 13.2 kV and the 500-kVA transformer was replaced with a 2,000-kVA transformer according the plan of No. 2 paper machine reinforcement in February 1988. At the same time, a 170-kVar condenser was installed to improve the power factor.

The transformer steps down the received power to 380 V and supplies it to the distribution board, which distributes the input power 5 ways to the individual sections.

The condenser is kept on to maintain the power factor at 90 percent or more.

(2) Measurements

The following measurements were made using watt-power factor meter (PFM-1000, PFMA-5210, PFM-1000P), AC clip-on power meter, and 12-point recorder.

(A) Measurements made on October 12 and 13

a)	Factory as a whole	: Figure 5–4–24
b)	Pulp	: Figure 5–4–25
c)	Deflaker (Despatill)	: Figure 5–4–26
d)	Refiner (Pilaos)	: Figure 5–4–27
e)	No. 1 M/C	: Figure 5–4–28
f)	No. 2 M/C	: Figure 5–4–29

(3) Power consumption

The factory operates 24 hours a day on three shifts. The load (Figure 5–4–24) of the factory as a whole varies greatly from 700 kW to 350 kW at shifting time. The recordings show that the load factor is 74.9 percent.

The load varies in the pulp, deflaker, and refiner processes where much labor is involved.

The power factor of the factory as a whole was improved to about 90 percent or more. It also provides satisfactory compensation for the feeder power factor of 70 to 80 percent. The condenser also helps to reduce the costs because the power factor penalty is no longer paid.

However, the condenser is now kept on at all times, and should be switched off when factory operation is stopped.

(4) Load leveling

From the recordings of a whole factory shown in Figure 5–4–24

Maximum power	: 748 kW
Mean power	: 565 kW
Load factor	: 74.9%

If the present operation is leveled by 10%, or about 70 kW, the basic charge will be reduced as follows:

70 kW X 3.2 X 12 (months) = 2688 U$S

(5) Maintenance of lights and local panels

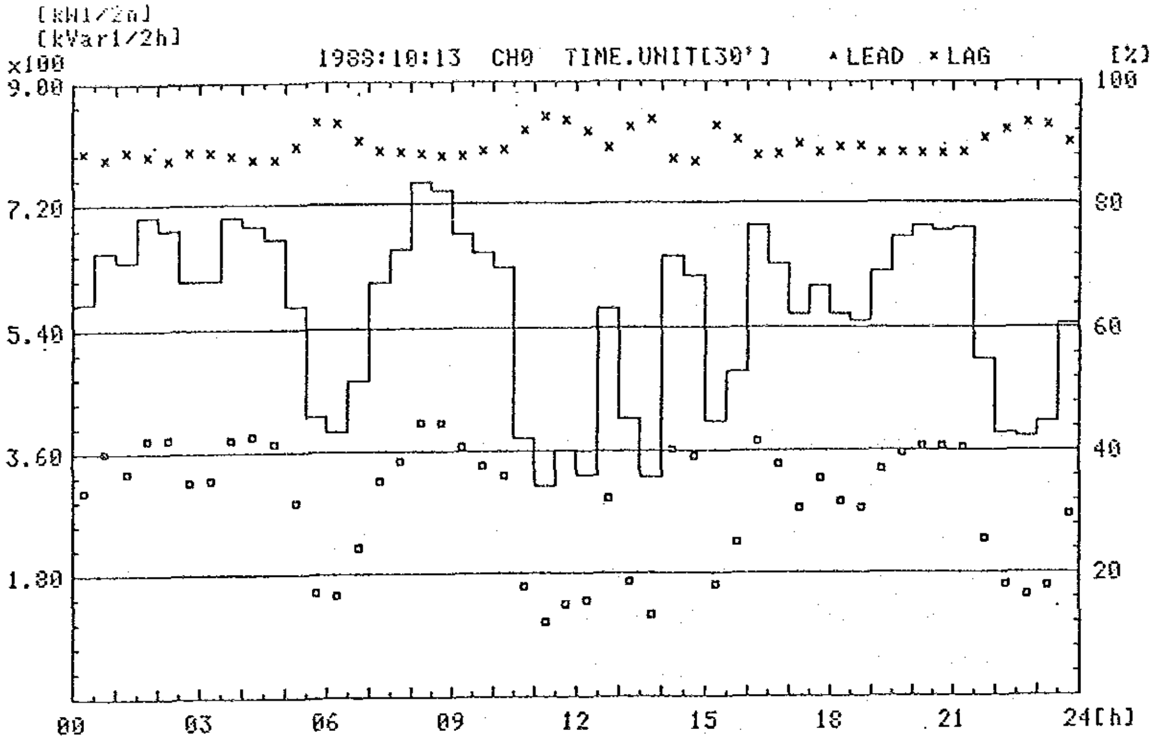
(A) Sunlight is taken through the ceiling, providing an illumination corresponding to 285 to 490 lux, which is sufficient.

(B) The transformer was stained with oil on the surface perhaps because it was spilled when filling the transformer.

Because it will adversely affect the transformer cooling effect, it is necessary to clean the transformer.

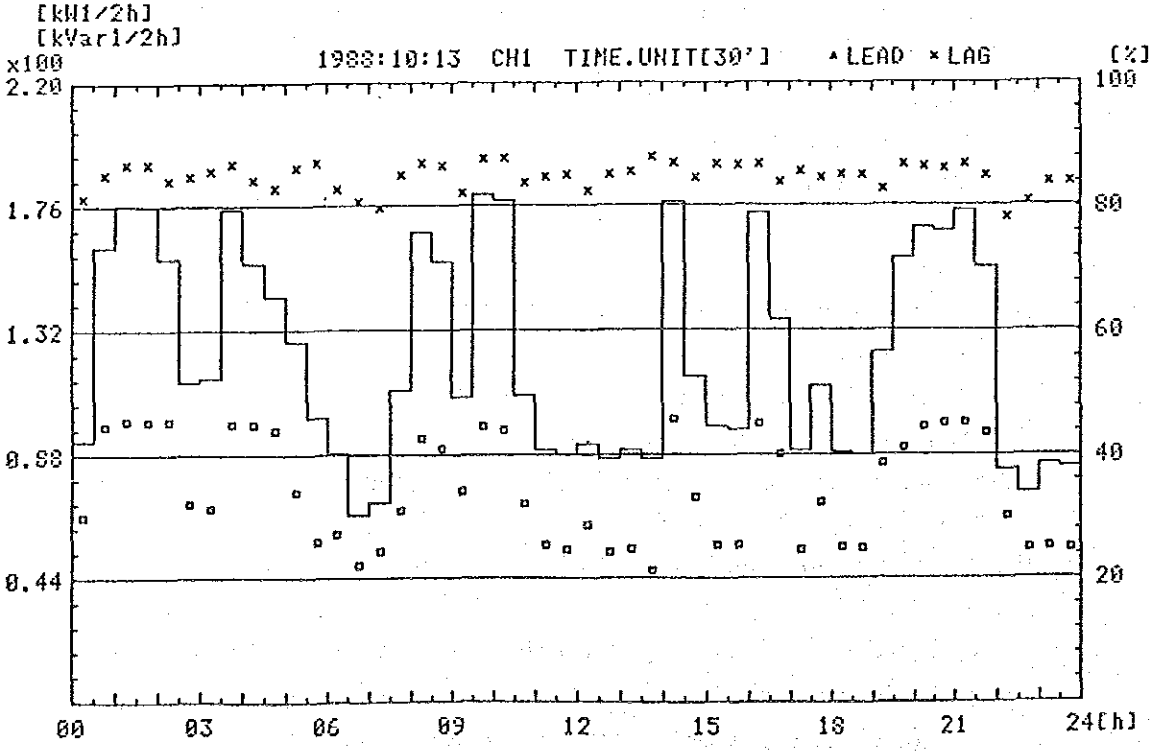
(C) The local panel in each section is dirty with paper dust. Clean it and keep it in good condition.

(D) The cable hole leading from the transformer to the electric room is too large to keep rainwater out. An appropriate step should be taken to keep rainwater out.



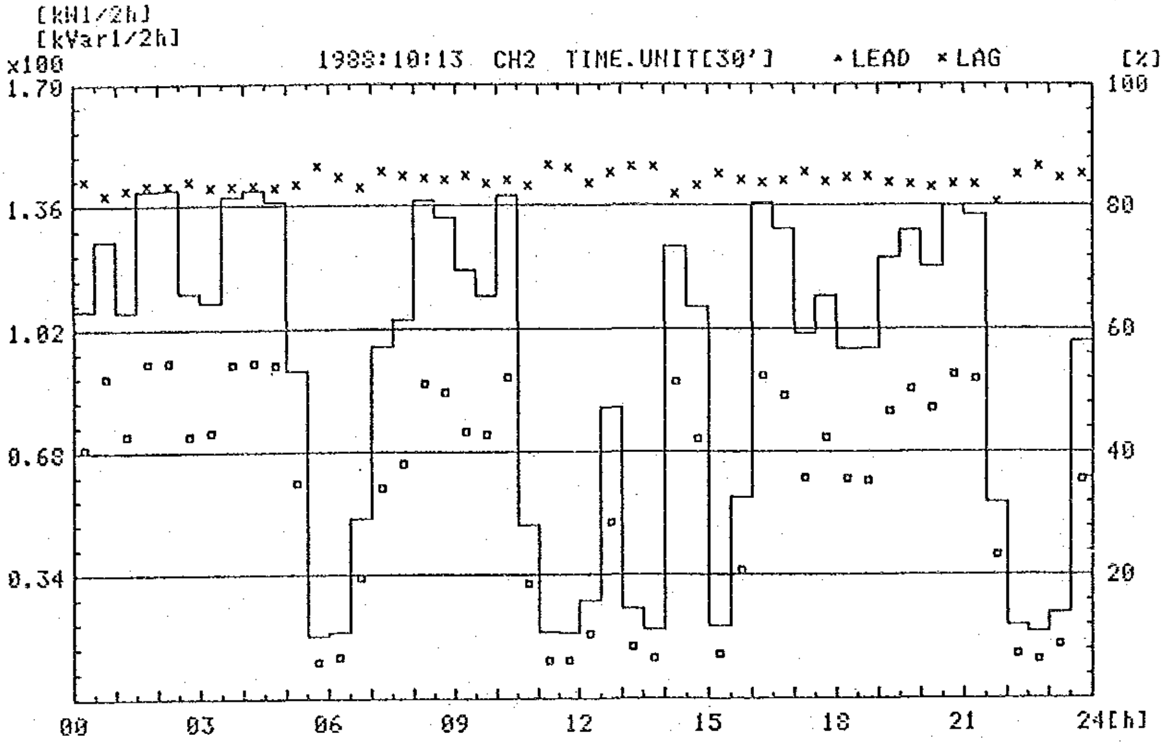
```
kWh[DAY]          13554            kVarh[DAY]          6854
DM.kW[30']          754  08°15'    AVE.PF[DAY]         -89.2%
AVE.kW[DAY]         565            LOAD.FACT[30']       74.9%
```

Fig 5-4-24 Load Condition of the Factory



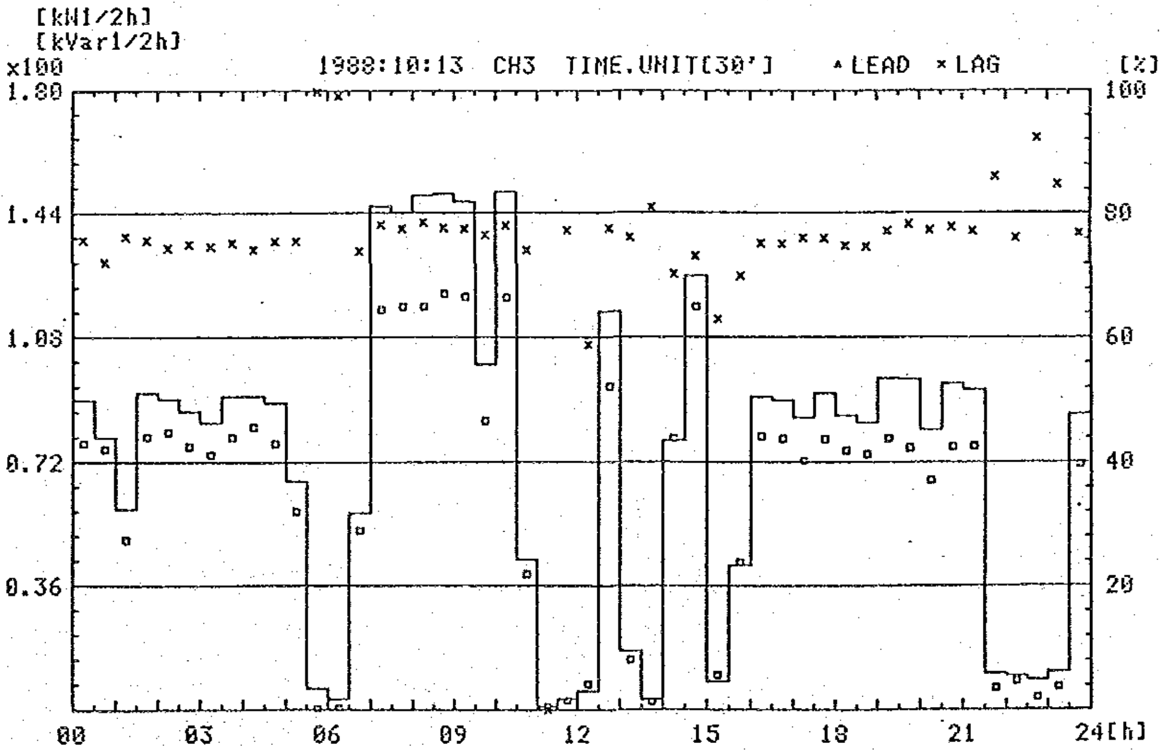
```
kWh[DAY]           2962            kVarh[DAY]          1812
DM.kW[30']          181  09°45'    AVE.PF[DAY]         -85.3%
AVE.kW[DAY]         123            LOAD.FACT[30']       68.3%
```

Fig 5-4-25 Load Condition of Pulp



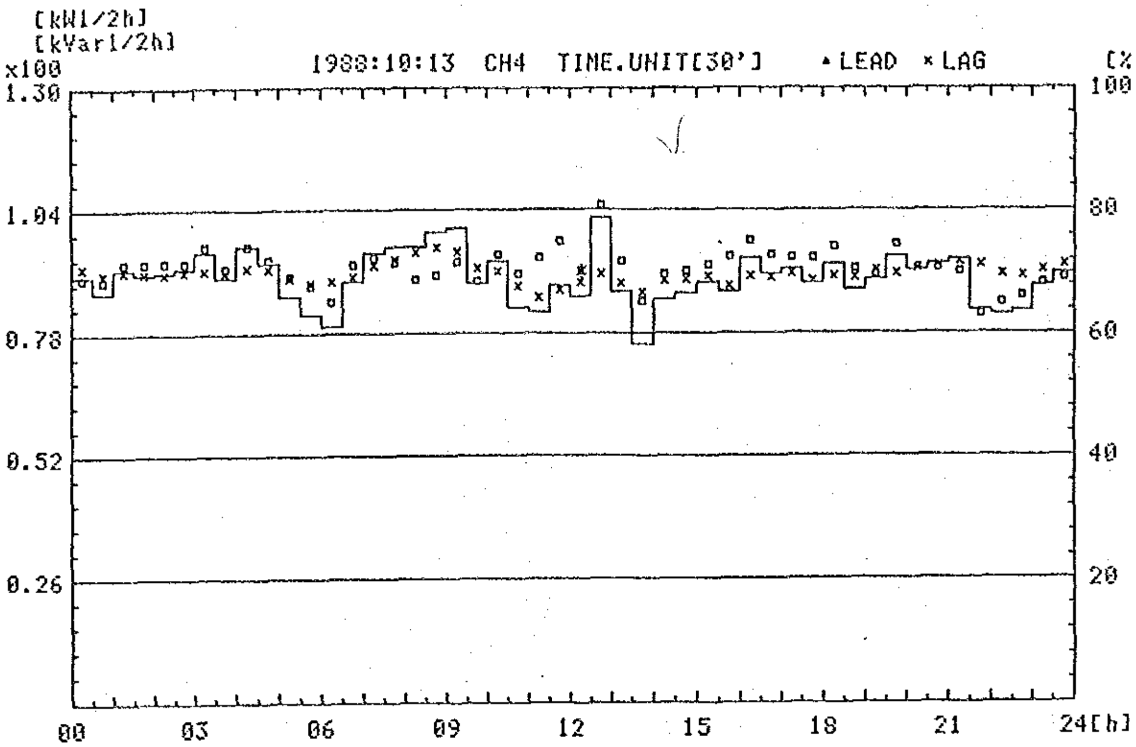
kWh[DAY]	2175		kVarh[DAY]	1410	
DM.kW[30']	141	02"15'	AVE.PF[DAY]	-83.9%	
AVE.kW[DAY]	91		LOAD.FACT[30']	64.5%	

Fig 5-4-26 Load Condition of Deflaker



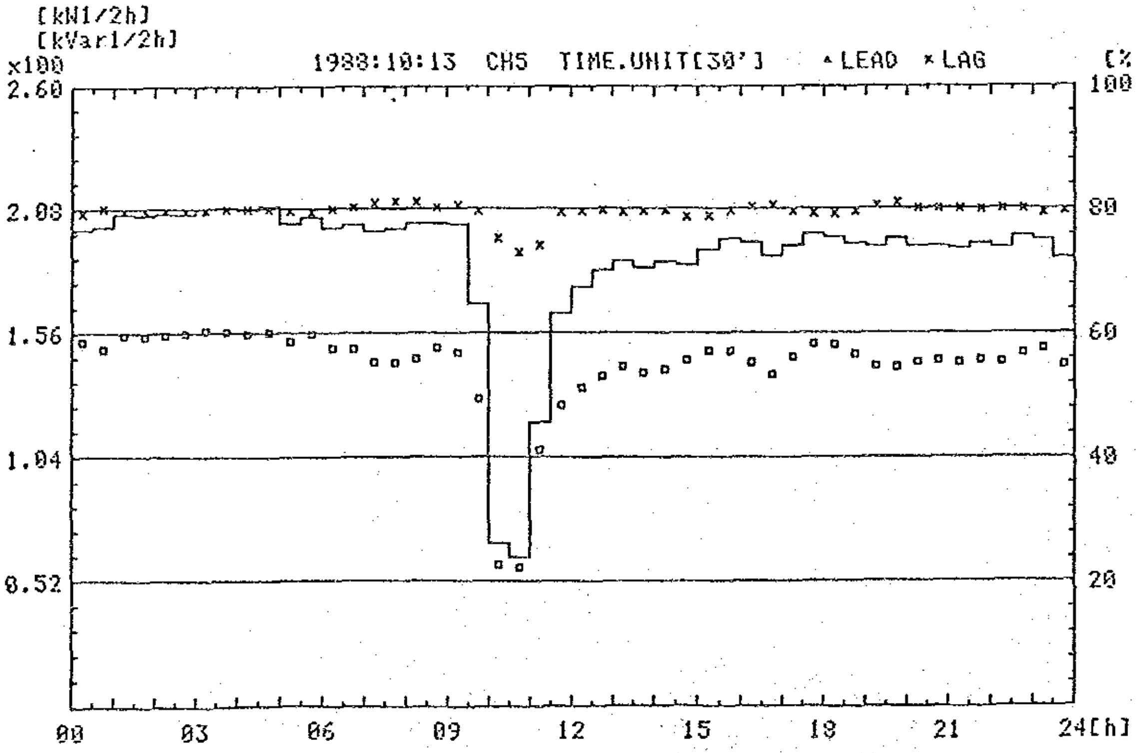
kWh[DAY]	1767		kVarh[DAY]	1500
DM.kW[30']	151	10"15'	AVE.PF[DAY]	-76.2%
AVE.kW[DAY]	74		LOAD.FACT[30']	48.9%

Fig 5-4-27 Load Condition of Refiner



```
kWh[DAY]           2155              kVarh[DAY]          2208
DM.kW[30']          102   12"45'     AVE.PF[DAY]        -69.8%
AVE.kW[DAY]          90              LOAD.FACT[30']      87.6%
```

Fig 5-4-28 Load Condition of No. 1 M/C



```
kWh[DAY]           4519              kVarh[DAY]          3414
DM.kW[30']          210   04"45'     AVE.PF[DAY]        -79.8%
AVE.kW[DAY]         188              LOAD.FACT[30']      89.8%
```

Fig 5-4-29 Load Condition of Continuous No. 2

5.4.3.14 Summary

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

Item		Possible annual amount of saving	%
Improvement of dryer steam supplying method	Gas	44,600 m^3	3.0
Heat insulation of the side of dryer		15,500	0.7
Improvement of boiler air shortage		126,000	5.5
Improvement of air ratio for low combustion of boiler		9,000	0.4
Cleaning of boiler heat transfer surface		87,700	3.8
Prevention of leakage of steam pipe		400	0.0
Heat insulation of steam pipe		67,900	3.0
Repair of steam trap		7,000	0.3
Prevention of flash steam diffusion		16,400	0.7
Heat insulation of condensate recovering pipe		11,200	0.5
Total		385,700	16.9

5.5 Results of Survey of Leather Factory

5. Survery of the Use of Energy in Model Factories

5.5 Results of Survery of Leather Factory

5.5.1 Outline of the Factory

(1) Name of the factory : Ventura Hermanos

(2) Type of product : Leather

(3) Location of the factory : Ruta Prov. 11 km 43 – (1913) Magdalena, Prove. de Buenos Aires

(4) Summary

Ventura Hermanos is a leather factory with a capacity of producing about 800 hides daily. It is next in scale to the 20 factories in Argentina that have a capacity of producing more than 1,000 hides daily.

The factory moved to the middle of a prairie from Buenos Aires seven years ago because of the environmental problem. It is a modern factory well laid out with efficient equipment.

Ventura Hermanos has been steadily increasing production while the leather production of Argentina decreases about 15 percent since the peak year of 1978. The leather industry is in a recession as a whole. The labor is reduced by 15 percent, and operation is on a single shift from 07:00 to 15:30. Daily production is limited to 300 to 350 hides. About 15 million head of cattle are slaughtered in Argentina, so the factory has a market share of less than 1 percent.

This factory has relatively small heat loss because processing temperature is below 80°C.

Condensers are already installed to improve the power factor and steam condensate is recovered under its energy conservation program.

(5) Number of employees : About 44 (no engineer)

(6) Survey period : October 17 – 21, 1988

(7) Survey members

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

INTI members

Name	Assignment
Mr. Jorge A. Fiora	Chief
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
Mr. Hector G. Citadino	Heat using equipment

Mr. Oscar W. Fuentes   Electric receiving and distributing equipment

(8) Interviewed

Mr. Juan Carlos Ventura, president

Mr. Edgardo Carlos Luppi, factory manager

(9) Production

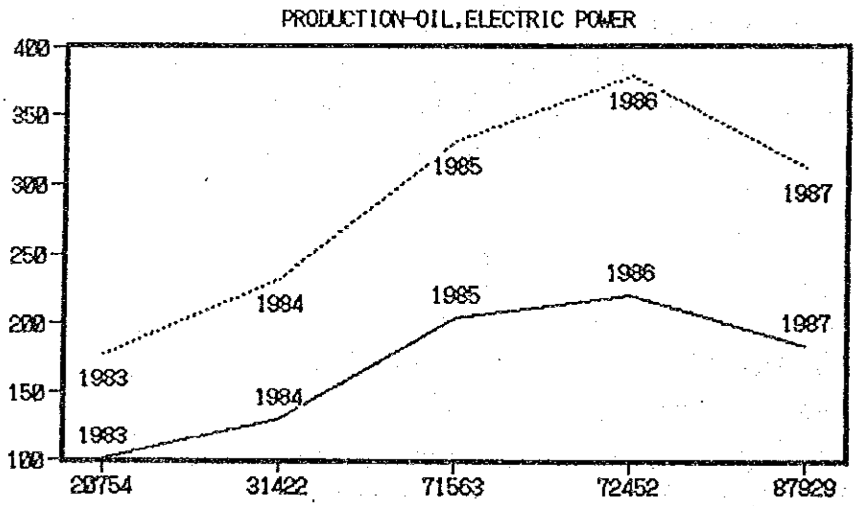
(10) Energy consumption

Table 5–5–1 Production

Year	1983	1984	1985	1986	1987
Number of hide	20754	31422	71563	72452	87929

Table 5–5–2 Energy Consumption

Year	1983	1984	1985	1986	1987
Oil kl	101	130	204	221	183
Elect. power MWh	177.0	231.8	331.2	379.2	312.4
Energy/product					
Oil l/hide	4.87	4.14	2.85	3.05	2.09
Power kWh/hide	8.53	7.38	4.63	5.23	3.55



OIL kℓ . . . ELECTRIC POWER MWh

Figure 5–5–1 Production and Energy Consumption

Unit: one thousand

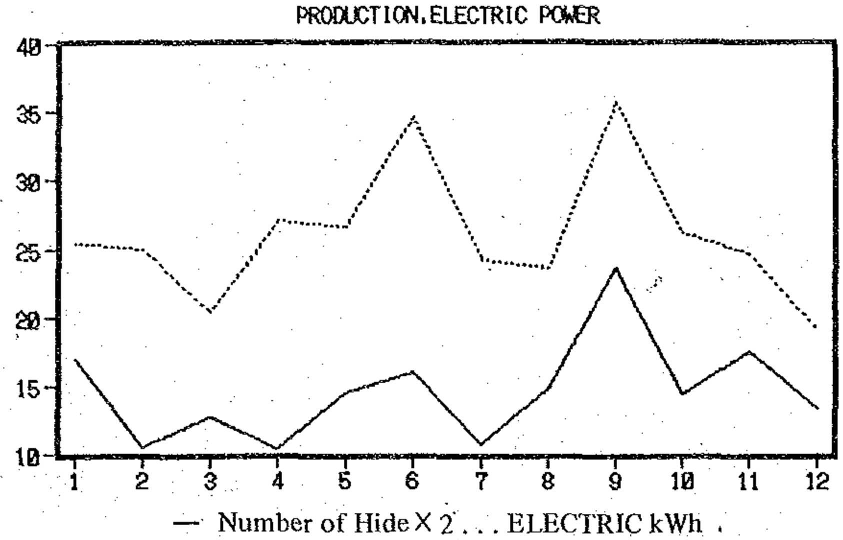


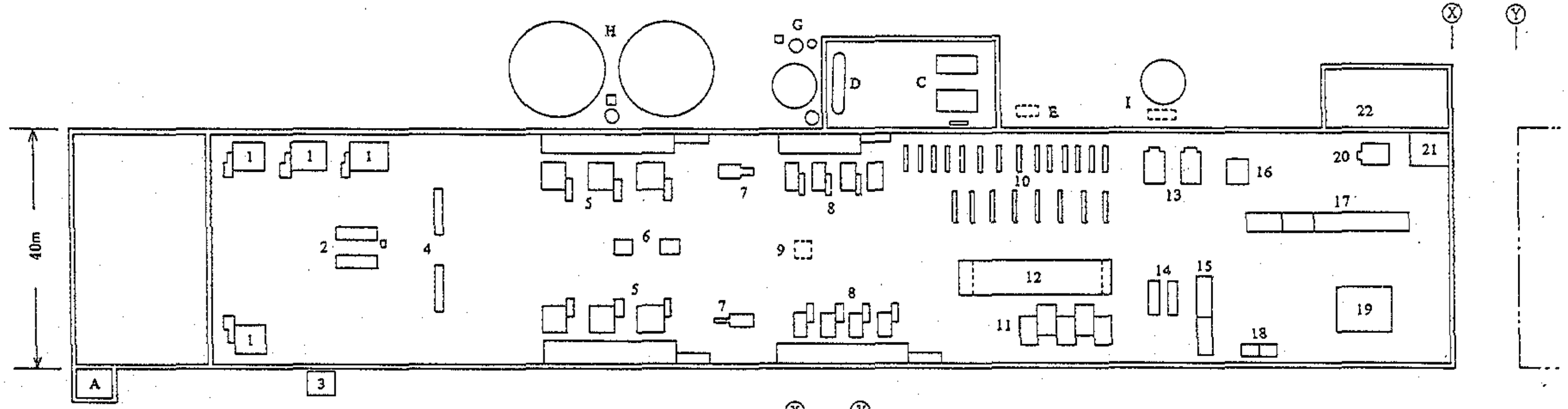
Figure 5–5–2 Monthly Production and Energy Consumption

Electric Power unit price	0.12U$S/kWh
Fuel Oil unit price	*119 U$S/kl*

Electric power unit price : 0.12 U$S/kwh

Fuel oil unit price : 119 U$S/kl

(11) Factory layout



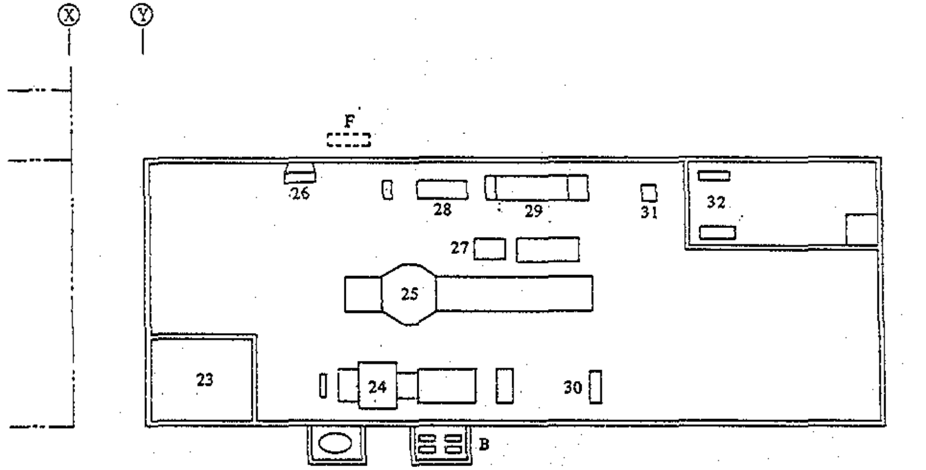


Figure 5–5–3 Factory Layout

No.	Name of machine and equipment	No.	Name of machine and equipment
1	Drum	22	Filing machine
2	Fleshing machine	23	Paint preparation
3	Hopper	24	Painting machine
4	Splitting machine	25	Painting machine
5	Drum	26	Spray booth
6	Squeezer	27	Tunnel dryer
7	Shaving machine	28	Tunnel dryer
8	Drum	29	Tunnel dryer
9	Balance	30	Ironing machine
10	Thermic plate dryer	31	Ironing machine
11	Tunnel dryer	32	Measuring machine
12	Tunnel dryer		
13	Vacuum dryer	A	Power receiving room
14	Dryer	B	Air compressor
15	Stretching machine	C	Boiler
16	Softening machine	D	Water heater
17	Tongs stretcher	E	Boiler feed water tank
18	Humidifier	F	Condensate pit
19	Glass dryer	G	Water softener
20	Drum	H	Water reservoir
21	Aspirator	I	Vacuum dryer water pit

(12) Production process

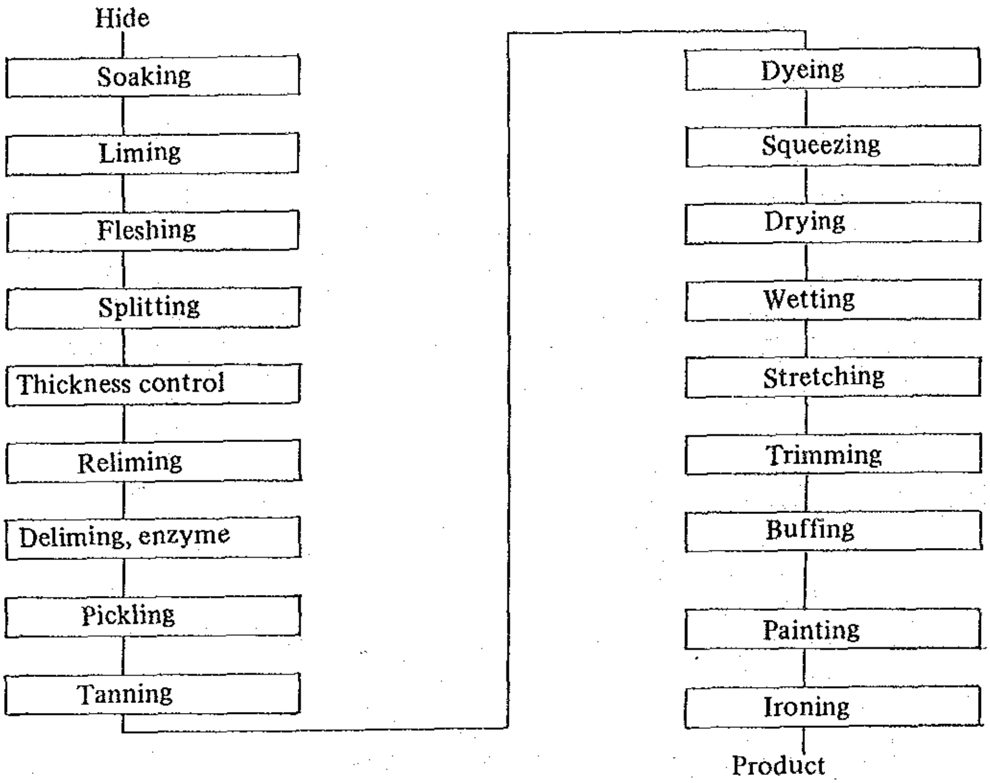


Figure 5–5–4 Production Process

(13) One line diagram

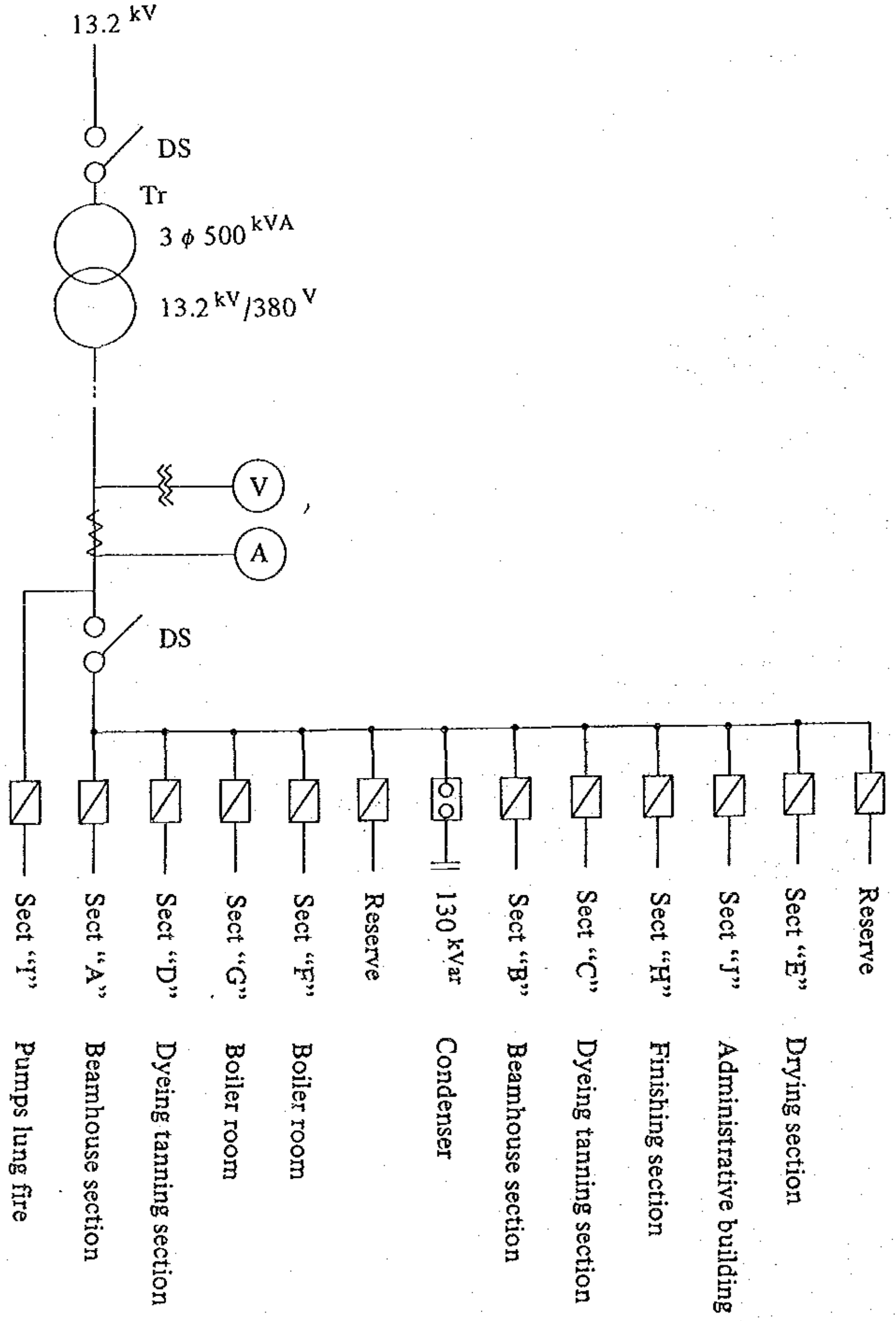


Figure 5–5–5 One Line Diagram

(14) Major equipment

Table 5–5–3 **Major Energy Consuming Equipment**

Name	Number	Specification
Boiler	2	2 t/h 8 kg/cm² Oil 1.5 t/h 10 kg/cm² Oil Flue and smoke tube type
Water heater	1	0.9 φ x 6.8 H
Thermic plate	22	9.63 m² x 8, 9.09 m² x 6, 8.88 m² x 8
Dryer	1	Tunnel 13.7L x 3.6W x 2.5H
Painting machine	1	Dryer 12.0L x 3.8W x 1.3H
Air compressor	4	20 Hp (2), 15 Hp (2)
Drum	17	3 φ x 4 H (4) 25 Hp 3 φ x 3 H (6) 25 Hp 2.5 φ x 1.5 H (7) 15 Hp

(15) Factory operating time

8.5 h/d x 250 d/y = 2,125 h/y (Production equipment)

10 h/d x 250 d/y = 2,500 h/y (Boiler)

5.5.2 Energy Management

(1) Energy conservation target

The factory executives are interested in energy conservation, but do not have a set target for it. Therefore, no concrete improvement plan has been prepared as yet.

The reasons for it are presumably as follows: the factory is a modern one, starting its operation in 1981, and the executives consider that energy saving measures have been taken and that there is no problem with the equipment. The operating temperature of the leather industry is generally low. It is difficult to make capital investments in the existing conditions of recession.

Similar to textile dyeing factories, however, leather factories need a large volume of hot water. In fact, Ventura Hermanos spends nearly U$S60,000 a year for energy. Under the present conditions where the factory is operating at a low rate and with a reduced labor force, energy saving will be an effective means of cost reduction. It is recommended, therefore, that Ventura Hermanos set up an energy conservation target and actively promote energy conservation.

As shown in Figure 5–5–1, energy consumption decreased over the preceding year while production increased to the highest level. According to the account of the factory, this was due perhaps to a larger percentage of semi-finished products. It would be better to set a consumption target for finished and semi-finished products respectively.

(2) Determining energy consumption.

To improve productivity and quality and reduce energy consumption, it is necessary first of all to record their data and operating conditions daily, and accurately determine the actual state of factory operation. If changes in their values are found, or if there occurs a difference between the actual values and planned or design values, the cause may be checked immediately and a remedial step be taken, thus paving the way to improvement.

Ventura Hermanos knows how much electricity it consumes a month by checking the electricity bill every month, but does not know how much electricity it consumes daily. The factory checks the quantity of fuel oil received with the invoices, but does not check daily or monthly consumption of fuel oil. Such as it is, the factory won't be able to know an unusual change in energy consumption until the bill is checked. It won't be possible for the factory to determine the cause or take an appropriate step while tracing the process. Simple steps of measuring actual energy consumption and letting the operators know it can automatically trigger an action for saving energy.

The factory consumes steam as heat energy. Install an integrating meter for feed water on the boiler water line, and a flow meter on the fuel oil line, and record their readings every hour. This will enable to know steam consumption trends, and compare the readings with the conditions of equipment shutdown and operation as well as with production to determine causes of energy loss. Also record the total amounts of feed water and fuel oil consumption in the boiler journal every day, and compare the recordings so that changes in boiler efficiency can be assumed. The total amount of feed water divided by the total amount of fuel consumed is called the evaporation ratio, which should be desirably higher than 13.

It is strongly recommended that a boiler journal be prepared and kept because it enables to assume the contamination of the heat transfer surfaces from changes in exhaust gas temperature and determine cleaning intervals; to check changes in recovery of condensate from feed water temperature, and other changes over a long period of time; and thus is effective for not only energy saving but also equipment maintenance.

(3) Education and training

Employees may be willing to make improvements, but can not do so without knowing how. It is therefore important to train the employees by means of training courses, for example.

Ventura Hermanos does not have engineers, and said that it neither holds training courses nor has opportunities to visit other leather factories. However, one possibility is to get duidance of the INTI's CITEC which is located near by.

New employees are educated about prevention of idling of the motors and about saving water. It is important to give actual information on energy consumption and call their attention to observing the work standard so that they will be aware of the importance of energy conservation.

(4) Equipment management

The factory is a modern one constructed about 8 years ago. It is properly laid out and the equipment is well maintained. However, some of the steam traps, thermometers, and automatic temperature controllers were found out of order. Assign serial numbers to all the valves and traps, record their defects, repairs, and other data in a management ledger, and perform periodic maintenance work on them. It is also necessary to properly file design data, drawings, modification data for the main equipment, and one line diagrams so that improvement plans may be drawn up and that trouble may be quickly dealt with.

5.5.3 Problems and Measures Regarding Use of Energy

5.5.3.1 Boiler

The steam supplied from the boilers is used as energy for the thermic plate, dryer, water heater, 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 for 10 hours a day, starting operation at 5:30 in the morning and stopping at 3:30 in the afternoon, while the 3-pass boiler on the right operates as an auxiliary boiler only in the winter morning from 5:30 to about 9:00. The present survey is made on the 3-pass boiler on the left that is in operation as the main boiler. It was maintained in good condition, but there was a partial leakage of steam from the valve of the boiler.

(1) Boiler specifications

Type : 3-pass, flue and smoke tube boiler
Evaporation : 2.2 t/h
Steam pressure : 9 kg/cm^2 G(rated)
Fuel : Heavy oil (Hl = 10,377,70 kcal/kg)
Fuel composition is assumed to be as shown below.
C = 85.50% H = 12.00% S = 1.00%
O = 1.00% N = 0.45% Water = 0.04%
Ash = 0.01%
Heating surface : 50 m^2
Date of manufacture : 1977
Structure : As shown in Figure 5–5–6

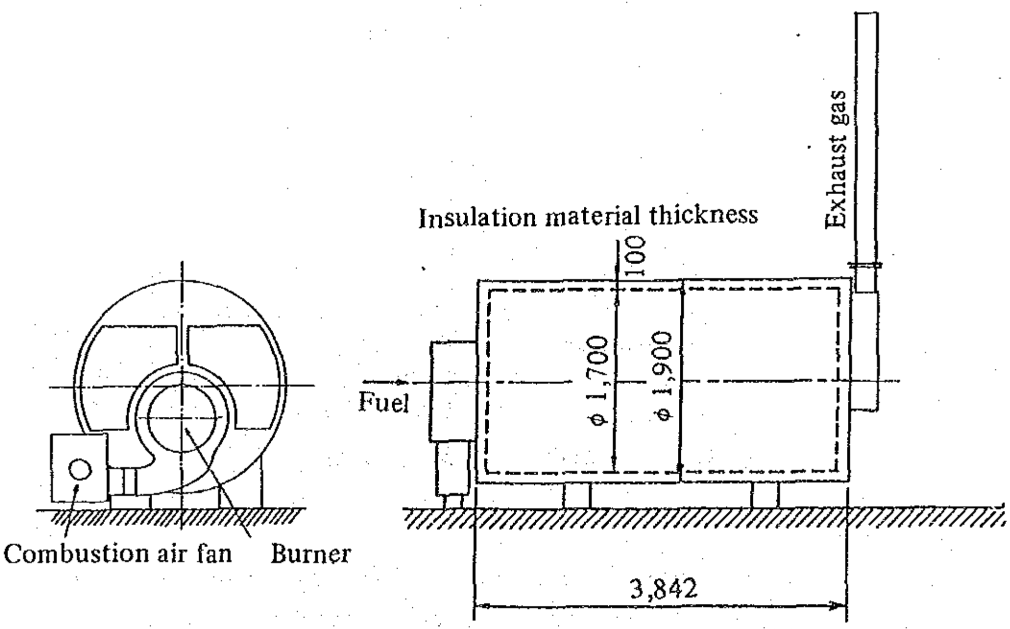


Figure 5–5–6 Boiler Structure

(2) Survey items and collected data

The boiler was surveyed on October 18, 1988.

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

(a) Data was gathered on the following items using the measuring instruments. The measuring points are shown in Figure 5–5–7 "Boiler Measuring Points."

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 visual observation items are as follows:

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

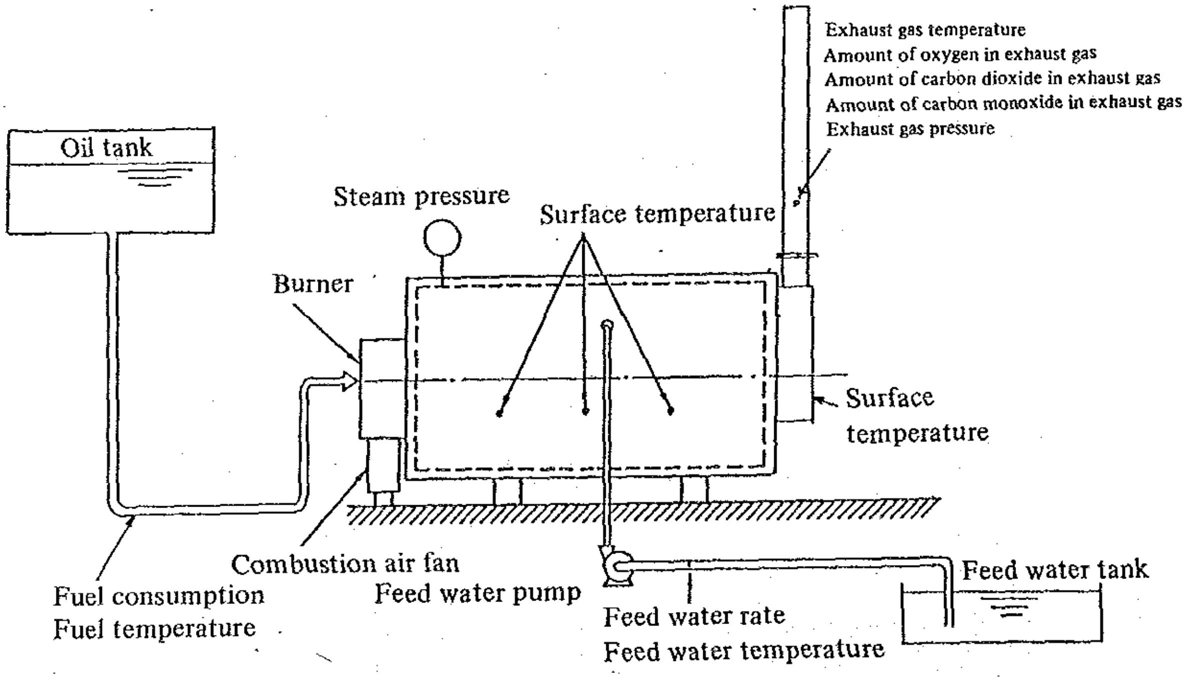


Figure 5–5–7 Boiler Measuring Points

(3) Heat balance of boiler

(a) The heat balance of the 3-pass boiler was calculated using the data collected from 13:00 to 14:00 on October 18. The details of the data are as follows:

1) Kind of fuel : Heavy oil
2) Calorific value (low level) (Hl) : 10,377.70 kcal/kg

3) Specific gravity of fuel (Sf) : 0.922
4) Specific heat of fuel (Cpf) : 0.45 kcal/(kg°C)
5) Fuel temperature (inlet of heater) (Tf) : 38.4°C
6) Reference temperature (To) : 26.2°C
7) Temperature of combustion air (Ta) : 27.4°C
8) Specific heat of combustion air (Cpa) : 0.31 kcal/(Nm^3 °C)
9) Theoretical amount of air (Ao) : 10.80 Nm^3/kg-fuel
10) Theoretical amount of wet exhaust gas (Go) : 11.47 Nm^3/kg-fuel
11) Fuel flow rate (Fm) : 78.37 kg/h
12) Exhaust gas temperature (Tg) : 291.9°C
13) O_2 % of dry waste gas (O_2) : 8.18%
14) Air ratio (m) : 1.43
15) Actual amount of combustion air (A) : 15.43 Nm^3/kg-fuel
16) Actual amount of wet exhaust gas (G) : 16.10 Nm^3/kg-fuel
17) Specific heat of exhaust gas (Cpg) : 0.33 kcal/(Nm^3 °C)
18) Exhaust gas pressure (Pg) : –5.61 mmH_2O
19) Feed water flow rate (based on weight) (Fw) : 1,061 kg/h
20) Feed water temperature (Tw) : 42.6°C
21) Steam pressure (Ps) : 6.48 kg/cm^2 G
22) Enthalpy of dry steam : 660.18 kcal/kg
23) Enthalpy of saturated water : 168.58 kcal/kg
24) Dryness of steam : 0.98
25) Enthalpy of wet steam (h'') : 650.35 kcal/kg
26) Enthalpy of feed water (h') : 42.990 kcal/kg

b) Heat input

Heat input per kg of fuel is calculated.

1) Combustion heat of fuel (H1)

H1 = 10,377.70 kcal/kg

2) Sensible heat of fuel (Qs)

Qs = 0.45 x (38.4 – 26.2) = 5.49 kcal/kg

3) Sensible heat of combustion air (Qa)

Qa = 15.43 x 0.31 x (27.4 – 26.2) = 5.74 kcal/kg

4) Total heat input (Qi)

Qi = H1 + Qs + Qa = 10,377.70 + 5.49 + 5.74 = 10, 388.93 kcal/kg

c) Heat output

Heat output per kg of fuel is calculated.

1) Heat content of steam (Qv)

$$Qv = \frac{1,061}{78.37} \times (650.35 - 42.99) = 8,222.65 \text{ kcal/kg}$$

2) Heat taken away by exhaust gas (Qg)

Qg = 16.10 x 0.33 x (291.9 – 26.2) = 1,411.66 kcal/kg

3) Heat radiation from boiler surface (Qr)

$$Qr = \frac{669 \times 2.83 + 150 \times 22.92 + 3.256 \times 2.83}{78.37} = 185.60 \text{ kcal/kg}$$

Average temperature and surface area of front plate: 78.9°C, 2.83 m^2

Average temperature and surface area of shell plate: 41.2°C, 22.92 m^2

Average temperature and surface area of rear plate: 193.9°C, 2.83 m^2

4) Other heat loss (Qm)

Qm = 568.97 kcal/kg

5) Total heat output (Qo)

$$Qo = Qv + Qg + Qr + Qm = 8{,}222.65 + 1{,}411.66 + 185.60 + 568.97 = 10{,}388.93 \text{ kcal/kg}$$

d) Heat balance table

The data shown above are summarized in Table 5–5–4.

Table 5–5–4 Heat Balance of Boiler

Heat input			Heat output		
Item	kcal/kg	%	Item	kcal/kg	%
Fuel combustion heat	10,377.70	99.89	Heat of Steam	8,222.65	79.15
Sensible heat of fuel	5.49	0.05	Heat taken away by exhaust gas	1,411.66	13.59
Sensible heat of combustion air	5.74	0.06	Heat radiation from surface	185.60	1.69
			Other heat loss	568.97	5.54
Total	10,388.93	100.00	Total	10,388.93	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 ratio, which can be calculated from the amount of oxygen in exhaust gas. The amount of oxygen in exhaust gas was 6.18% and the air ratio was 1.43. If the amount of oxygen is reduced to 4.5%, the air ratio will be 1.27 and the amount of exhaust gas will be reduced by about 8%.

The amount of air can be 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.

Table 5–5–5 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		%	6.18	4.5
2	Air ratio	m		1.43	1.27
3	Theoretical amount of air	Ao	Nm^3/Nkg	10.80	10.80
4	Theoretical amount of exhaust gas	Go	Nm^3/Nkg	11.47	11.47
5	Actual amount of air	A	Nm^3/Nkg	15.44	13.72
6	Actual amount of exhaust gas	G	Nm^3/Nkg	16.10	14.39
7	Exhaust gas temperature	tg	°C	291.9	291.9
8	Heat taken away by exhaust gas	Qg	kcal/Nm^3	1,411.66	1,261.73

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

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{10{,}388.93 - 1{,}411.66}{10{,}388.93 - 1{,}261.73} = 0.0164 = 1.64\%$$

where Hi: Heat input per kg of fuel (kcal/kg);

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

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

Assuming that the annual consumption of fuel is 85 ℓ/h X 10 h/d X 250 d/y = 212,500 ℓ/y, the amount of annual saving can be calculated as follows:

212.5 kℓ/y x 0.0164 x 119 U$S/kℓ = 415 U$S/y

(b) Boiler water quality control

The quality of feed water and boiler water was found to be as shown in Table 5–5–6.

Table 5–5–6 Quality of Feed Water and Boiler Water

Kind	Measured value			Reference		
	Temperature	pH	Electric conductivity	Temperature	pH	Electric conductivity
Well water	24.3 ℃ 25.5 ℃	8.81 8.05	3.40 mS/cm 3.43 mS/cm	–	–	–
Soft water	20.8 ℃ 23.0 ℃	8.83 8.05	3.19 mS/cm 3.36 mS/cm	–	–	–
Feed water	30.2 ℃ 29.1 ℃	9.17 8.56	1.95 mS/cm 2.12 mS/cm	25 ℃	7～9	–
Boiler water	44.1 ℃ 34.7 ℃	13.62 11.80	out of range out of range	25 ℃	11～11.8	<4.5 mS/cm

Boiler water is controlled by bottom blow of boiler water. Bottom blow, lasting about 30 seconds, is done 3 or 4 times a day. The study shows that the electric conductivity value of the boiler water is abnormally high. This means that a large amount of impurity is contained in the boiler water, causing the insufficient heat transmission of the boiler as well as the shortening of the life of the boiler.

In case that the quality of the boiler water is adjusted only by blowing, a large amount of continuous blows are required unless the conductivity of feed water is less than 0.4 mS/cm, and it cannot be applied actually. Therefore, it is necessary to thoroughly control the quality of the feed water. However, the total salt cannot be removed by the existing water solfener alone.

The salt concentration can be lowered by the following methods.

(1) The salt concentration of the feed water is lowered by increasing the recovery rate of steam condensate.

(2) The quality of the feed water is improved by lowering the salt concentration through the use of a part of raw water (well water) for the unit such as reverse osmosis equipment.

(3) The amount of salt in soft water can be reduced slightly because a large part of M alkali in raw water can be removed (the residue is 5 – 15 mg/ℓ) by changing the current softener to the dealkali softener.

(4) If the above mentioned measures cannot be taken, the deoxydation process using chemicals should be conducted thoroughly as a temporary measure because the corrosion due to chlorine ion is likely to be accelerated.

(c) Inertial operation of boiler

Boilers can continue to supply steam by the remaining pressure for some time after the extinguishing. Therefore, it is advisable to stop the boilers before the end of operation in consideration of the operating condition of the boilers. Attention should also be paid to avoid the too early rise in the morning.

After the boilers are stopped, the draft effect remains. Therefore, the aire suction must be closed to minimize the body cooling by cool air.

(5) Improvement of boiler feed water quality

(A) Measures against contamination of boiler feed water

(a) Results of analyzing boiler feed water

The results of analyzing boiler feed water are shown in Table 5–5–7, which reveals the following.

(i) The raw water is ground water which has abnormally high degrees of alkalinity, chlorine ion concentration, and electric conductivity.

(ii) Figure 5–5–8 is a graph of the chlorine ions and electric conductivity of the boiler feed water and raw water. The boiler feed water is a mixture of recovered condensate and soft water. Two of the six values of water analysis were found abnormal.

Compared with soft water, the boiler feed water had about 3 times higher concentration of chlorine ions and silica ions, electric conductivity, and total dissolved solids.

Table 5–5–7 Results of Water Quality Analysis

Object of analysis		JIS	Boiler water		Condensate	Raw water	Soft water	Boiler feed water (condensate + soft water)		
Item of analysis		Standard value	Apr. '88	Jly. '88	Jly. '88	Jly. '88	Jly. '88	Jly. '88	Apr. '88	Mar. '88
pH		11~11.8	12.1	12.1	9.2	7.8	7.8	11.9	9.25	10.2
Total alkalinity	ppm	100~800	17,450	9,000	100	750	750	2,530	420	1,860
Bicarbonate(as $CaCO_3$)	ppm	~			80				240	160
Carbonate (as $CaCO_3$)	ppm	80~600	12,500	6,000	20	750	750	1,860	180	1,700
Total hardness (as $CaCO_3$)	ppm	0				80	20			
Chlorine ion (Cl^-)	ppm	400>	14,280	7,840	56	630	630	2,100	294	1,480
Silica ion (SiO_2)	ppm	~	535	186	4	28	28	64	22	105
Phosphoric acid ion (PO_4^{3-})	ppm	20~40	320	240						
Electric conductivity	µs/cm	4,000>	62,000	32,000	570	2,760	2,760	8,600	1,810	8,810
Total dissolving solid	ppm	2,500>	52,700	26,400	320	1,840	1,840	6,800	1,170	5,150

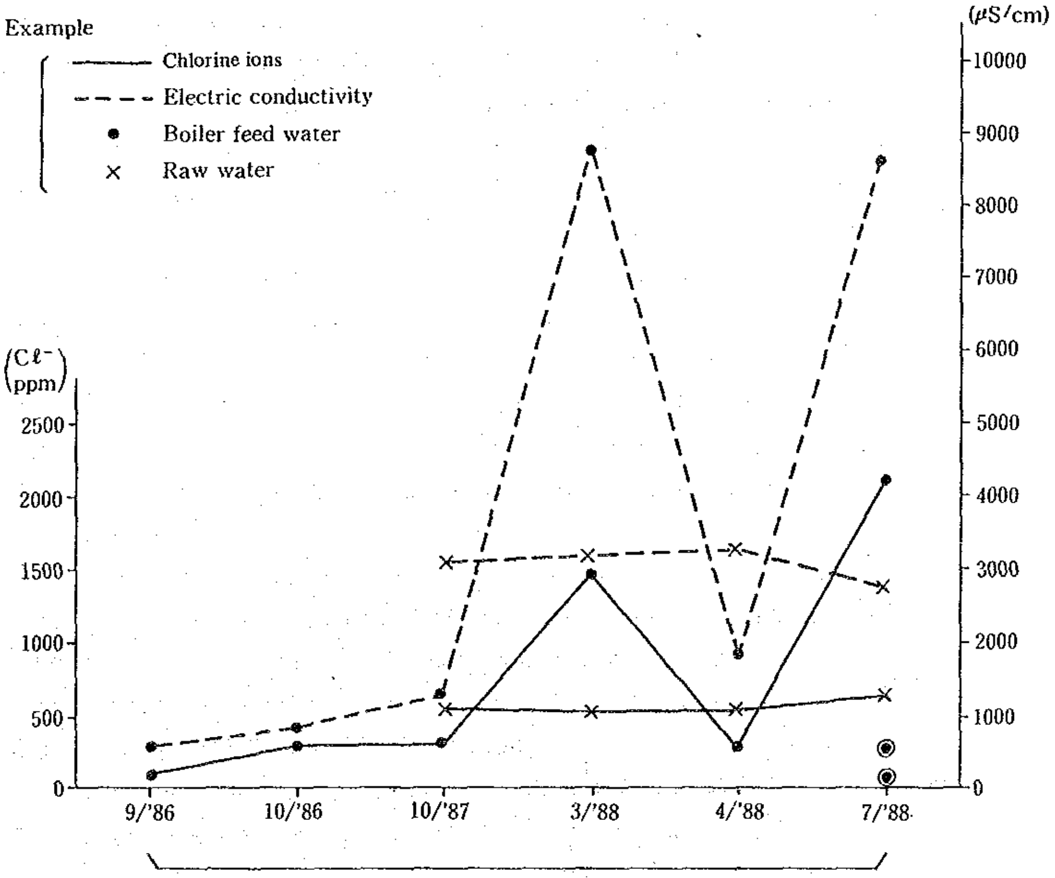


Figure 5–5–8 Changes of Boiler Feed Water Quality

(iii) The boiler water, affected by the improper quality of the boiler feed water, showed an abnormal value for each item of water quality.

It had a concentration 12 to 22 times higher than the raw water.

If the water to be supplied to the boiler is not of proper quality, it may cause corrosion of the heat transfer surfaces, form layers of hard scale, and trigger a boiler explosion. Layers of scale will block heat transfer. If oil or fat is mixed into the water, bubbling will occur, and an undesirable phenomenon involving bubbles and waterdrops in the steam may occur. Therefore, the water in the boiler must be controlled to be always in the best condition.

(b) Causes of abnormality of boiler feed water

The present boiler feed water system is shown in Figure 5–5–9. The following were found as a result of checking this system.

(i) The blow water discharged from the boiler water level meter was connected to the condensate recovery pipe for the boiler fuel oil heater so that the blow water was flowing down into the underground tank for boiler feed water.

Because the water was not blown so often from level meter, this is not assumed to be a direct source of contamination.

(ii) The tank for boiler bottom blow water is mounted on top of the boiler feed water underground tank. (Figure 5–5–9).

As a result of checking it, it was assumed that leaking blow water from this tank was the main cause of boiler feed water contamination. The blow water level in the steel tank was considerably lower than the overflow level.

- o The concrete pit encircling this steel tank should be dry inside, but was filled with water up to the same level as in the steel tank, indicating that the steel tank was leaking.
- o The concrete pit had a crack in its bottom toward the boiler feed water tank, and traces of mud pouring to the top of the boiler feed water tank were observed. From what has been pointed out above, it is assumed that the boiler blow water in the tank was leaking into the boiler feed water tank to contaminate the water.

(iii) Heavy oil was floating on the surface of the boiler feed water in the tank.

There are two possible ways of heavy oil entering the underground feed water tank. About the possible leakage from the boiler oil heater to the condensate recovery pipe, no contamination was observed at the opening of the recovery pipe.

However, the opening of the condensate recovery pipe from the underground heavy oil storage tank was found stained with heavy oil, indicating heavy oil leakage from this system. If the steam heating pipe in the underground heavy oil tank is corroded or becomes loose at the joint, there will be a negative pressure inside the pipe when the boiler is not operating, causing the heavy oil to leak into the steam heating pipe. When steam heating is started again, the leaking heavy oil will flow together with condensate into the feed water tank.

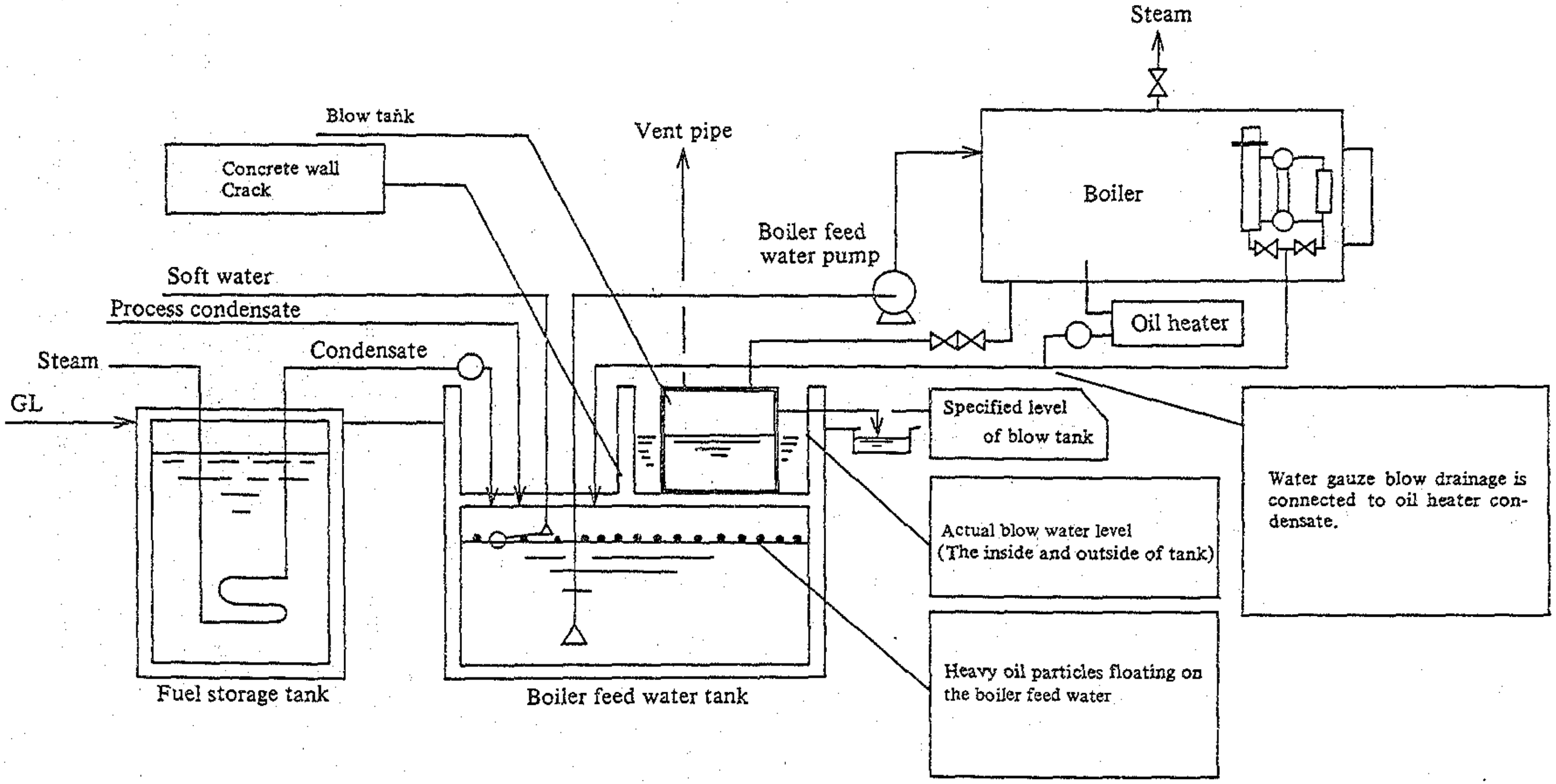


Figure 5–5–9 Flow Sheet of Boiler Feed Water

(c) Measures to improve the quality of boiler feed water

(i) Preventing mixture of boiler blow water

Move the boiler blow tank to somewhere on the ground away from the underground feed water tank.

(ii) Changing blow water discharge pipe for boiler water level meter

Disconnect it from the condensate recovery pipe for the oil heater, and connect the blow water discharge pipe to the blow tank.

(iii) Preventing heavy oil leakage

Stop recovery of condensate from the oil heater of the underground heavy oil tank. Discharge condensate to a point where it can be easily checked daily to determine whether heavy oil is leaking.

(B) Use of water softener

(a) Observations of water quality analysis table (Table 5–5–7)

It was found from the analysis of raw water and soft water made on July 13, 1988 that soft water had a very high total hardness of 20 ppm compared with raw water which showed a total hardness of 80 ppm. The total hardness of boiler feed water must be less than 1 ppm (0.05° dH) according to the standard.

(b) Use of water softener

The water softener has dimensions of 1,050 mm in inside diameter and 1,700 mm in body length. Its regenerating cycle is one month. It uses 40 kg salt per regeneration, and generates about 6 m^3 soft water daily.

(c) Required resin quantity and quantity of soft water obtained

The required quantity of resin is calculated from the amount of salt used.

If the required amount of salt is 100 g/ℓ-Resin, $R = \frac{40 \times 1{,}000}{100} = 400$ ℓ-Resin.

That is, resin layer is about 460 mm thick.

The amount of soft water obtained per 1 ℓ of resin at a raw water hardness of 80 ppm (4.6° dH) is 500 ℓ from Figure 5–5–10.

Thus, the maximum amount of soft water obtained per cycle will be 500 x 400 = 200,000 ℓ.

Generally, ion exchange resin lowers in ion exchange capacity with time due to flowing out in broken pieces, algae covering the resin, or chemical reaction with interfering ions.

The rate of capacity lowering is about 15 percent in five years.

It is already seven years since the start of production, and the present processing capacity is assumed to have lowered to about 80 percent of the original capacity. Therefore, the allowable amount of soft water obtained will be as follows:

$200 \times 0.8 = 160\ m^3/\text{cycle}$.

If 6 m^3 of soft water is used daily, regeneration will be needed every 26 days (160 divided by 6).

The present regenerating cycle of one month is reasonable, and there is no design problem with the water softener.

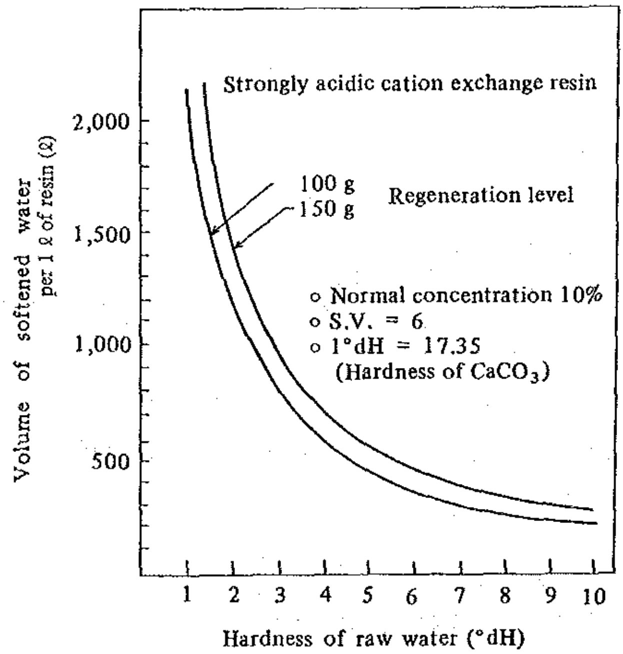


Figure 5–5–10 Relation between the Volume of Collected Water and the Hardness of Raw Water

(d) Important points about the operation of water softener

Attention must be paid to the following so that there will be no leakage of hardness.

(i) Have the boiler water and soft water checked for quality about once a month, and plot the hardness analysis results into a graph. This will make it easy to find anything abnormal and take appropriate steps for it. It is also desirable that a simple hardness checker of reagent type be kept on hand.

(ii) Showing the operation manual for water softener

Transcribe the instructions of the operation manual for the water softener on panels, and show them near the water softener at a point where they can be easily read.

(iii) Make sure that the soft water flow rate (m^3/h) will be correct, not too high or too low. If it is too high, ion exchange will be insufficient, causing hardness leakage. It is too low, the hardness constituents in resin resulting from ion exchange will be solved again.

The reasonable flow rate is 12 to 15 m^3/h

(iv) Relation of the amount of soft water obtained and hardness is shown in Figure 5–5–11. If the allowable limit of soft water production is exceeded, hardness leak will occur immediately. Generally, an integrating flow meter is used to control the allowable limits of soft water production. It is strongly recommended that an integrating flow meter be installed because it is relatively low-priced.

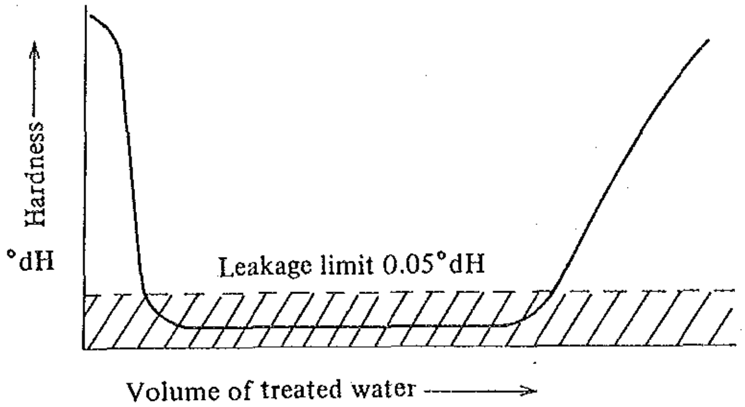


Figure 5–5–11 Softening Curve of Ion Exchange Resin

(v) Strictly observe the monthly regenerating cycle.

(vi) Observe the instructions in the manual for the flow rate and time in the various operations of backwashing, regeneration, extrusion, and rinsing.

(vii) Check the ion exchange resin that it is up to the required level (at least 400 ℓ at present).

(viii) Take part of the ion exchange resin, and have a water treatment company check for performance. Depending on the results of the check, add or change the resin.

(e) Others

(i) The soft water tank 25 m^3 in capacity has a cover so old that leather dust in the air discharged from the adjacent dust collector enters the tank to mix with the soft water.

5.5.3.2 Water Heater

(1) Hot water and steam consumption

(A) Hot water consumption

Hot water is mainly used for tanning and dyeing. Hot water temperatures in these processes are about 35°C and 60°C.

The water heater now produces hot water of about 70°C by indirect heating with steam. The amount of water supplied for a total of 4 hours 43 minutes from 09:50 to 14:33, October 19 (at an average water temperature of 42.5°C) was 4,615 ℓ, which corresponds to an average 969 kg/hour in terms of weight.

(B) Quantity of heat in terms of steam

Average temperature of feed water at water heater inlet : 42.5°C
Average temperature of hot water at water heater outlet : 61.5°C
Temperature difference between feed water and hot water : 19.6°C
Latent heat of evaporation of 6.5 kg/cm^2 G steam : 491.6 kcal/kg

The quantity of heat consumed can be calculated in terms of steam (Qkg/h) as follows:

$$Q = \frac{969 \text{ kg/h} \times 19.6 \text{ kcal/kg}}{491.6 \text{ kcal/kg}} = 38.6 \text{ kg/h}$$

(2) Problems and remedies

The present problems with the water heater are as follows:

(a) When hot water is not used, the hot water in the water heater rises into the feed water pipe, causing heat radiation loss.

A remedial plan is shown in Figure 5–5–12.

The hot water rises because the hot water replaces the cold water in the feed water pipe due to their difference in specific gravity. This phenomenon can be prevented by connecting 4 elbows and a short pipe to the feed water pipe as shown in Figure 5–5–12.

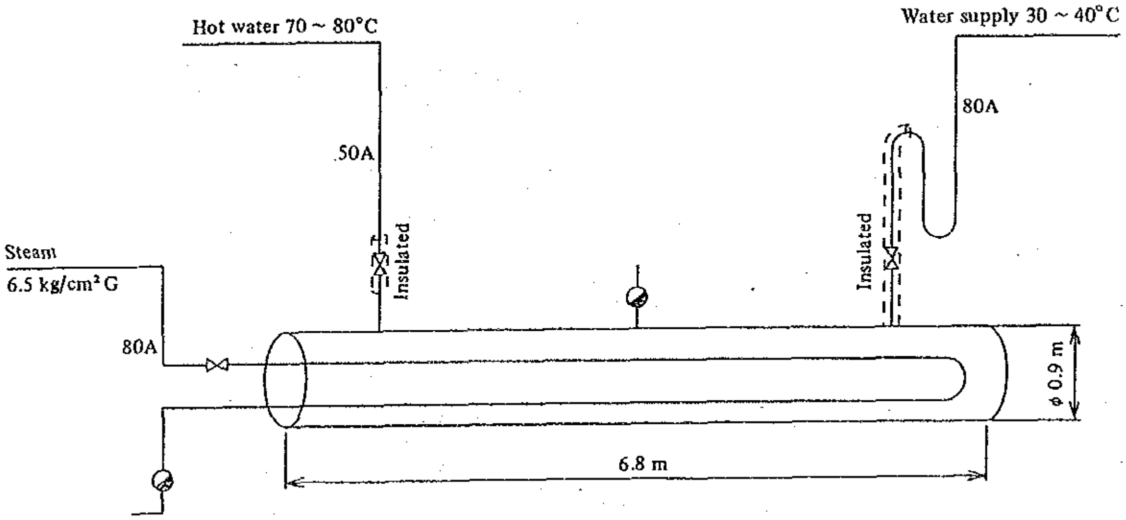


Figure 5–5–12 Improved Hot Water Heater

(b) The temperature in the water heater falls to about 30°C in the morning, and it takes about 40 to 45 minutes to start the water heater.

There was much variance in the temperature of hot water flowing out of the water heater. In fact, it varied by about 30°C from 46°C to 76°C as measured on October 19 as shown in Figure 5–5–13. The temperature of hot water falls as its flow rate increases.

To shorten the startup time of the water heater and reduce the temperature variance, the existing indirect heating should be replaced by a steam-water mixing system which has a higher speed of heat exchange.

There are two types of steam-water mixing system: One is the nozzle injection type, and the other is the mixing valve type. The water heater used in this factory is an enclosed, water filling type, and the modification to the nozzle injection type has problems about safety and the difficulty of dealing increased water quantity. It is recommended, therefore, a steam-water mixer such as shown in Figure 5–5–14 be additionally installed in each place necessary.

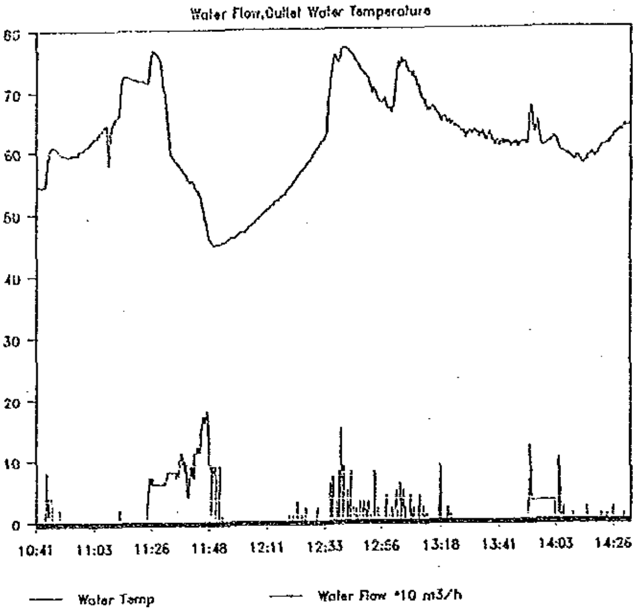


Figure 5–5–13 Water Heater

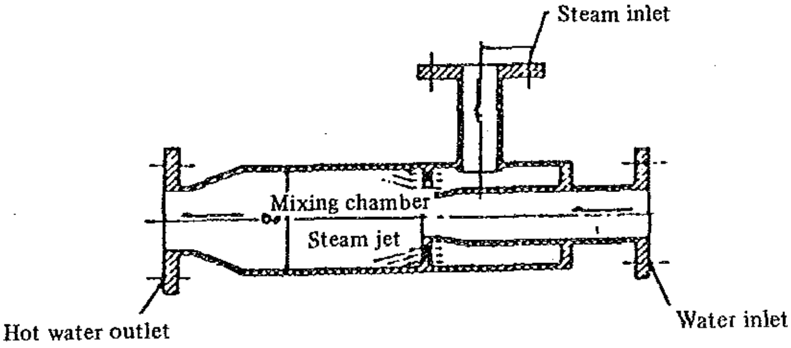


Figure 5–5–14 Inline Mixer

If the recommended steam-water mixers are installed, work can be started without waiting for the hot water temperature in the water heater to rise.

It may be pointed out, however, that, when the steam-water mixers are used, the steam flow rate changes with steam pressure, thus causing the hot water temperature to change. It is necessary, therefore, to install a reducing valve on the steam piping so that hot water can be produced under constant steam pressure.

5.5.3.3 Steam System

(1) Selection, maintenance, and management of steam traps

(A) Steam trap operation

The operation of the steam traps was checked using the diagnostic instruments taken along from Japan and with the eyes and touches. The results of this check are shown in Table 5–5–8. 65 percent of the operating steam traps were faulty.

Table 5–5–8 **Result of Steam Trap Inspection**

Trap type	: Disk
Steam press	6.5 ~ 8.0 kg/cm^2 g
No. of traps inspected	33
Working	20
Good	7
Not good	13
Failure rate	65%
Blowing	6
Leaking	7
Equipment where blowing traps were found	
Thermic plate	4
Tunnel dryer	1
Boiler header	1

(B) Type of steam trap

Ventura Hermanos uses disk type steam traps. As mentioned above regarding the check results, most of the steam traps were faulty. The main reasons for it are that disk traps are used for condensate recovery in a pipe on the thermic plate system and that the traps were not properly maintained.

Disk type traps are subject to the following limitations on pressure.

(a) Steam trap back pressure must be less than 50 percent of the inlet pressure.

If the back pressure is gradually raised while maintaining the inlet pressure constant, the steam will leak or keep blowing.

(b) In case of low pressure, there must be a pressure difference of more than 0.3 kg/cm^2 between the inlet and outlet.

Not only the disk type but also the thermodynamic type trap is unsuited to condensate recovery.

Thermostatic traps (bellows type, bimetal type) are also unsuited to condensate recovery. Depending on the design, thermostatic traps tend not to discharge condensate when back pressure rises to push the valve, or keeps steam blowing under increased back pressure.

Mechanical traps, such as the float type and bucket type, would be better for use in places subject to the back pressure, as in acodensate recovery system. It is recommended that the existing steam traps be replaced by degrees with mechanical traps of uniform size. This will facilitate their management.

(C) Steam trap maintenance and management

The person responsible for the maintenance of the steam traps must maintain the steam traps in satisfactory condition at all times with minimum labor and cost, keep the steam using equipment in efficient operation, and minimize steam loss.

(a) Inspection

When making an inspection round in the factory, be sure to check the steam traps for operation.

The steam traps are subject to deterioration with time. It is suggested, therefore, that an accurate periodic inspection be made twice a year if the percentage of faulty traps is high, or once a year if the percentage of faulty falls to less than 10 percent.

Prepare a book of the history of the traps, and record the inspection results in it. This will facilitate preventive maintenance, troubleshooting, and management against trap deterioration.

(b) Inspection and maintenance methods

There are three kinds of steam trap trouble: Blow, faulty discharge, and steam leakage. These faults and abnormalities can be detected early and remedied by the following inspection and maintenance methods.

1 Visual method

If a sight glass is mounted on the outlet of the steam trap to be checked, its operation can be directly checked with the eyes. This is the most accurate method. It is recommended that a sight glass be installed on the condensate recovery piping at the necessary points.

2 Hearing method

Listen to the operating sound of the steam trap using a stethoscope, and determine whether it is faulty or not.

3 Touching method

Wear gloves, grip the inlet and outlet pipes of the steam trap to find the temperature difference between them, and determine its operation.

4 Instrumental method

Use an ultrasonic instrument to check the operating sound of the steam trap. Instruments that automatically determine the acceptability of steam traps by measuring their operating sound, surface temperature, type of trap, and steam pressure are now available.

5 Maintenance

Disassemble the steam traps and clean the strainers and sight glasses. If any steam trap is found faulty, replace or repair it.

(D) Effect prediction and economy

The amount of steam leakage from the steam traps is calculated as follows:

Blow rate (kg/h) = $0.4 \times p \times d^2$

d : Equivalent orifice diameter (2.06 mm)

p : Absolute pressure (7.5 kg/cm^2)

The amount of leakage is assumed to be 1/10 of the blow rate.

The calculation results are as follows:

No. of steam traps	State	Steam leakage
6	Blow	76.2 kg/h
7	Leak	9.1 kg/h
	Total	85.3 kg/h

Amount of steam leakage from steam traps per annum

85.3 kg/h x 2,125 h/year = 181.3 t/y

On the other hand, the amount of fuel oil required for generating the steam of 1 t in the heat balance data of boiler is 80.1 ℓ.

Therefore, by replacing steam traps that are blowing or leaking, a fuel oil saving of 1,728 U$S will be made possible each year.

181.3 x 80.1 x 0.119 = 1,728 U$S/y

(2) Improvement of condensate recovery

1 Present state

Condensate recovery flow is shown in Figure 5–5–15. All is an underground type, designed to discharge condensate into the concrete ditch just adjacent to the main steam using equipment.Gathering pit with a cover are located about 15 meters apart from each other. The covers are sealed on top when finishing the floor with asphalt, but are found weakened together with their joints. Most of them were cracked, some could be easily moved; some were so much damaged, such as those in the tunnel dryer, that steam was leaking through their clearances.

Concrete and bricks will develop cracks when exposed to hot water, such as condensate, because their constituents are solved away, or when exposed to repeated variation of temperature. If cracks develop in this type of covered conduits, water for cleaning the floor may flow into it. Even though condensate is lost underground, it cannot be detected, and it is difficult to make repairs.

It would be better to replace the existing condensate recovery ditches with steel pipes, heat-insulate them, and hang them on the wall or from the ceiling to ensure ease of maintenance.

(3) Preventing steam leakage and heat insulation

(A) Preventing steam leakage

(a) Steam leaking points

The steam leaking points found by our survey are shown in Figure 5–5–15 (steam piping diagram).

Steam leakage was found at the two expansions the main piping, but there were not many leaking points on other piping, and the degree of leakage from the them were slight.

There were four internal leaking points assumed due to defective small sized steam valve connected to production machinery not in operation.

(b) Management for preventing steam leakage

(i) The expansions for the main piping that were found leaking to a considerable extent were exposed to repeated heat stress. A detailed check on them is necessary.

It is suggested that the omitting of the expansion joints by letting the piping absorb thermal expansion be studied.

(ii) If leaks from the valve glands and inside leaks in the small sized valves are left as they are, the leaking points will rapidly grow due to the high-speed steam errosion through the clearances so that the quantity of leaking steam will exponentially increase. This will increase repair expenses more than necessary.

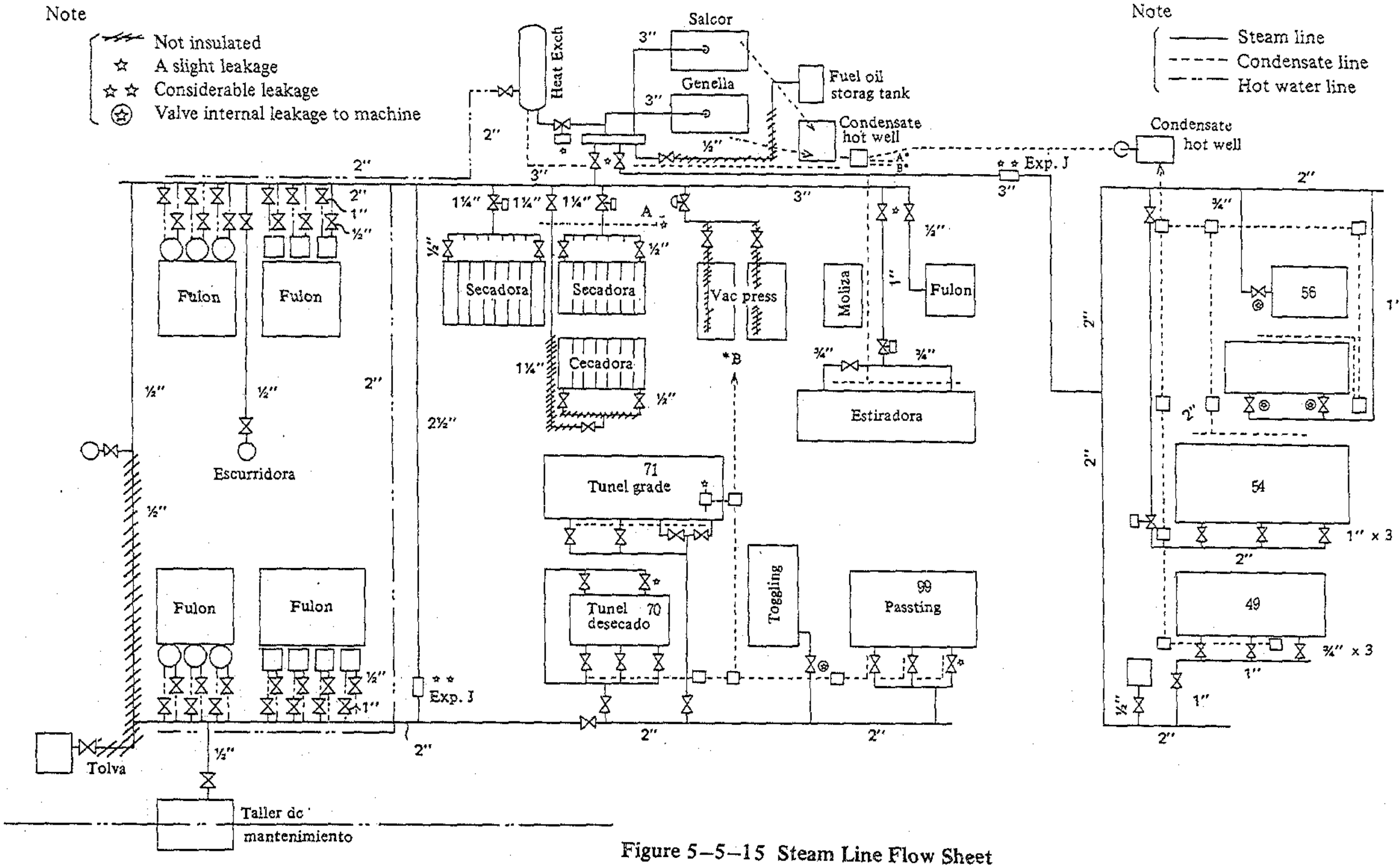


Figure 5–5–15 Steam Line Flow Sheet

(iii) Check for steam leaks periodically, for example, every week, when the factory is in operation.

When leaking points are found, attach a piece of red cloth, for example, for easy location for repairs later on.

(c) Estimating steam leakage loss

It is difficult to quantitatively determine the amount of steam leakage, but it can be estimated from experience as follows:

o Estimate steam leaking hole diameter for each leaking point, and record the data as shown in Table 5–5–9.

o Calculate the amount of leaking steam by the following approximation equation.

$G = 0.5484AP^{097}$

where G : Steam leaking rate (kg/h);

A : Hole area (mm^2);

P : Absolute pressure (kg/cm^2).

By repairing these leaking points, fuel oil can be saved as much as 351 U$S a year.

$$\frac{14.73}{1{,}000} \times 2{,}500 \times 80.1 \times 0.119 = 351 \text{ U\$S/y}$$

Table 5--5–9 Results of Research on Leakage of Steam

Place of leakage	Degree of leakage	No. of leakage places	Leakage portion		Steam pressure (kg/cm^2 G)	Amount of leaked steam (kg/h)	Total amount of leaked steam (kg/h)
			Equivalent hole diameter (mm ϕ)	Equivalent area (mm^2)			
Pipe expansion joint	***	2	1.0	7.85×10^{-1}	6.5	244	4.88
Valve	*	4	0.1	7.85×10^{-3}	6.5	0.024	0.096
Dryer valve	***	4	1.0	7.85×10^{-1}	6.5	244	9.76
						Total	14.73

Degree of leakage * very slight amount
*** large amount (with strong sound)

As the amount of leaked steam, the value obtained by multiplying the calculated value by the flow coefficient of 0.8.

(B) Heat insulation of piping

(a) Present state of heat insulation

The present heat insulation of the pipings is shown in the steam piping diagram of Figure 5–5–15.

The main pipings for steam and hot water were heat-insulated in satisfactory condition. The branch pipes to the production machinery were also well heat-insulated. However, the new pipings were partially uninsulated.

The valves and flanges accessory to the steam piping and production machinery were left bare. The surface area of these parts is relatively large.

(b) Bare heat radiation area

The results of checking the bare heat radiation area of the steam piping are shown in Table 5–5–10.

As shown in the Table, bare parts of the piping accounted for 72 percent of the total bare heat radiation area, and the valves accounted for 22 percent of it. By production machinery, the piping connected to the hot thermic plate and the piping connected to the dryer (for the pretreatment) accounted for 60 percent of the exposed radiation surfaces.

Table 5–5–10 Total of Heat Radiation Area (m^2)

Process	Pipe	Valve	Flange	Strainer	Total	%
Steam header	1.022	0.872	0.472	–	2.366	15.4
Painting dryer (54) (56) ㊾ (3 sets)	0.617	0.785	0.171	–	1.573	10.2
Hot thermic plate (21 sets)	4.518	0.258	–	–	4.776	31.0
Dryer (70) (71) (99) (3 sets)	2.922	1.047	0.295	0.07	4.334	28.1
Others	1.998	0.364	–	–	2.362	15.3
Total	11.077	3.326	0.938	0.07	15.411	100
Component ratio (%)	71.9	21.6	6.1	0.4	100	–

Note: The calculation of the heat radiation area including valves is based on the data sheet of Energy Conservation Center.

(c) Energy saving effect by heat insulation

The quantity of heat that can be reduced by insulating the heat radiating area is shown in Table 5–5–11.

Conditions of heat calculation

- o Bare surface temperature was calculated from steam pressure.
- o The ambient temperature was 25°C when measurements were made.
- o An emissivity of 0.8 was chosen for the radiation surfaces from experience.
- o Heat transfer coefficient was calculated using a personal computer program of the Energy Conservation Center.
- o Heat insulation was assumed to be of a single blanket 25 mm thick of rock wool.

(d) Economic evaluation of heat insulation

Heat insulation will save fuel by 15.8 kiloliters a year. It costs US$ 1,894 for heat insulation. This cost can be recovered in 1 year.

$$\frac{38,745}{491.6} \times \frac{0.0801}{1,000} \times 2,500 = 15.8 \text{ k}\ell/\text{y}$$

$$\frac{1,894}{15.8 \times 119} = 1.0 \text{ y}$$

Tabl 5–5–11 Heat Radiation and Heat Insulation Effect of Steam Pipe

(unit: kcal/h)

Process	Heat radiation	Heat radiation after insulation	Heat insulation effect	Component ratio	Remarks
Steam header (boiler chamber)	6,020	876	5,204	13.4%	Excluding boiler
Painting dryer	4,616	621	3,995	10.3	49 , 54 , 56
Hot thermic plate	12,754	1,805	10,949	28.3	21 sets
Dryer	13,440	1,786	11,654	30.1	70 , 71 , 99
Other equipment	8,152	1,209	6,943	17.2	Remaining equipment excluding boiler
Total	44,982	6,237	38,745	100%	(Based on the heat insulation effect)

Note: The calculation of heat radiation is based on the personal computer program of Energy Conservation Center.

Conditions for calculation:

The heat radiation surface temperature is a saturated steam temperature.
The ambient temperature is 25°C.
The emissivity of the heat radiation surface is 0.8.
Rock wool heat insulation 25 mm thick is used as the heat insulating material.

5.5.3.4 Feed Water System

(1) Improving the method of operating the feed water pumps

(A) Present problems

The feed water system is shown in Figure 5–5–16. It uses a pressure tank to raise the efficiency of pump operation. Two feed water process pumps are operating parallel, repeating frequent automatic start and stop as shown in Figure 5–5–17.

It can be known from the data that the average operating time of the pressure pumps is 40 seconds, and that the average stoppage time of the pressure pumps is 85 seconds.

The average number of starts is 27. Generally, however, the allowable number of starts per hour is 2 or less for large motors, and 12 or less for small motors.

(B) Analysis of the present state

(a) Results of measuring feed water rate during high-load operation

Process water consumption for the two lines was measured, and the data obtained from it was summarized in Table 5–5–12. The data shows the following.

o Process water was most used about 11:30 AM by both the south and north lines.

o The total maximum water rate was 485 ℓ/min.

(b) Estimating pumping rate

The pump specifications are assumed to be as follows:

o Motor capacity : 5 Hp (3.7 kW)
o Motor speed : 2P (1,450 rpm)

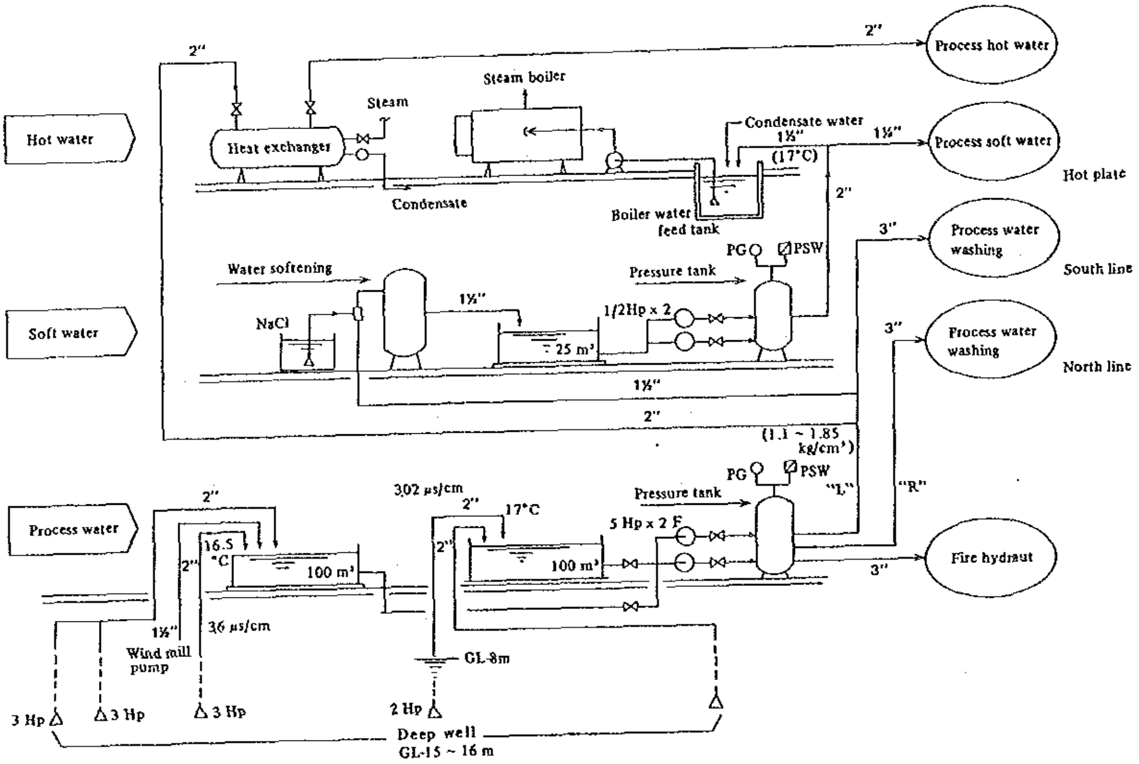


Figure 5–5–16 Water Line Flow Sheet

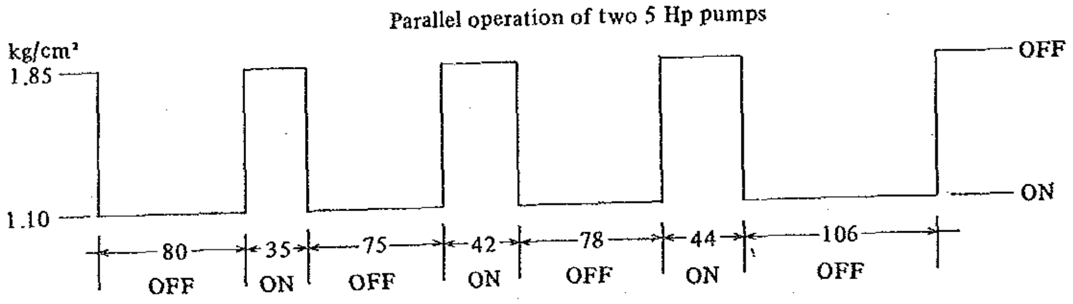


Figure 5–5–17 ON-OFF Cycle of Process Water Supply Pump

Table 5–5–12 Measurement of Water Used for Process

Amount of supplied water by line		L (South line)	R (North line)	Total
Measurement time	min	160	160	160
Integrated water supply amount	ℓ	4,394	10,688	15,082
Unit water supply amount	ℓ/min	27.5	66.8	94.3
Maximum water flow rate and its occurrence time by line	ℓ/min	227.0 (11°35′)	300.3 (11°36′)	–
Maximum water flow rate and its occurrence time for the whole process	ℓ/min	205.9	278.9	484.8 (11°35′)

Measuring instrument: Ultrasonic flow meter

- Diameter of pipes connected to pumps : 80 mm
- Type of pump : Centrifugal
- Head : 2.0 kg/cm², making some allowance for pump pressure of 1.85 kg/cm² upon stoppage
- Margine for motor capacity : 1.2 (As general)

The pumping rate was calculated on the basis of the conditions specified above.

$$P\,(\text{kw}) = \frac{H\,(\text{m}) \times Q\,(\text{m}^3/\text{min}) \times \gamma\,(\text{kg/m}^3)}{102 \times 60 \times n} \times \alpha$$

$$\text{Therefore, } Q = \frac{3.7 \times 102 \times 60 \times 0.45}{20 \times 1{,}000 \times 1.2} = 0.425\ \text{m}^3/\text{min}\ (425\ \ell/\text{min})$$

The pressure pump discharge rate is estimated to be 380 ℓ/min, considering 10 percent deterioration of the pumps with time.

(c) Effective volume of pressure tank

The effective volume of the pressure tank means the volume of the tank between the water level when the pumps are stopped and the water level when the pumps are started.

Total tank capacity (V) : 3,050 ℓ
Effective colume (V_A)
Pressure upon pump stoppage (P_{off}) : 1.85 kg/cm² G
Air volume upon pump stoppage (V_{off})
Pressure upon pump start (P_{on}) : 1.10 kg/cm² G
Air volume upon pump start (V_{on})

Under the conditions specified above,

$$V_{on} \times (P_{on} + 1.33) = V_{off}\,(P_{off} + 1.033)$$

$$V_A = V_{on} - V_{off}$$

$$\therefore\ V_A = V_{on}\left(1 - \frac{P_{on} + 1.033}{P_{off} + 1.033}\right) = V_{on}\frac{P_{off} - P_{on}}{P_{off} + 1.033}$$

As $P_{on} = 1.10$, $P_{off} = 1.85$,

$$V_A = V_{on} \times \frac{1.85 - 1.10}{1.85 + 1.03} = 0.26\,V_{on}$$

The average time of pump operation is 40 seconds and the average time of pump stoppage is 85 seconds. The pump discharge rate is 380 ℓ/min. Therefore, the rate of using water is $\frac{V_A}{85}$ ℓ/sec.

$$380 \times 2 \times \frac{40}{60} = V_A\left(1 + \frac{40}{85}\right)$$

$$\therefore V_A = 345$$

$$\text{As } V_A = 0.26V_{on},\ V_{on} = \frac{345}{0.26} = 1{,}327\ \ell$$

$$V_{on}/V = 1{,}327/3{,}050 = 0.43$$

The above 0.43 is far smaller than the general V_{on}/V of 0.7. Thus, V_A is similarly small, which tells the reason why the pumps are frequently started and stopped.

V_A can be increased by raising $P_{off} - P_{on}$ and lowering P_{on}. If the number of pump starts and stops is decreased, the motors and pumps will have a longer service life.

(C) Improving the method of pressure pump operation

(a) Maintaining the effective level of pressure tank

Maintenance once a year, involving a check inside the pressure tank, is recommended to secure the required air volume for the tank. It would be better for this purpose to take care of the water level gauge and mark the limit line for supplying air.

(b) It can be known from the measurement data that only one pump is enough to supply water during light-load operation. The number of pump starts can be reduced to less than half the present number if the effective volume is maintained and if only one pump is used.

To ensure parallel operation of two pumps during high-load operation, install an additional pressure switch so that there will be a difference in starting pressure, thus permitting to control the operation of each pump.

(c) Lower the starting pressure to an extent of not adversely affecting pumping; raise the stop pressure, and increase the effective volume.

(2) Water source management

(A) Measures against slime in water tanks

Two water tanks, 100 m^3 each, are used in parallel. Despite the clear ground water supplied to them, the tanks were full of green algae over the surfaces. The simple measure of covering the tanks with sheets to keep sunlight out would be effective to prevent green algae.

(B) Source water quality

The source ground-water has an abnormally high chlorine ion (Cl^-) level of 500 to 600 ppm. It is suggested that Cl^- ions be analyzed, well by well, to use high-quality water preferentially for the boiler.

5.5.3.5 Process

(1) Changing the working steam pressure

(A) Steam pressure and usable quantity of heat

The present steam pressure is 6.5 to 8.0 kg/cm^2 G. Steam is used in the dryers and water heaters, where the maximum working temperature is below 90°C. Neither of them needs high-pressure steam. 2.0 kg/cm^2 G is sufficient.

In case of indirect heating with steam, only the latent heat of steam evaporation is used. The latent heat of steam evaporation increases as steam pressure decreases. In other words, steam consumption decreases as steam pressure lowers. The relationship between saturated steam pressure and evaporation latent heat is shown in Figure 5–5–18.

When steam pressure is 2.0 kg/cm^2 G, the latent heat of steam evaporation is 517.2 kcal/kg. When steam pressure is 6.5 kg/cm^2 G, however, the latent heat of steam evaporation is 491.6 kcal/kg. That is, the former has an evaporation latent heat of 105.2 percent of the latter.

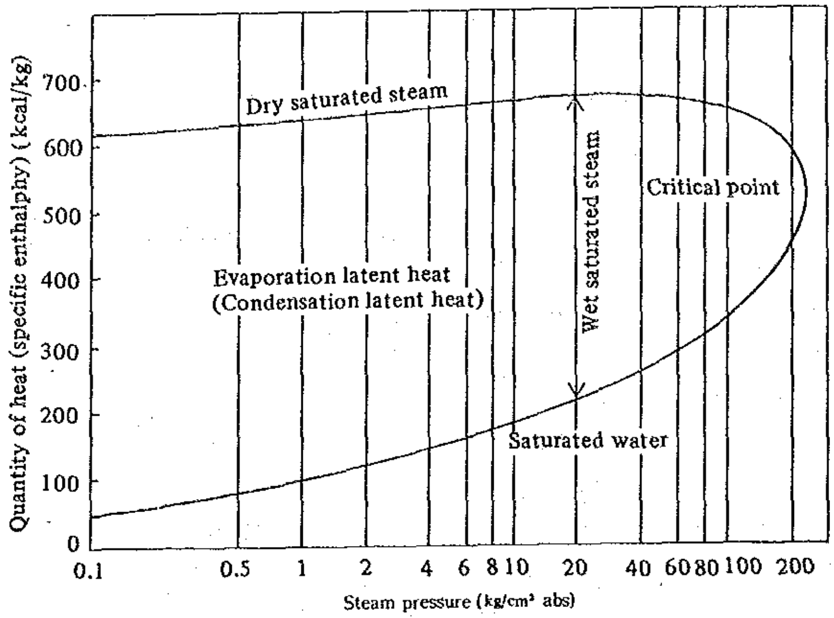


Figure 5–5–18 Relation Between the Saturated Steam Pressure and the Quantity of Heat

(B) Predicted effects of lowering steam pressure

(a) Less steam will be needed for indirect heating.

As mentioned before, if steam pressure is lowered from 6.5 kg/cm² G to 2.0 kg/cm² G, steam consumption can be reduced by about 5 percent at indirect heating points. If the steam consumed for indirect heating accounts for 70 percent of overall steam consumption, there will be a steam saving of 3.5 percent.

(b) Increased generation of steam per kilogram of fuel

The enthalpy of wet steam (Dryness 0.98) is as follows:

640.22 kcal/kg at 2.0 kg/cm² G

650.35 kcal/kg at 6.5 kg/cm² G

If feed water temperature is 42.6°C, the percentage of fuel saving in generating the same weight of steam can be calculated as follows:

$$\text{Effective heat ratio } (\eta) = \frac{\text{Fuel combustion heat} - \text{exhaust gas sensible heat}}{\text{Combustion heat}}$$

$$= \frac{10{,}388.93 - 1{,}411.66}{10{,}388.93} = 0.864$$

$$\text{Fuel saving} = \frac{650.35 - 640.22}{650.35 - 42.99} \times \frac{1}{0.864} = 0.0193$$

Thus, there will be a fuel saving of total 5.4 percent by lowering the steam pressure.

If the amount of fuel used per year is 212.5 kl, it is possible to save the fuel by 212.5 X 0.0154 X 119 = 1366 U$S/y.

In addition, decreased leakage from the steam traps and valves can be expected from lowered steam pressure. However, steam velocity through the piping will increase.

So lower the steam pressure little by little while making sure that there will be no problems.

(2) Leather dryness management

(a) Results of measuring leather moisture

The water content of the leather was measured using the dryer and moisture meter in the laboratories of Ventura Hermanos. (Those marked * were measured with the moisture meter.)

Results of measuring leather water content
Before drying with thermic plate : 69.26%
After drying with thermic plate : 33.73%
After drying with tunnel dryer : 10.81%
Before drying with toggle dryer : *20.00%
After drying with toggle dryer : *14.50%
After paint drying (product) : *8.00%

As shown above, the water content after tunnel drying and paint drying (product) are low. This and the equilibrium moisture mentioned later indicate overdryness. By increasing the moisture by about 5.0 to percent, not only the quality can be improved by also fuel can be saved.

(b) Atmospheric humidity and equilibrium moisture

The relationship between atmospheric humidity and equilibrium moisture is shown in Figure 5–5–19.

As shown, chrome-tanned calf skin contained about 18 percent moisture in the dry leather after keeping it at a relative humidity of 60 percent and a temperature of 25°C for 32 days. The moisture of the same measured at a relative humidity of 40 percent was about 16 percent.

The atmospheric relative humidity in the Argentine Republic appears to be mostly 40 to 60 percent, so if hide is left in the air, it will naturally dry to about 17 percent in water content. It would be meaningless to dry it further. Preventing overdryness drying process is important as a means of energy saving.

(c) Method of controlling dryer operation

1 Dry thermic plates

For the convenience of explanation, numbers are assigned to the individual thermic plates as shown in Figure 5–5–20. Thermic plates 8 to 14 are indirectly heated by steam, while thermic plates 1 to 7 and 15 to 22 are heated by directly injecting steam.

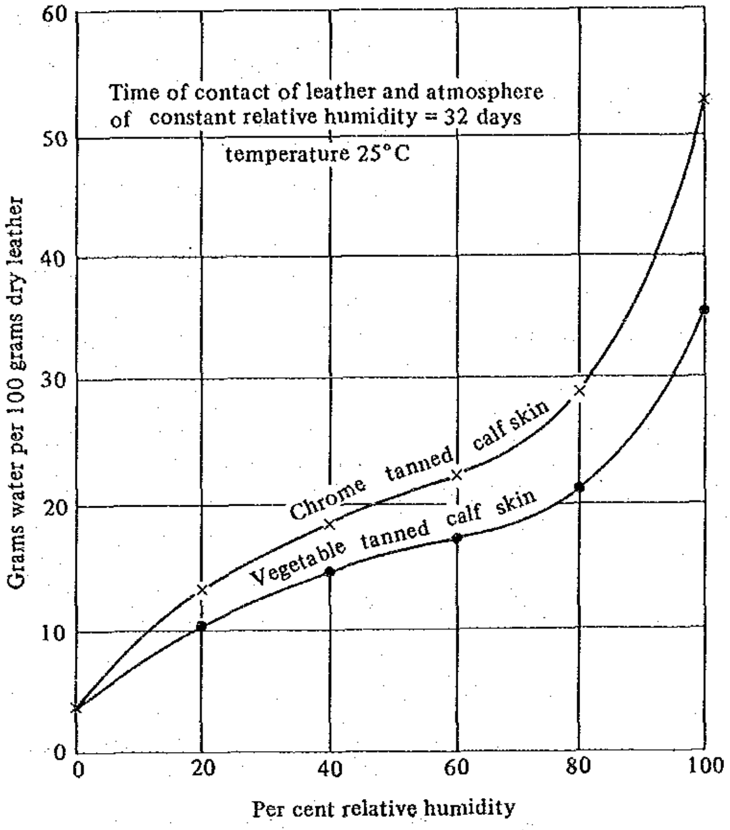


Figure 5–5–19 Effect of the Relative Humidity of the Air upon the Water Content of Chrome and Vegetable-Tanned Calf Leather

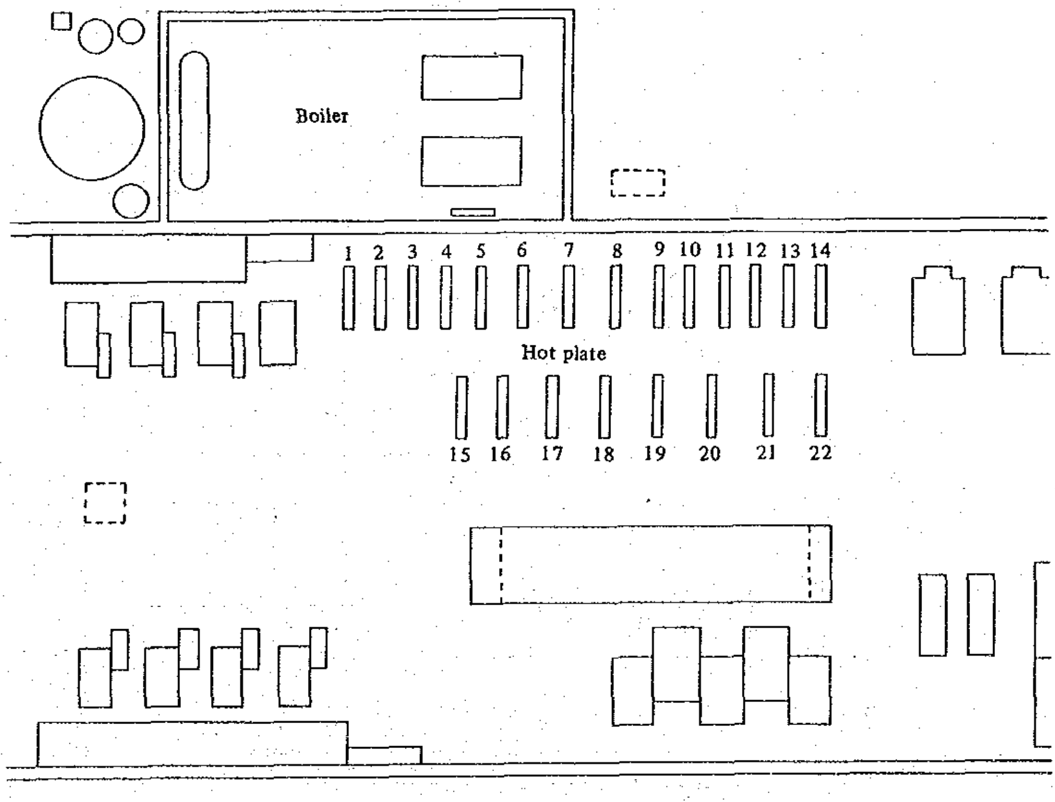


Figure 5–5–20 Thermic Plate Number

Data recorded of the operation of the thermic plates is shown in Tables 5−5−13 and 5−5−14. The problems with thermic plate operation and their solutions are mentioned below.

Table 5−5−13 Thermic Plate Temperature

'88 10/18 Test

Plate No.	Start	Initial temp. (°C)	End	Final temp. (°C)	Drying time (min)
8	10:13	83	10:22	82	9
9	10:14	90	10:24	88	10
10	10:16	93	10:25	88	9
11	10:17	93	10:26	90	9
12	10:19	83	10:27	90	8
13	10:20	83	10:29	81	9
14	10:21	91	10:30	90	9

Table 5−5−14 Thermic Plate Temperature

'88-10-19

Plate No.	Water temp. (°C)	Surface temp. (°C)	Surface area (°C)	Steaming	Condensate line	Hot water over flow	Condensate
1	81	81.1	3210 x 1500	Direct steam	Individual exhaust	O	Exhaust to the floor as hot water
2	83	79.5	↓	↓	↓	X	
3	X	74.9	↓	↓	↓	O	
4	75	73.4	↓	↓	↓	O	
5	79	71.9	↓	↓	↓	X	
6	X	75.8	↓	↓	↓	X	
7	87	74.8	↓	↓	↓	X	
8	86	86.4	↓	Indirect steam	Combined exhaust		Gathered in a pipe temp. 110°C
9	79	73.5	3010 x 1510	↓	↓		
10	82	76.2	↓	↓	↓		
11	75	68.4	↓	↓	↓		
12	69	65.0	↓	↓	↓		
13	67	65.4	↓	↓	↓		
14	80	73.2	↓	↓	↓		
15 ~ 22			3000 x 1480	Direct steam	Combined exhaust to the sewer		

1. Do not keep the steam on for unused thermic plates.
2. Prepare a schedule to ensure continuous operation. Steam loss will increase with interruption in operation.
3. Some thermometers are out of order, giving wrong readings or no readings at all.

   Periodically check the thermometers to ensure that they always give the correct readings.
4. Radiating heat loss tends to increase near the entrance door due to air currents. Either place screens or polyethylene curtains.
5. The thermic plates vary in temperature from one another. More careful management is necessary.

   Check overflow water to see whether the thermic plates have the proper water level.
6. The steam control valves installed for the individual systems must be checked for operation and properly maintained.

Efficiency of steam use for thermic plate drying

Leather moisture before thermic plate drying : 69.3%
2.25 g-H_2O/g-leather
Leather moisture after thermic plate drying : 33.7%
0.51 g-H_2O/g-leather
Leather processing speed : 72 sheets/hour
Average weight per sheet of hide : 4 kg
Thermic plate operation : 8 units
Thermic plates actually used : 6 units
Average thermic plate temperature : 80°C
Specific heat of leather : 0.6 kcal/(kg · °C)
Room temperature : 23°C
Overflow hot water from thermic plate = condensate
312.6 kg/h
Overflow hot water temperature : 80°C
Enthalpy of steam (6.5 kg/cm^2 G) : 660.2 kcal/kg
Steam evaporation latent heat : 551.5 kcal/kg, at atmospheric pressure, 80°C

If the theoretical steam rate required for drying leather is Qkg/hour,

$$Q = \frac{72 \times 4 \times 0.6\,(80 - 23) + 72 \times 4 \times (1 - 0.693) \times (2.25 - 0.51) \times 551.5}{660.2}$$

$$= 143.4 \text{ kg/h}$$

The efficiency of use of steam for thermic plate drying will be:

$$\eta = \frac{143.4}{312.6} \times 100 = 45.9\%$$

provided that there is no uncondensed steam.

2 Tunnel dryer

Hot·air 40 to 50°C is produced by indirect heating with steam, and is blown at right angles to the direction of movement of leather. The dryer was 45°C in the center and about 30°C at the inlet and outlet. The problems and remedial measures are mentioned below.

1. The steam was kept on but there were frequent interruptions in the flow of leather, leaving the process off load for much time.
   A production schedule should be prepared to ensure continuity of operation.
2. Flash steam was leaking from the cover on the condensate collector at the outlet of the tunnel dryer, leaving dried leather exposed to steam. Repair the steam leaking points to eliminate the cause of uneven drying.

3 Vacuum drying

Vacuum drying is used for sole leather and shoe strings. Heating surface temperature is 70°C to 80°C, and drying time is 30 seconds, or 2 minutes for some products. The vacuum dryer is a bare open type under the thermic plate, and is located so close to the entrance/exit doors that it has much heat loss due to air flow.

It would be better to install a polyethylene skirt around the part of the vacuum dryer under the thermic plate.

5.5.3.6 Power Receiving and Distributing and Electrical Facilities

(1) Outline of power receiving facilities

The Coop Electrica de Atalaja in the area where Ventura Hermanos is located receives electric power of 22 kV from SEGBA, steps it down to 13.2 kV, and supplies it to the factory via the 500 kVA transformer nearby where the voltage is further stepped down to 380 V.

The distribution board has a digital integrating wattmeter and reactive power meter installed on it, and distributes the received power to the individual sections through 12 feeders.

A condenser of 130 kVar which automatically adjusts the power factor was installed in August 1988 to control the power factor at about 90 percent.

(2) Measurements

The following were measured using watt-power factor meter (PFM-1000, PFMA-5210, PFM-1000P), AC clip-on power meter, and 12-point recorder.

The electric power consumed by the factory as a whole and by the individual branches was measured.

(3) Power consumption

The load conditions of the factory as a whole are shown in Figure 5–5–21. The maximum load of the factory during the operating hours (from 07:00 to 15:00) was about 160 kW, about one half the capacity. The load during the nighttime is about 30 kW because only the liming drum is operating.

The power factor has been improved from about 50 – 60 percent to higher than 90 percent because the automatic control condenser of 130 kVar was installed. However, the power factor for the drums was still very low at about 30 to 35 percent. To reduce the resistance loss of the cables from the local drum panels to the distribution board, it would be better to install a condenser for power factor improvement on the local panels. This should be taken into consideration in view of economic advantages in the case of the improved operating ratio of the drum in the future.

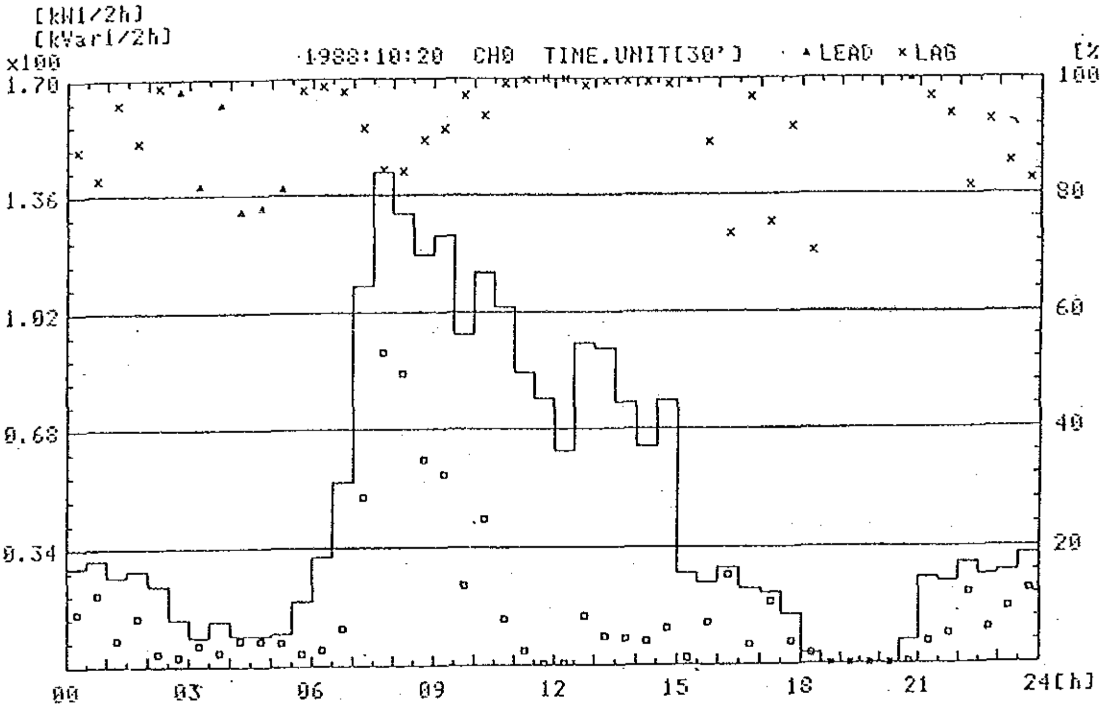


Figure 5–5–21 Factory as a Whole

(4) Controlling compressed air leakage

The four compressors on the finishing line are used to supply compressed air for paint spraying.

Air leakage was measured as follows:

While no compressed air was being used, the pressure fell from 6.5 kg/cm^{2}G to 5.5 kg/cm^{2}G in the time space of 29.9 minutes. Assuming the internal volume of the piping to be 0.6 m^3, compressed air leakage can be calculated as follows:

$$\text{Leakage rate} = \frac{1 \times 0.6}{29.9/60} = 1.2 \text{ m}^3/\text{h}$$

In this case, the required compressor power can be calculated from the following equation:

$$P = \frac{k}{k-1} \times \frac{P \cdot Q}{6{,}120} \times \left\{ \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1 \right\} \times \frac{1}{\eta ad \cdot \eta m} \text{ (kW)}$$

where P : Compressor power (kW);

k : Ratio of constant pressure specific heat and constant volume specific heat heat (1.4 for air);

P_1 : Absolute suction pressure (kg/m^2);

P_2 : Absolute discharge pressure (kg/m^2);

Q : Suction volume (m^3/min);

ηad : Adiabatic efficiency, 0.8 (0.7 to 0.85);

ηm : Mechanical efficiency, 0.7.

$P_1 = 1 \text{ kg/cm}^2 = 10{,}000 \text{ kg/m}^2$

$P_2 = 6 \text{ kg/cm}^2$

$Q = 1.2 \text{ m}^3\text{/h} \div 60 = 0.02 \text{ m}^3\text{/min}$

$$\text{Therefore, } P = \frac{1.4}{1.4-1} \times \frac{10{,}000 \times 0.02}{6{,}120} \times \left[\left(\frac{6}{1}\right)^{\frac{1.4-1}{1.4}} - 1 \right] \times \frac{1}{0.7 \times 0.8}$$

$$= 3.5 \times 0.0327 \times (1.67 - 1) \times \frac{1}{0.56}$$

$$\fallingdotseq 0.137 \text{ kW}$$

Because compressed air leakage occurs throughout the year, power loss from a compressed air leak of 1.2 m^3/hour will be:

0.137 kW X 24 h X 365 d = 1,200 kWh/y.

Leaking points can be detected by listening to leaking sound during the silent hours of night, or wetting suspected joints with soap and water. It is suggested that leaking points be regularly checked about twice a year, and be repaired as necessary.

(5) Reducing power consumption by lowering compressor discharge pressure

Figure 5–5–22 shows an example of how much power consumption can be reduced by lowering the discharge pressure. If the compressed air for paint spraying is lowered from the present 7 kg/cm² to 3.5 kg/cm², power consumption can be reduced by 25 percent.

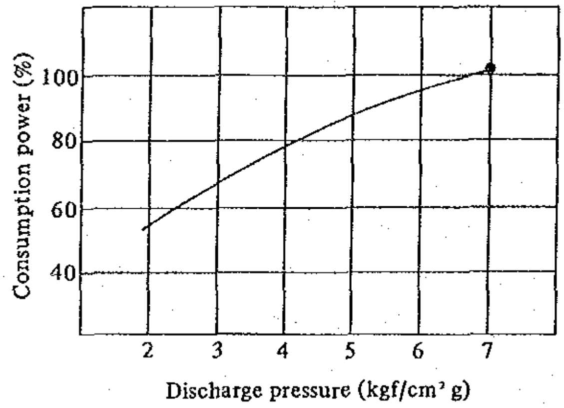


Figure 5–5–22 Relation between Discharge Pressure and Consumption Power

The power required for the four compressors in this factory to raise air pressure to 7 kg/cm² was as shown in Table 5–5–15 according to our measurements. If the number of operating days is 130, and if the compressors are used for one hour daily, power saving will amount to:

30.4 kW X 0.25 X 1 h X 130 d = 988 kWh/y.

Table 5–5–15

Compressor	Power
No. 1	7.8 kW
No. 2	5.8 kW
No. 3	7.8 kW
No. 4	9.0 kW
Total	30.4 kW

(6) Improvement of receiving line reliability

We encountered two power failures while we were making measurements in the factory. These power failures were caused by a blown fuse and by an interline shortcircuit because the wooden poles that support the receiving lines carrying the 13.2 kV power supplied by the Coop were not strong enough to keep the lines steady against winds. We heard that a power failure occurs often. Ventura Hermanos should request the Coop to reinforce the poles and receiving lines from the standpoint of energy saving.

(7) Lighting and others

(A) Lighting in the factory was satisfactory at over 420 lux.

(B) The electric facilities are satisfactory because the factory is still new. But it should conduct periodic inspection hereafter.

5.5.3.7 Summary

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

Item		Possible annual amount of saving	%
Improvement of boiler air ratio	Heavy oil	3,500 ℓ	1.6
Repair of steam trap		14,500	6.8
Prevention of leakage of steam pipe		2,900	1.4
Heat insulation of steam pipe		15,800	7.4
Change of steam pressure		11,500	5.4
Total		48,200	22.6
Prevention of leakage of compressed air	Electric power	1,200 kWh	0.4
Lowering of compressed air pressure		1,000	0.3
Total		2,200	0.7

5.6 Results of Survey of Chemical Factory

5. Results of Survey of Chemical Factories

5.6 Investigation

5.6.1 Outline of the Factory

(1) Name of Factory: NORENPLAST S.A.C.I.F.

(2) Type of Business: Chemical

(3) Location of the factory: Ruta Nacional 3 km 35.4
Gonzalez Catan (1759)
Prov. Buenos Aires

(4) History of the factory:

It is a factory which produces 80 t/month of acrylic plates, 60 t/month of polyurethane (Prepolymer Resin) for shoe soles, etc., as well as 250 t/month of emulsion which is used in coatings, paper pastes, fiber processing, binder of synthetic fibers, cement and water treatment.

It was established in 1969 with British technology. Since then technical improvements have been made by its own technology, and it has developed into the present state.

Product development, process research are being advanced in a laboratory built close. Product inspection is made adequately, and great emphasis is placed on quality control also.

In the factory, there are large numbers of batch reactors where heating by steam and heating medium oil, and cooling by chilled water and air are repeated.

The technical level of the engineers is very high, and factory management such as keeping it neat and tidy, operational instructions, etc. are properly observed. Thus, it can become an excellent energy saving factory by improving a few items which is pointed out below.

(5) Number of employees: 148, of which one each is heat and electrical engineers.

(6) Survey period: October 24 to 29, 1988.

(7) Investigators:

Name	Assignment
Mr. Issei Furugaki	Chief, energy management
Mr. Teruo Nakagawa	Heat management
Mr. Toshio Sugimoto	Electrical management
Mr. Naoshi Honda	Chemical process
Mr. Keiji Sawada	Heat management
INTI members	
Mr. E. M. Leikis	Chief
Mr. M. A. Silvosa	Heat using equipment, process
Mr. J.A. Fiora	Heat using equipment, process
Mr. A. Berset	Heat using equipment
Mr. A. A. Monzon	Heat using equipment, mobile unit driving
Mr. M. A. Bermejo	Electric receiving and distribution equipment
Mr. A. D. Verghelet	Electrical receiving and distribution equipment

Mr. P. L. Cozza Electrical receiving and distribution equipment

(8) Interviewed

Mr. Humberto VIGNON
Mr. Ruben DICOCO
Mr. Albert RIVA
Mr. Ernesto PARDO

(9) Production

Table 5–6–1 Production (t)

Year	1983	1984	1985	1986	1987
Plate			408.5	497.5	492.5
Emulsion			1,343.7	1,838.0	1,958.8
Polyurethane			350.3	444.4	386.9
Others			242.5	384.8	76.8
Total			2,345	3,165	2,915

(10) Energy consuption

Table 5–6–2 Energy Consumption

Year	1983	1984	1985	1986	1987
Natural gas 1000 Nm^3	669.0	691.0	624.0	850.0	
Elect. power MWh	900.0	970.0	892.0	1,130.0	
Energy/production					
Natural Gas Nm^3/t			266	269	
Power kWh/t			380	357	

Electric power	unit price	0.08 U$S/kWh
Natural gas	unit price	0.08 U$S/$Nm^3$

(11) Factory layout

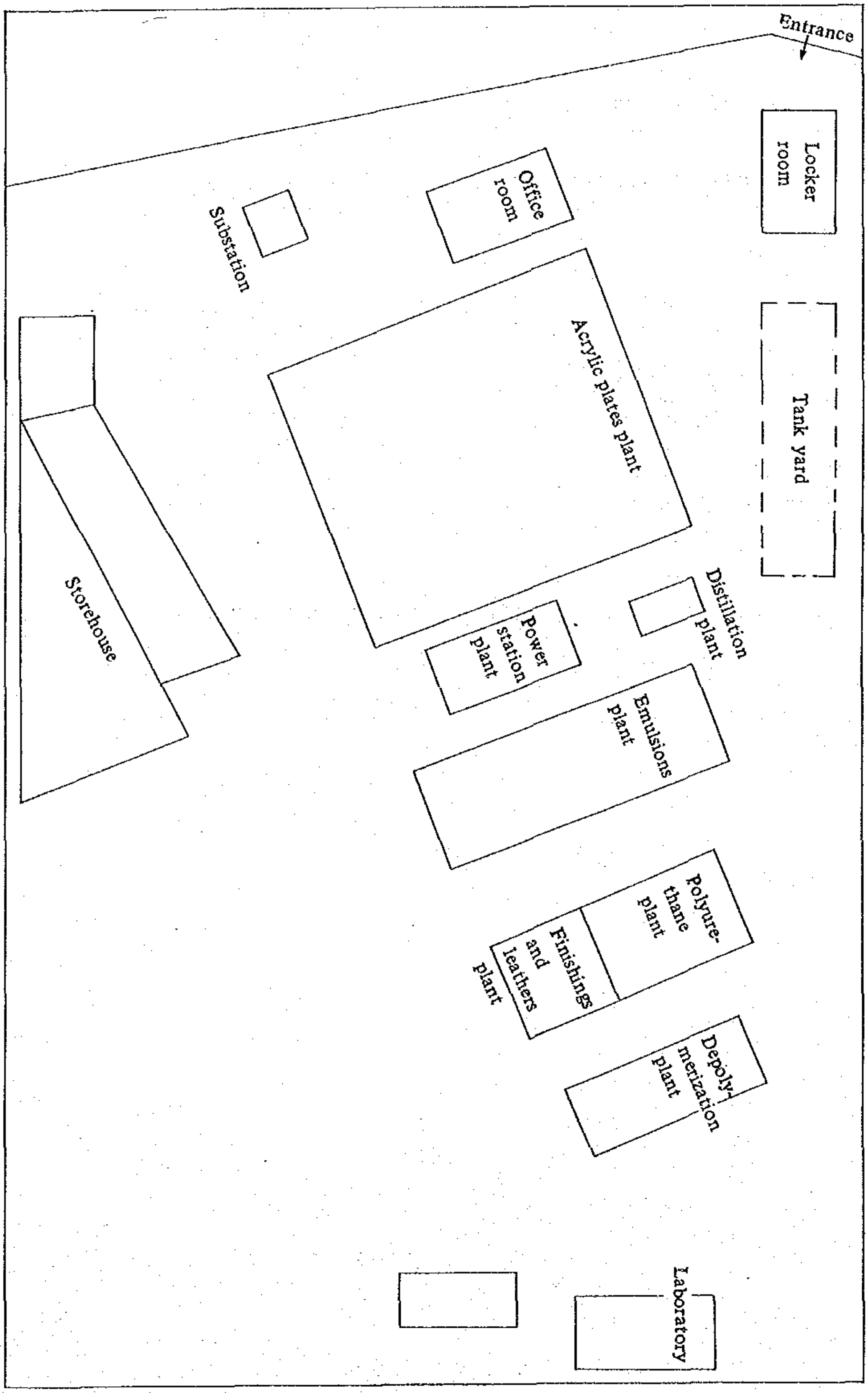


Figure 5–6–1 Factory Layout

(12) Production process

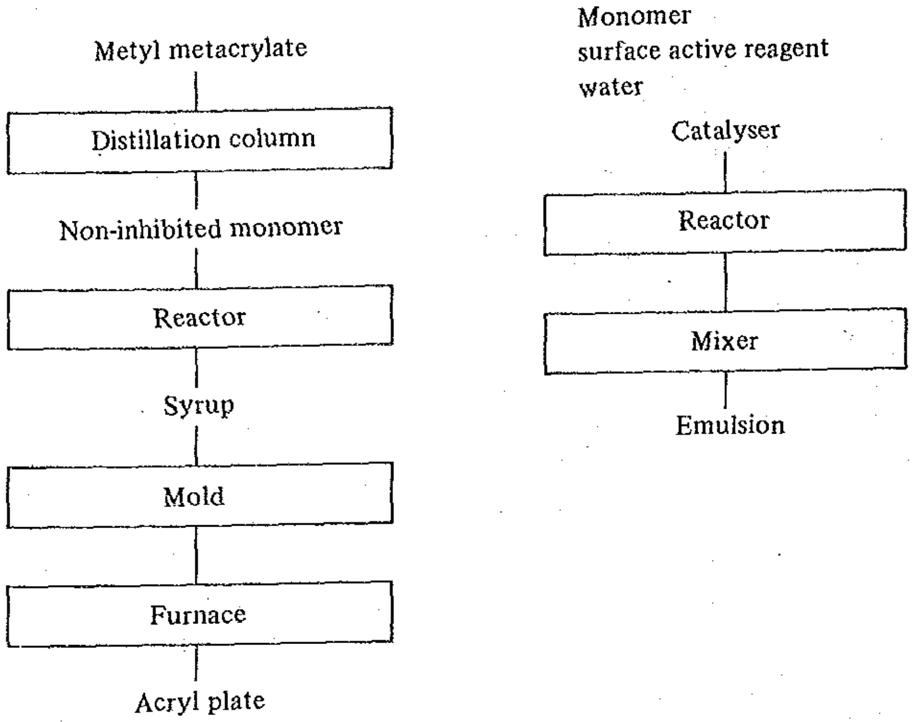


Figure 5–6–2 Production Process

(13) One line diagram

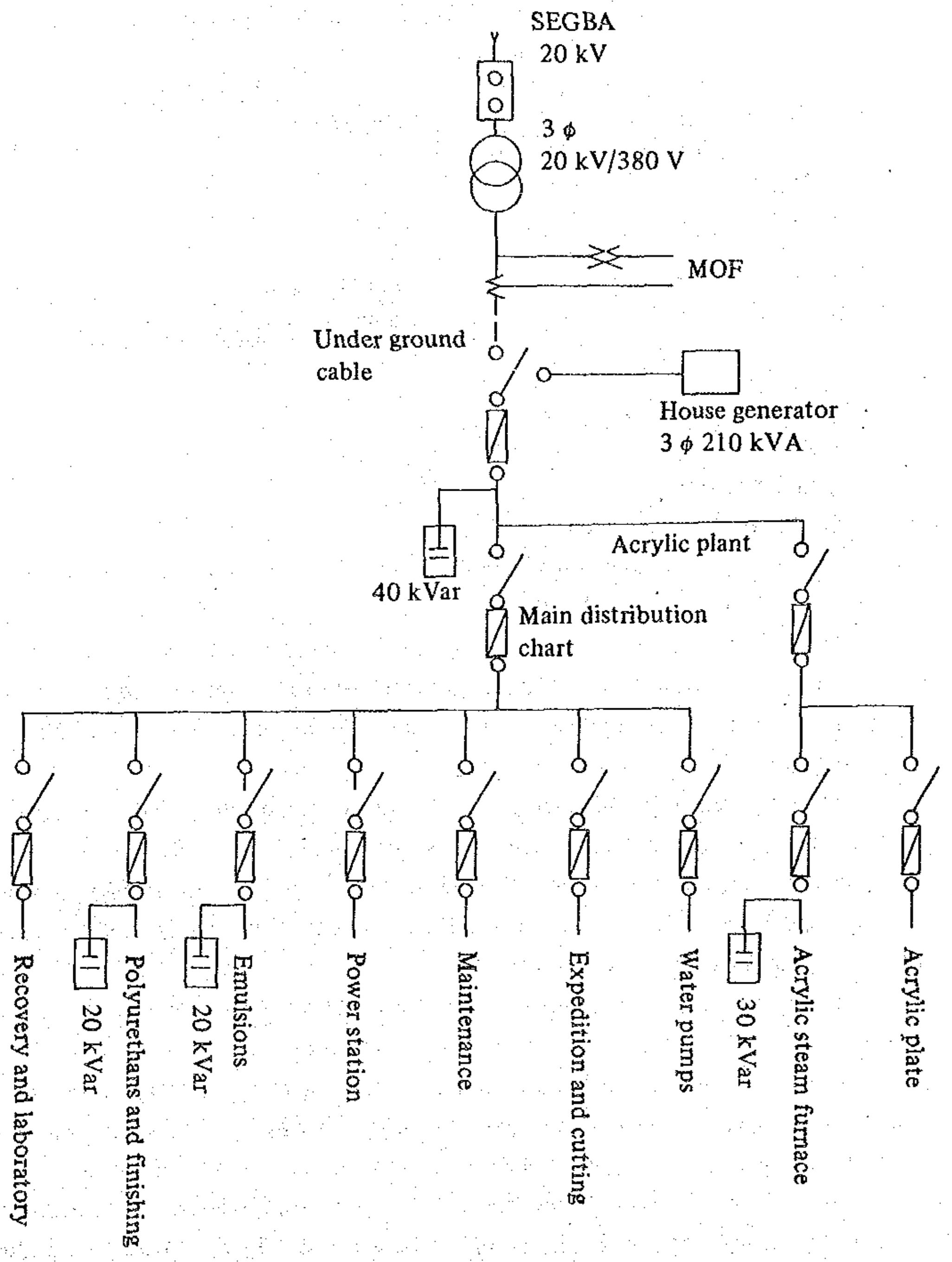


Figure 5–6–3 One Line Diagram

(14) Major equipment

Table 5–6–3 Major Energy Consuming Equipment

Name	Number	Specification
Distillation column	1	2.7 t/batch
Acryl plate furnace	10	
Refrigerator	2	30 CV
Vacuum pump	4	75 CV
Boiler	1	3.3 t/h
Thermal fluid heater	1	400,000 kcal/h
Reactor	12	Vertical drum with jacket, agitator

(15) Factory operating time

24 h/d X 250 d/y = 6,000 h/y

5.6.2 Energy Management

(1) Energy conservation target

Neither the company nor the factory has any energy conservation target particularly set.

The factory engineers have broad knowledge and great enthusiasm on energy.

They have taken part in this survey. For instance, as mentioned later on, when the measured value of the oxygen in the exhaust gas was high, they made adjustments immediately on the spot.

Although the ratio of energy cost to the manufacturing cost is less than 1%, the expenditure of gas and electric power is not small as mentioned previously, and considering the technical power and the management ability of this factory, if a clear target is set, and an effort is made, we believe that excellent results can be obtained steadily.

(2) Determining energy consumption

In order to aim at the improvement of facilities and operation, it is important to prepare the data, and accurately grasp the actual condition.

The data related to the energy should be controlled together with the data for operating conditions, process control, and production control, and then the management of the whole factory will become better, and the achievements will improve.

At least, if the unit energy consumption rate for each process is grasped usually, when its changes are observed, comparisons are made in the operating conditions and the quality, and then abnormalities can be detected, or information for improvement can be obtained.

In order to grasp the actual conditions even more accurately, it is necessary to install various kinds of measuring instruments. In particular, the temperature control is important for chemical processes. It is desirable to install more thermometers, since they are not so expensive.

Particularly for boiler, the installation of various measuring instruments is necessary by changing from an operation which depends on guessing to an operation under scientific control, various results will be improved and the cost of various measuring instruments will be paid back quite easily.

(3) Engineer education and employee training

Since this factory is equipped with energy equipment such as boilers and coolers, it is desirable for engineers to possess special knowledge related to such equipment.

It seems that the managers of the factory possess sufficient knowledge, but even the person in charge and the operators will require education and study according to their job about the knowledge.

The improvement of the technical level will lead to the grasping of problems and their solutions, and it will be useful not only in improvement of operation but also in promoting the saving of energy.

About general employees, it is desired to enlighten them so that each and every operator will have the interest to save energy.

In order to do so, it would be necessary to give the employees certain information and to educate them to a certain level.

If the operator who actually handles the machine determines to save energy, actual results can be expected.

(4) Equipment management

The equipments of this factory are not necessarily modern, but they are well kept and their operation is done by paying attention to daily maintenance. However, there is room for improvement in equipment management system, and if this is done, it can be expected to become an even better plant.

For example, it seems that the data of design calculation, drawings, and records of remodeling and repairing work are kept at each Department, and they can be found as required. However, it is more desirable to assemble them at one place, and keep them as something like a equipment ledger.

In certain points there were steam pipes with leakages as well as steam pipes without any insulation.

However, generally speaking, it seemed that the repair was being done rather carefully.

If we are allowed to hope for more, we think it is preferable to insulate the valve portion also.

5.6.3 Problems with Use of Energy and Remedial Measures

5.6.3.1 Boiler

The steam supplied from the boilers is used as energy for the reactor, furnace, etc. and plays an important role in the manufacturing process.

(1) Boiler specifications

Type : 3-pass, flue and smoke tube boiler
Evaporation : 3 t/h
Steam pressure : 9 kg/cm^2 G (rated)
Fuel : Natural gas
CH_4 = 95.80% C_2H_6 = 1.51% C_3H_6 = 0.25%
i-C_4H_{12} = 0.08% n-C_4H_{12} = 0.12% i-C_6H_{12} = 0.07%
n-C_6H_{12} = 0.06% C_6H_{14} = 0.13% N_2 = 1.52%
CO_2 = 0.46%
Heating surface : 75 m^2
Date of manufacture : 1969
Structure : As shown in Figure 5–6–4

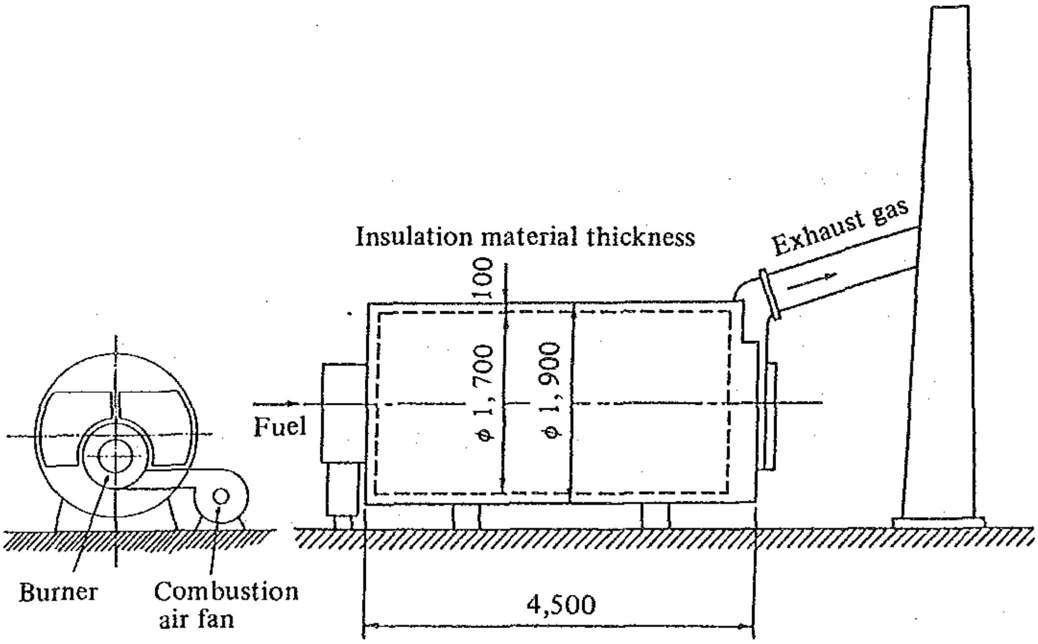


Figure 5–6–4 Boiler Structure

(2) Survey items and collected data

The boiler was surveyed from October 25 to 26, 1988.

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

(a) Data was gathered on the following items using the measuring instruments. The measuring points are shown in Figure 5–6–5 "Boiler Measuring Points."

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 visual observation items are as follows:

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

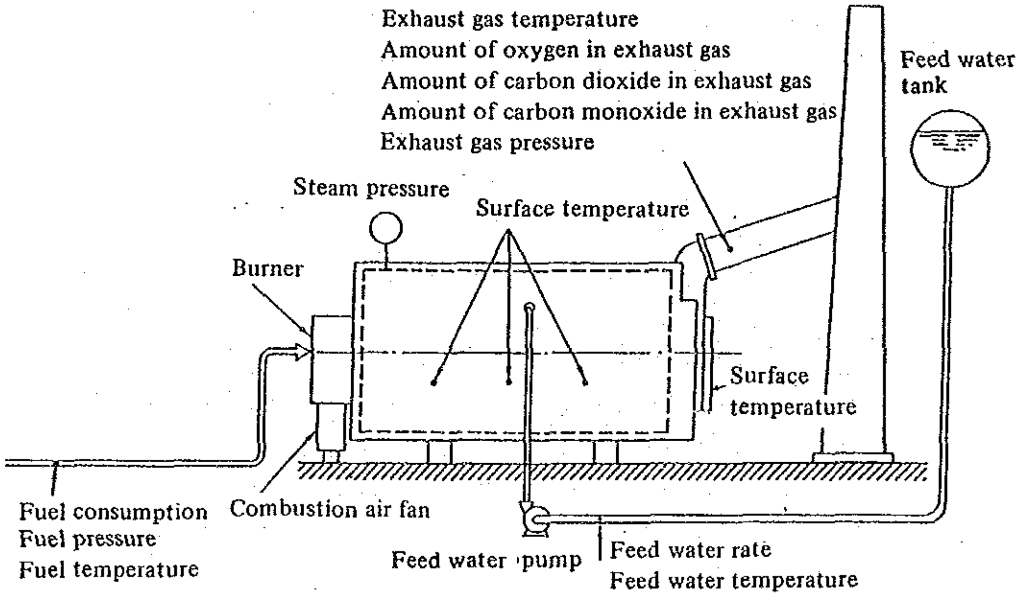


Figure 5–6–5 Boiler Measuring Points

(3) Heat balance of boiler

(a) The heat balance of the boiler was calculated using the data collected from 16:30 to 17:30 on October 25. The details of the data are as follows:

1)	Kind of fuel		: Natural gas
2)	Calorific value (low level)	(Hl)	: 8,636.3 kcal/Nm^3
3)	Specific gravity of fuel	(Sf)	: 0.754 kg/Nm^3
4)	Specific heat of fuel	(Cpf)	: 0.39 kcal/(Nm^3 °C)
5)	Fuel temperature	(Tf)	: 25.6°C
6)	Reference temperature	(To)	: 21.3°C
7)	Temperature of combustion air	(Ta)	: 22.2°C
8)	Specific heat of combustion air	(Cpa)	: 0.31 kcal/(Nm^3 °C)
9)	Theoretical amount of air	(Ao)	: 9.61 Nm^3/Nm^3-fuel
10)	Theoretical amount of wet exhaust gas	(Go)	: 10.62 Nm^3/Nm^3-fuel

Main burner combustion

11) Main burner combustion period (Pm) : 18.5 min.
12) Fuel flow rate (Fm) : 252.94 Nm^3/h
13) Fuel consumption (Cm) : 77.99 Nm^3/h
14) Exhaust gas temperature (Tgm) : 208.0°C
15) O_2 % of dry exhaust gas (O_2m) : 6.4%
16) Air ratio (m) : 1.45
17) Actual amount of combustion air (A) : 13.93 Nm^3/Nm^3-fuel
18) Actual amount of wet exhaust gas (G) : 14.95 Nm^3/Nm^3-fuel

Pilot burner combustion

19) Pilot burner combustion period (Pp) : 41.5 min.
20) Fuel flow rate (Fp) : 14.24 Nm^3/h
21) Fuel consumption (Cp) : 9.85 Nm^3/h
22) Exhaust gas temperature (Tgp) : 160.0°C
23) O_2 % of dry exhaust gas (O_2p) : 19.8%
24) Air ratio (m) : 25.75
25) Actual amount of combustion air (A) : 247.46 Nm^3/Nm^3-fuel
26) Actual amount of wet exhaust gas (G) : 248.47 Nm^3/Nm^3-fuel

27) Total fuel consumption : 87.84 Nm^3/h
28) Specific heat of exhaust gas (Cpg) : 0.33 kcal/(Nm^3 °C)
29) Exhaust gas pressure (Pg) : –0.67 mmAq
30) Feed water amount (based on weight) (Fw) : 761.0 kg
31) Feed water temperature (Tw) : 49.1°C
32) Steam pressure (Ps) : 6.52 kg/cm^2 G
33) Enthalpy of dry steam : 660.31 kcal/kg
34) Enthalpy of saturated water : 169.15 kcal/kg
35) Dryness of steam : 0.98
36) Enthalpy of wet steam : 650.49 kcal/kg
37) Enthalpy of feed water (h') : 48.98 kcal/kg

(b) Heat input

Heat input per Nm^3 of fuel is calculated.

1) Combustion heat of fuel (Hl)

$$Hl = 8{,}636.3 \text{ kcal/Nm}^3$$

2) Sensible heat of fuel (Qs)

$$Qs = 0.39 \times (25.6 - 21.3) = 1.58 \text{ kcal/Nm}^3$$

3) Sensible heat of combustion air (Qa)

$$Qa = \frac{(1.087 + 2.437)}{87.84} \times 0.31 \times (22.2 - 21.3) = 11.19 \text{ kcal/Nm}^3$$

4) Total heat input (Qi)

$$Qi = Hl + Qs + Qa = 8{,}636.3 + 1.68 + 11.19 = 8{,}649.17 \text{ kcal/Nm}^3$$

(c) Heat output

Heat output per Nm^3 of fuel is calculated.

1) Heat content of steam (Qv)

$$Qv = \frac{761.0}{87.84} \times (650.49 - 48.98) = 5{,}212.09 \text{ kcal/Nm}^3$$

2) Heat taken away by exhaust gas at the combustion of main burner (Qgm)

$$Qgm = 14.95 \times \frac{77.99}{87.84} \times 0.33 \times (208.0 - 21.3) = 817.80 \text{ kcal/Nm}^3$$

3) Heat taken away by exhaust gas at the combustion of pilot burner (Qgp)

$$Qgp = 248.47 \times \frac{9.85}{87.84} \times 0.31 \times (160.0 - 21.3) = 1{,}198.00 \text{ kcal/Nm}^3$$

4) Heat radiation from furnace surface (Qr)

$$Qr = \frac{1{,}028 \times 2.84 + 297 \times 26.9 + 1{,}536 \times 2.84}{87.84} = 173.76 \text{ kcal/Nm}^3$$

Average temperature and surface area of front plate:	96.3°C, 2.84 m^2
Average temperature and surface area of shell plate:	48.9°C, 26.9 m^2
Average temperature and surface area of rear plate:	122.6°C, 2.84 m^2

5) Other heat loss (Qm)

$$Qm = 1{,}247.52 \text{ kcal/Nm}^3$$

6) Total heat output (Qo)

$$Qo = Qv + Qgm + Qgp + Qr + Qm = 8{,}649.17 \text{ kcal/Nm}^3$$

(d) Heat balance table

The data shown above are summarized in Table 5–6–4.

Table 5–6–4 Heat Balance of Boiler

Heat input			Heat output		
Item	kcal/Nm^3	%	Item	kcal/Nm^3	%
Fuel combustion heat	8,636.30	99.85	①Heat possessed by steam	5,212.09	60.26
Sensible heat of fuel	1.68	0.02	②Heat taken away by exhaust gas	817.80	9.46
Sensible heat of combustion air	11.19	0.13	③Heat taken away by exhaust gas	1,198.00	13.85
			④Heat radiation from surface	173.76	2.01
			⑤Other heat loss	1,247.52	14.42
Total	8,649.17	100.00	Total	8,649.17	100.00

(4) Problems and Remedies

(a) Reduction of the heat taken away by exhaust gas due to the improved air ratio at the combustion of main burner (1)

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 ratio, which can be calculated from the amount of oxygen in exhaust gas. The amount of oxygen in exhaust gas when the measurement was made at the time of combustion was 6.4% and the air ratio was 1.45. If the amount of oxygen is reduced to 4.5%, the air ratio will be 1.27 and the amount of exhaust gas will be reduced by about 12%.

The amount of air can be 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.

Table 5–6–5 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		%	6.4	4.5
2	Air ratio	m	Nm^3/Nm^3	1.45	1.27
3	Theoretical amount of air	Ao	Nm^3/Nm^3	9.61	9.61
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	13.93	12.20
6	Actual amount of exhaust gas	G	Nm^3/Nm^3	14.95	13.21
7	Exhaust gas temperature	tg	°C	208	208
8	Heat taken away by exhaust gas	Qg	$kcal/Nm^3$	817.80	722.62

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

$$S = 1 - \frac{Hi - Oga}{Hi - Ogi} = 1 - \frac{8{,}649.17 - 817.80}{8{,}649.17 - 722.62} = 0.012 = 1.2\%$$

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 77.99 Nm^3/h X 6,000 h/y = 467,940 Nm^3/y, the amount of annual saving can be calculated as follows:

467,940 Nm^3/yx 0.012 x 0.08 US\$/Nm^3 = 449 US\$/y

b) Reduction of the heat taken away by exhaust gas due to the improvement of combustion method at the combustion of pilot burner (2)

The air ratio is abnormally high when the main burner is extinguished and only the pilot burner is combustioned.

This is because a part of the air from the combustion air fan is leaked in the boiler from the closed damper through the main burner when it is introduced from the front of the damper to the pilot burner by another pipe to be used for the combustion air of the pilot burner. To improve the air leakage from the damper of main burner, it is necessary to adjust the damper between the fan and the main burner so that it closes tightly when only the pilot burner is combustioned. This adjustment will lead to the reduction of the amount of oxygen in exhaust gas. If the amount of oxygen is reduced to 4.5% as shown in Table 5–6–6, the amount of exhaust gas will decrease by 95%. As any additional equipment is not necessary for the adjustment, no direct investment is required.

Table 5–6–6 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		%	19.8	4.5
2	Air ratio	m		25.75	1.27
3	Theoretical amount of air	Ao	Nm^3/Nm^3	9.61	9.61
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	247.46	12.20
6	Actual amount of exhaust gas	G	Nm^3/Nm^3	248.47	13.21
7	Exhaust gas temperature	tg	°C	160	160
8	Heat taken away by exhaust gas	Qg	$kcal/Nm^3$	1,198.00	63.69

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

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{8{,}649.17 - 1{,}198.00}{8{,}649.17 - 63.69} = 0.1321 = 13.21\%$$

where

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

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

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

Assumming that the annual consumption of fuel for pilot burnors is 9.85 Nm^3/h X 6,000 h/h 59,100 Nm^3/y, the amount of annual saving can be calculated as follows:

59,100 Nm^3/y X 0.132 X 0.08 U\$S/Nm^3 = 625 U\$S/y

c) Effect of the decrease of the heat taken away by exhaust gas

Another method to reduce the heat taken away by exhuast gas, is to lower the exhaust gas temperature. In most cases, the heating surface is cleaned, and the heat of exhaust gas is recovered for the feed water preheat and combustion air preheat.

Since this factory conducts the condensate recovery and the feed water temperature has already reached 50 – 60°C, any further rise of the feed water temperature is meaningless. If you want to further raise the feed water temperature, you had better consider to carry out the condensate recovery more effectively.

In the case of the present boiler, the exhaust gas temperature is 208°C, and the main burner operating period is short. Therefore, no economic effect can be expected for air preheating. It is recommended that the variations of the exhaust gas temperature be monitored and the inner and outer heating surfaces be cleaned periodically.

d) Decrease of the radiation heat of furnace and others

As for the heat radiated from the furnace of this boiler, the surface temperature of the body is 50°C because it is insulated in almost good condition. However, the front plate of the burner side and the rear plate of the stack side are not insulated sufficiently to such an extent that their surface temperature is 100 – 120°C. The thickness of the insulating materials for these plates seems to have been made thin for facilitating the opening of these plates for cleaning the fire tube. However, if the thickness of the insulating materials used for lining is increased and the surface temperature is lowered to 80°C, the radiation heat will be decreased as shown below.

$$(1{,}028 - 600)\ \mathrm{kcal/(m^2\,h)} \times 2.84\ \mathrm{m^2} = 1{,}215\ \mathrm{kcal/h}$$

$$(1{,}536 - 600)\ \mathrm{kcal/(m^2\,h)} \times 2.84\ \mathrm{m^2} = 2{,}658\ \mathrm{kcal/h}$$

The decreased radiation heat totals as given below.

$$1{,}215 + 2{,}658 = 3{,}873\ \mathrm{kcal/h}$$

Thus, the amount of fuel conservation annually is calculated by the following equation.

$$\frac{3{,}873\ \mathrm{kcal/h}}{8{,}649.17 - 722.62\ \mathrm{kcal/Nm^3}} \times 6{,}000\ \mathrm{h/y} \times 0.08\ \mathrm{US\$/Nm^3} = 216\ \mathrm{US\$/y}$$

If the thickness of the insulating materials is increased at the next maintenance, almost no expenses will be necessary.

e) Feed water quality control

The quality of feed water and boiler water was found to be as shown in Table 5–6–7.

Table 5–6–7 Quality of Feed Water and Boiler Water

	pH	Temp.	Conductivity	Temp.
Raw water	7.7	22.6°C	0.910 mS/cm	23.5°C
Soft water	7.6	22.1°C	0.877 mS/cm	23.0°C
Condensate	6.5	27.0°C	0.320 mS/cm	27.1°C
Feed water	7.5	30.3°C	0.423 mS/cm	27.1°C
standard	7.0 – 9.0	25.0°C	not specified	
Boiler water	11.9	35.3°C	10.38 mS/cm	35.0°C
standard	11.0 – 11.9	25.0°C	4.5 mS/cm under	25.0°C

The pH values of the feed water and boiler water are good. However, the value of the electric conductivity of the boiler water is abnormally high. This means that a large amount of impurities are contained in the water, causing to make the life of the boiler short.

For the feed water at this factory, a water softener is used to improve the water quality, and the condensate recovery is carried out. However, as the value of the electric conductivity of the feed water is good, the high value of the electric conductivity of the boiler water is resulted from the insufficient water quality control for the boiler water.

The quality of the boiler water can be made by blowing, the use of boiler compounds and the improvement of the feed water quality. To regulate the quality of boiler water by blow only, a continuous blow of about 10% will be necessary as expressed by the following equation.

$$\begin{aligned} Fb &= Fc/(Bc - Fc) \times 100 \\ &= 0.423/(4.5 - 0.423) \times 100 \\ &= 10.38\% \end{aligned}$$

where

Fb: Blow ratio (%);

Fc: Electric conductivity of feed water;

Bc: Electric conductivity of boiler water.

The following methods can be used to lower the salt concentration for the improvement of the feed water quality.

(1) The salt concentration of the feed water is lowered by increasing the steam condensate recovery rate.

(2) To lower the concentration of salt 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 softener is changed to a dealkali softener, most of the M-alkali in the raw water can be eliminated (remaining 5 to 15 mg/liter) so that the salt content of the soft water can slightly lowered.

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

5.6.3.2 Oil Heater

The high temperature oil of 250°C supplied from the oil heater is used as the heat source for the emulsion reactor, and plays an important role in the manufacturing process.

(1) Oil heater specifications

Type : Helical coil type downward combustion system

Heating capacity : 400,000 kcal/h

Fuel : Natural gas

CH_4 = 95.80% C_2H_6 = 1.51% C_3H_6 = 0.25%

$i\text{-}C_4H_{12}$ = 0.08% $n\text{-}C_4H_{12}$ = 0.12% $i\text{-}C_6H_{12}$ = 0.07%

$n\text{-}C_6H_{12}$ = 0.06% C_6H_{14} = 0.13% N_2 = 1.52%

CO_2 = 0.46%

Structure : As shown in Figure 5–6–6

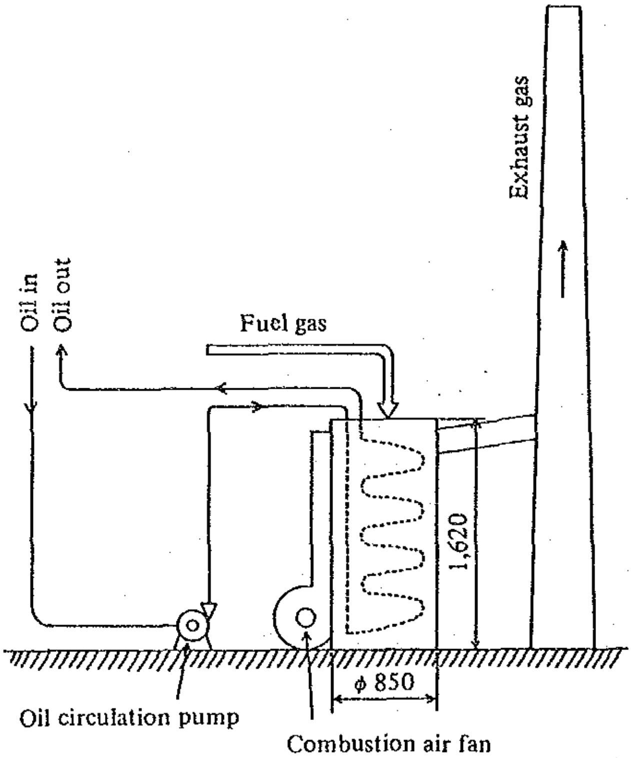


Figure 5–6–6 Oil Heater Structure

(2) Survey items and collected data

The oil heater was surveyed on October 26, 1988.

The measuring instruments brought by the study team were used to survey the oil heater, and the heater operating condition was observed visually.

a) Data was gathered on the following items using the measuring instruments. The measuring points are shown in Figure 5–6–7 "Oil Heater Measuring Points."

1) Exhaust gas temperature and pressure, O_2 %, CO_2 %, and CO% in exhaust gas
2) Inlet and outlet temperatures of heating oil
3) Fuel gas flow rate, temperature and pressure
4) Furnace surface temperature
5) Ambient (reference) temperature

b) The visual observation items are as follows:

1) Burning condition, smoke from the stack
2) Combustion control method
3) Heat-insulation of furnace and piping
4) Oil leakage
5) Equipment maintenance

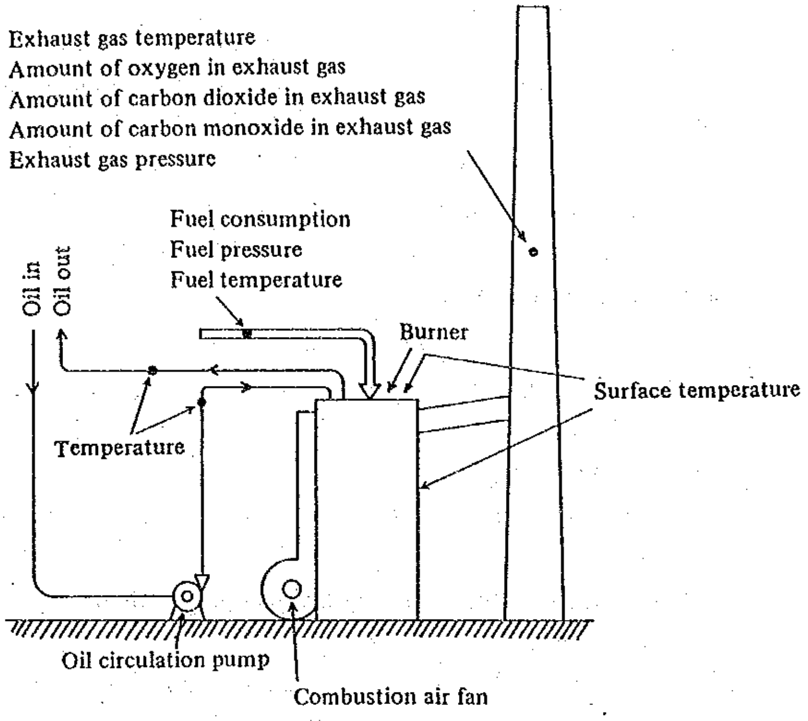


Figure 5–6–7 Oil Heater Measuring Points

(3) Heat balance of oil heater

a) The heat balance of the oil heater was calculated using the data collected from 13:00 to 14:00 on October 26. Since the oil circulation volume of heating medium cannot be measured, it is not possible to accurately determine the amount of heat output. Therefore, the heat balance is calculated by the heat loss method. The combustion is made by On-Off system, and the combustion and its stoppage are repeated at an interval of two or three minutes.

The details of the data are as follows:

1)	Kind of fuel		: Natural gas
2)	Calorific value (low level)	(Hl)	: 8,636.30 kcal/Nm³
3)	Specific gravity of fuel	(Sf)	: 0.7535 kg/Nm³
4)	Specific heat of fuel	(Cpf)	: 0.39 kcal/(Nm³ °C)
5)	Fuel temperature	(Tf)	: 36.9°C
6)	Reference temperature	(To)	: 30.5°C
7)	Temperature of combustion air	(Ta)	: 30.5°C
8)	Specific heat of combustion air	(Cpa)	: 0.31 kcal/(Nm³ °C)
9)	Theoretical amount of air	(Ao)	: 9.61 Nm³/Nm³-fuel
10)	Theoretical amount of wet exhaust gas	(Go)	: 10.62 Nm³/Nm³-fuel
11)	Fuel flow rate	(F)	: 12.80 Nm³/h
12)	Exhaust gas temperature	(Tg)	: 325.4°C
13)	O_2% of dry waste gas	(O_2)	: 8.3%
14)	Air ratio	(m)	: 1.67
15)	Actual amount of combustion air	(A)	: 16.05 Nm³/Nm³-fuel

16)	Actual amount of wet exhaust gas	(G)	: 17.06 Nm^3/Nm^3-fuel
17)	Specific heat of exhaust gas	(Cpg)	: 0.33 kcal/(Nm^3 °C)
18)	Exhaust gas pressure	(Pg)	: –4.26 mmAq

b) Heat input

Heat input per Nm^3 of fuel is calculated.

1) Combustion heat of fuel (Hl)

$$Hl = 8,636.30 \text{ kcal/Nm}^3$$

2) Sensible heat of fuel (Qs)

$$Qs = 0.39 \times (36.9 - 30.5) = 2.50 \text{ kcal/Nm}^3$$

3) Sensible heat of combustion air (Qa)

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

4) Total heat input (Qi)

$$Qi = Hl + Qs + Qa = 8,636.30 + 2.50 + 0 = 8,638.80 \text{ kcal/Nm}^3$$

c) Heat output

It is calculated for the fuel 1 Nm^3 by the heat loss method.

1) Heat taken away by exhaust gas (Qg)

$$Qg = 17.06 \times 0.33 \times (325.4 - 30.5) = 1,660.23 \text{ kcal/Nm}^3$$

2) Heat radiation from furnace surface (Qr)

$$Qr = \frac{625 \times 0.57 + 229 \times 4.32}{12.80} = 105.08 \text{ kcal/Nm}^3$$

Average temperature and surface area of top plate:	75.1°C, 0.57 m^2
Average temperature and surface area of shell plate:	49.8°C, 4.32 m^2

3) Other heat loss (Qm)

$$Qm = 8,638.80 \times 0.05 = 431.94 \text{ kcal/Nm}^3$$

4) Heat content of oil (Qo)

$$Qo = Qi - Qg - Qr - Qm = 6,441.55 \text{ kcal/Nm}^3$$

d) Heat balance table

The data shown above are summarized in Table 5–6–8.

Table 5–6–8 Heat Balance of Oil Heater

Heat input			Heat output		
Item	kcal/Nm^3	%	Item	kcal/Nm^3	%
Fuel combustion heat	8,636.30	99.97	Heat possessed by oil	6,441.55	74.57
Sensible heat of fuel	2.50	0.03	Heat taken away by exhaust gas	1,660.23	19.22
Sensible heat of combustion air	0	0	Heat radiation from furnace	105.08	1.22
			Other heat loss	431.94	5.00
Total	8,638.80	100.00	Total	8,638.80	100.00

(4) Problems and Remedies

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

The temperature of the exhaust gas from the oil heater is 325.4°C on the average that is higher than those of boiler and others. However, because the oil outlet temperature of the heated matters is 200°C to 250°C, it is not possible to lower the average temperature of the exhaust gas to 300°C or less owing to the heat exchange efficiency. Therefore, the exhaust gas loss cannot be reduced by lowering the exhaust gas temperature.

In the meantime, the heat taken away by exhaust gas can be reduced by the reduction of exhaust gas amount. It can be achieved by keeping the amount of combustion air for fuel at a proper level. The amount of oxygen in exhaust gas when the measurement was made at the time of combustion was about 8.3% and the air ratio was 1.67 as shown in Figure 5–6–8. If the amount of oxygen is reduced to 4.5%, the air ratio will be 1.27 and the amount of exhaust gas will be reduced by about 23% as shown in Table 5–6–9.

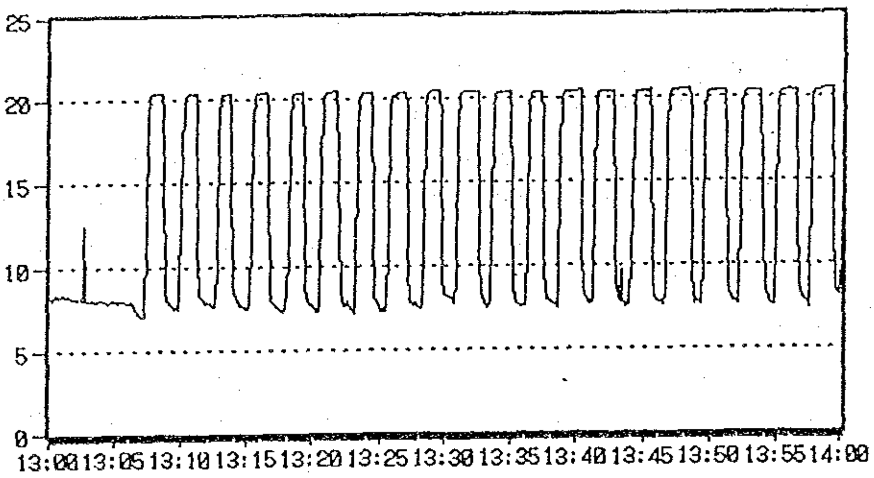


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Figure 5–6–8 O_2 % in Exhaust Gas

The amount of air can be 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.

Table 5–6–9 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		%	8.3	4.5
2	Air ratio	m		1.67	1.27
3	Theoretical amount of air	Ao	Nm^3/Nm^3	9.61	9.61
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	16.05	12.20
6	Actual amount of exhaust gas	G	Nm^3/Nm^3	17.06	13.21
7	Exhaust gas temperature	tg	°C	325.4	325.4
8	Heat taken away by exhaust gas	Qg	$kcal/Nm^3$	1,660.23	1,285.56

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

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{8{,}638.80 - 1{,}660.23}{8{,}638.80 - 1{,}285.56} = 0.0510 = 5.10\%$$

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 annaul consumption of fuel is 12.80 $Nm^3/h \times 6{,}000\ h/y = 76{,}800\ Nm^3/y$, the amount of annual saving can be calculated as follows:

$76{,}800\ Nm^3/y \times 0.0510 \times 0.08\ US\$/Nm^3 = 313\ US\$/y$

b) Prevention of the cooled air suction when the combustion is stopped.

As shown in Figure 5–6–8, the oxygen in exhaust gas when the combustion is stopped is 20.6%, and it is clear that the cooled air is sucked in the exhaust gas. When the air is sucked, the heat accumulated in the furnace is released from the stack as the exhaust loss. It is recommended that the inlet louver of the combustion air fan be adjusted to close when the combustion is stopped to prevent the suction of cooled air into the furnace.

5.6.3.3 Reactors

(1) Usage conditions of reactors

Several reactors with agitators are used for emulsion polymerization of acrylic esters, and they possess jackets which can switch from steam heating to water cooling and vice versa, as well as reflux condenser, and the amount of steam consumption is great.

Among these reactors, the reactor having the largest volume of 13 tons was selected, and its heat balance was studied.

Since the polymerization reaction of acrylic ester is exothermic, after the contents are heated to 80 – 82°C and the reaction is started, while adding raw materials gradually, the jacket is switched to cooling, and maintains a suitable reaction temperature.

The cooling is attained by recycling industrial water and chilled water in the jacket, and by removing the condensing latent heat of the monomer in the reflux condenser.

By summarizing the information shown by the factory and the calculated data, the reaction procedure, addition amount of raw materials, heating and cooling amount are shown as below.

1) Charge 2,000 kg of treated water into the reactor, and heat this to about 80 – 82°C in about 2 hours.

If the initial temperature is assumed to be 25°C, the required quantity of heat is 112 M cal.

2) Add monomer at the ratio of 1,064 kg/h for 6 hours.

During this period, add treated water little by little until the total amount becomes 12,000 kg. As a result, the amount of monometer added during this period will be 6,384 kg, and the amount of treated water added will be 3,616 kg.

The reaction heat based on the polymerization reaction is shown as 149 M cal/h. The reaction heat quantity for the whole period will be 894 M cal.

3) When the reaction is completed, the contents are heated to 89°C.

The temperature rising time is short, and it is shown to be about 3 minutes.

The heat quantity required for raising the temperature of the contents from 81°C to 89°C will be 68 M cal if we assume the average specific heat of the polymerization product as 0.71 kcal/kg °C.

4) Cool the polymerization product from 89°C to 50°C in 6 – 6.5 hours.

If the above mentioned specific heat is used, the cooling quantity of heat will be 332 M cal.

5) Add various additives, and after the physical properties are adjusted, cool to about 30°C. The cooling quantity of heat required for this will be 170 M cal.

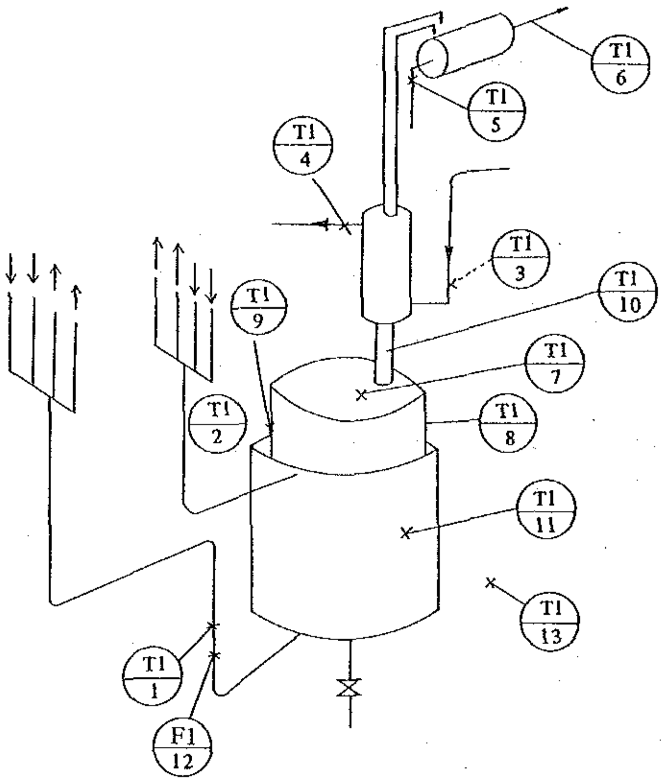
This completes the whole reaction process. Take out the reaction product, and fill up it into containers.

(2) Heat balance

(a) Measuring point and measured value

In order to obtain the heat balance, the temperature at various parts of the reactor, and the heating and cooling water flow were measured by the measuring instrument that we brought. The measurement was taken from 18:00, October 25, to 06:00 October 27. The measurement points are shown in Figure 5-6-9.

As representative values of the recorded values, the inlet, outlet water temperature, the water temperature difference between inlet and outlet of jacket at the time of heating and cooling, and the exterior surface temperature at the reactor top portion are shown in Figure 5-6-10 ~ Figure 5-6-12.



TI 1	Temperature of cooling water to jacket, or condensate
TI 2	Temperature of water from jacket, or inlet steam
TI 3	Temperature of the cooling water at the inlet of reflux condenser
TI 4	Temperature of the cooling water at the outlet of reflux condenser
TI 5	Temperature of the cooling water at the inlet of total condenser
TI 6	Temperature of the cooling watet at the outlet of total condenser
TI 7	Temperature of the upper surface of reactor
TI 8	Temperature of the side surface of reactor
TI 9	Temperature of the side surface of reactor
TI 10	Temperature of the inlet vapor of reflux condenser
TI 11	Temperature of jacket surface
FI 12	Flow of jacket cooling water (condensate)
TI 13	Room temperature

Figure 5–6–9 Schematic Diagram of Reactor Measuring Point

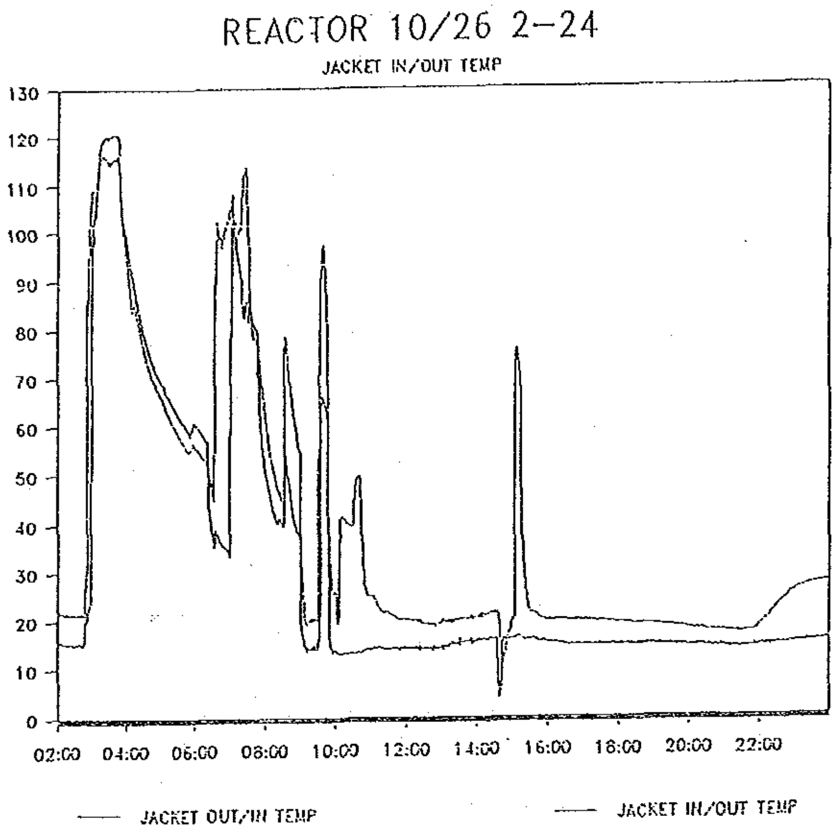


Figure 5–6–10 Jacket In/Out Temperature for Heating and Cooling Jacket

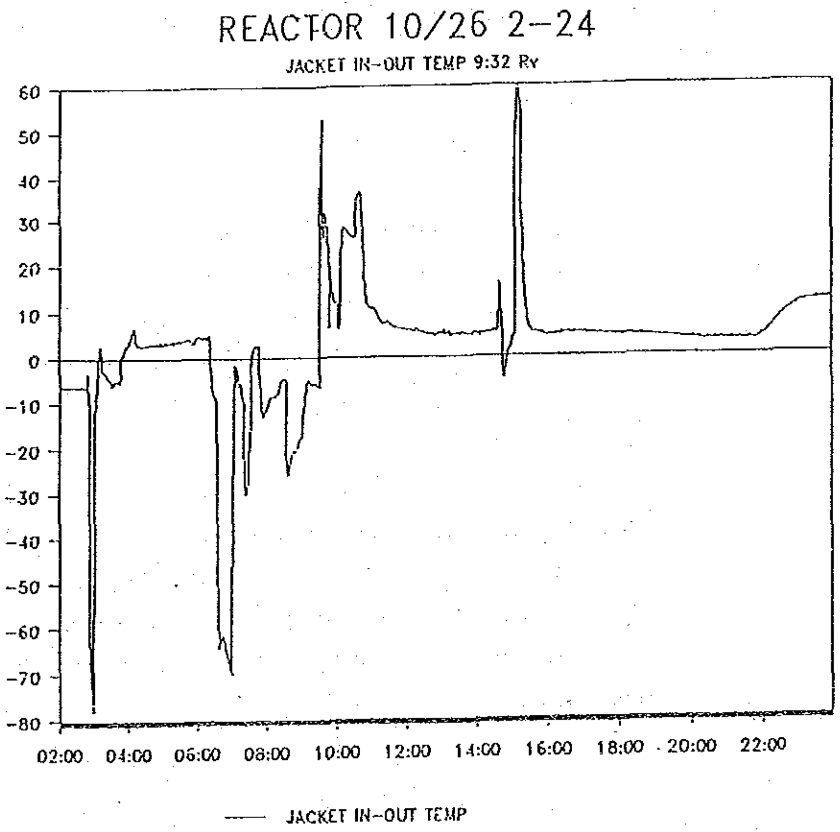


Figure 5–6–11 Difference of Jacket In/Out Temperature for Heating and Cooling
(△ t reversed at 9:32)

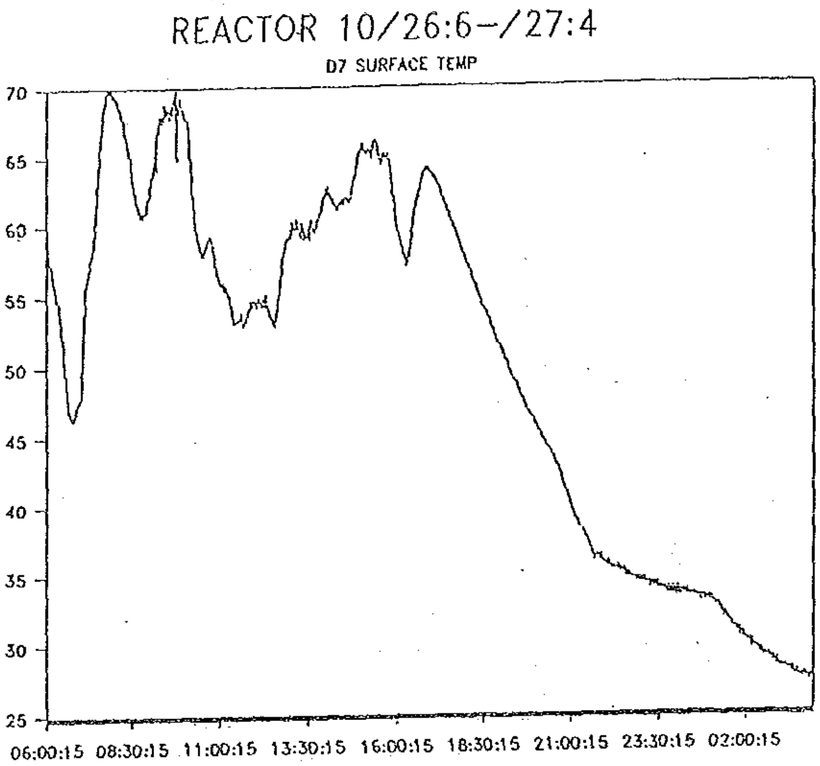


Figure 5–6–12 Outer Surface Temperature of Upper Part of Reactor

(b) Basis of the heat balance calcuation

Since the reactor is batch operation, the heat balance was obtained by the charging amount per one operation as standard.

a. Material balance

Monomer charging amount	6,384 kg
Amount of treated water	5,616 kg
Amount of water charged prior to reaction	2,000 kg
Amount of water charged after reaction began	3,616 kg

Since that amount of surface active reagent, emulsion stabilizer, polymerization castalysts are extremely small in comparison with the raw materials above mentioned, they shall be neglected.

b. Reactor dimensions

Exterior surface area of jacket portion	23.07 m^2
Area of reactor top exposed portion	10.6 m^2
Area of exposed pipe from reactor to the condenser	0.52 m^2

c. Calcuation equation for the quantity of heat dissipation

The heat dissipation caused by natural convection can be expressed by the following equation.

$Qc = \alpha \times A \times \Delta t$

where

Qc = Natural convection heat transfer quantity per hour [kcal/h]

α = Heat transfer coefficient of natural convection [$kcal/m^2 \cdot h \cdot {}^\circ C$]

where

in case of top facing horizontal surface

$\alpha = 2.8 \times \Delta t^{0.25}$

in case of vertical plane

$\alpha = 2.2 \times \Delta t^{0.25}$

in case of bottom facing surface

$\alpha = 1.5 \times \Delta t^{0.25}$

A = Heat transfer area [m^2]

Δt = Logarithmic mean temperature difference

Heat transfer quantity by radiation is obtained by the following equation.

$$Qr = 4.88 \times \epsilon \times A\left[\left(\frac{t_1 + 273}{100}\right)^4 - \left(\frac{t_2 + 273}{100}\right)^4\right]$$

where

Qr = Transfer heat quantity/hr by radiation [kcal/h]

ϵ = Emissivity (In this case 0.5 shall be used)

A = Heat transfer area [m^2]

t_1, t_2 = Temperature of radiation side and heat receiving side [°C]

d. Prediction of specific heat

The specific heat of acrylic ester monomer was obtained by using the estimation equation of Chow and Bright.

$$C_{20}{}^* = \frac{[P] + B}{A\,[R_0]}$$

where

$C_{20}{}^*$ = Specific heat of liquid at 20°C, atmospheric pressure [kcal/kg °C]

[P] = Parachor

[R_0] = Molecular refraction by D line

A, B = Constants determined by organic homologous series

If the specific heat is obtained by calculating the [P], [R_0] of methyl acrylate and ethyl acrylate from the chemical structure factors, and A, B from the structures, it will be as follows:

	[P]	[R_0]	A	B	Specific heat [kcal/kg . °C]
Methyl acrylate	207.2	21.742	20.25	–5.8	0.45
Ethyl acrylate	247.2	25.259	20.25	–5.8	0.47

Since the polymerization degree for the product was not clear, the specific heat which was calculated by utilizing the average specific heat of two monomers and their weight ratio versus water, was used as the specific heat for the polymerization product.