5. Survey of the Use of Energy in Model Factories

5.1 Results of Survey of Juice Factory

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5.1.1 Summary of Factory

(1) Name of factory: Jugos S.A

(2) Kind of product: Food

(3) Location : Parque Industrial Reginense, Villa Regina
Rio Negro

(4) Outline of factory

This factory produces about 3,500 tons of concentrated apple juice annually.

The area along the Rio Negro 12 km long south to north and 100 km wide east to west has been a large apple producing area since about 1923, shipping about 900,000 tons of apples annually. This factory is located in the center of the area. It was constructed in 1977 by the 50 apple growers in the area for the purpose of using apples that cannot be shipped because of size and shape. Therefore, the material apples are cheap in cost, and can be relatively easily obtained even in bad crop years.

Almost all the concentrated juice produced here (95%) is exported to North America, etc.

Argentina has 18 concentrated juice factories across the country, and Jugos S.A. is about an average factory in size because it accounts for about 5% to 8% of the total juice production, though the percentage varies depending on the apple crop.

The apple harvest season is from February to June so that the factory produces concentrated apple juice for about 100 to 120 days only from March to June. The factory remains out of operation from September through January during which the production facilities are only maintained. The factory started producing concentrated pear juice before apple juice from 1987.

The factory was partially modified to boost the production capacity. Specifically, an Oliver filter was installed in 1985, and a preconcentrator in 1986. Despite its apple processing capacity of 30 tons/day, the factory now processes only 15 tons/day. Operation hour per day is 20 hours, and the remaining 4 hours is used for cleaning and maintaining the equipment. One gallon of juice is produced from 40 kg of apples on the average.

(5) No. of employee

43 to 45 persons, of which 2 are engineers

(6) Survey period

March 14 to 19, 1988

(7) Survey team members

Japanese members

Name	Assignment
Takashi Niikura	Leader
Mitsuo Iguchi	Energy management
Teruo Nakagawa	Boiler and steam equipment
Kaoru Nakao	Food processing

Takashige Taniguchi — Steam, water line
Kenichi Kurita — Electric power facilities

INTI members

Mr. Mario Ogara — Leader
Mr. Jorge Fiora — Heat process and steam equipment
Mr. Alberto Berset — Boiler and steam equipment
Mr. Arturo Verghelet — Assistance in thermal techniques
Mr. Marcelo Silvosa — Electric power facilities
Mr. Miguel Bermejo — Assitance in electrical techniques
Mr. Anibal Monzon — Measurement and mobile unit driver
Mr. Hector Citadino — Measurement

(8) Interviewees in the factory

Mr. Antonio Pirri — President
Mr. Hugo Durazzi — Administration Manager
Mr. Armando Criado — Production Manager
Mr. Toncovic — Engineer

(9) Production

Table 5–1–1 Production (tons)

Year	1983	1984	1985	1986	1987
Apple Juice	2675	2259	2295	1355	3051
Perfume	111	88	144	51	69
Pear Juice	–	–	–	486	486

Table 5–1–2 Monthly Production in 1987 (kg)

Month	Apple Juice	Apple Perfume	Pear Juice	Pear Perfume
2	23,608	908	485,981	34,691
3	839,338	25,197	–	–
4	800,656	14,528	–	–
5	685,224	20,657	–	–
6	575,318	6,129	–	–
7	108,371	1,135	–	–
8	19,034	227	–	–
Total	3051,549	68,781	485,981	34,691

(10) Energy consumption

Table 5–1–3 Energy Consumption

Year	1983	1984	1985	1986	1987
Natural Gas 1000m^3	1103	926	1132	932	1,529
Elec. Power Mwh	522	476	529	483	837
Well Water 1000m^3	288	288	288	288	288
City Water 1000m^3	10	10	10	10	10
Energy/Product					
N. Gas m^3/t	412	410	493	506	461
Power kwh/t	195	211	231	262	237

Table 5–1–4 Monthly Natural Gas Consumption in 1987

Mon.	Consumed Actual m^3	Calorie kcal/m^3	Consumption as 9300 kcal	Price		Rate
				A/m^3	\$/m^3	m^3/t
1	149	9,920	159	0.206	0.134	
2	190,330	9,800	200,562	0.0647	0.042	393.6
3	335,664	9,840	355,154	0.0658	0.043	423.1
4	342,318	9,955	366,427	0.0657	0.041	457.7
5	308,521	9,795	324,948	0.0689	0.038	474.2
6	254,861	9,775	267,878	0.0784	0.040	465.6
7	82,534	9,825	87,193	0.0862	0.038	804.6
8	15,056	9,825	16,003	0.112	0.043	840.8
Tot.	1,529,433	9,840	1,618,324		0.041	

Table 5–1–5 Monthly Electric Power Consumption in 1987 (kWh)

Mon.	Consumption kWh	Price		Rate
		A/kWh	$/kWh	kWh/t
1	6120	0.225		
2	99648	0.057	0.037	195.5
3	180144	0.049	0.032	214.6
4	154440	0.051	0.032	192.9
5	163224	0.051	0.028	238.2
6	113472	0.070	0.035	197.2
7	70560	0.088	0.039	651.1
8	24336	0.118	0.045	1278.6
9	8712	0.276		
10	6408	0.466		
11	5688	0.510		
12	4680	0.593		
Tot.	837432		0.035	

The juice production in Tables 5–1–2 are expressed by the horizontal axis, and the gas and electricity consumption in Table 5–1–4 and 5–1–5 by the vertical axis as shown in Figure 5–1–1 and 5–1–2 below. All are closely related to each other. A regression formula is shown in the figures.

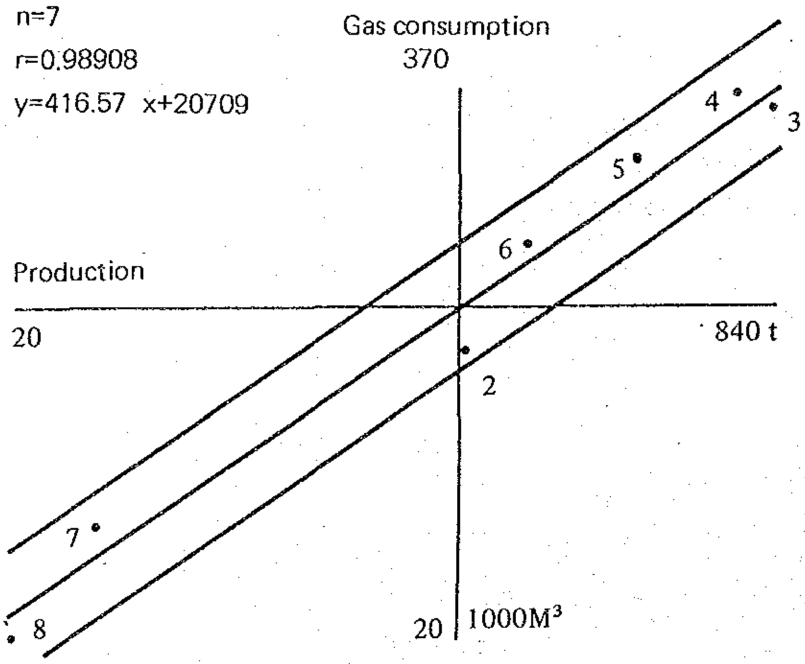


Figure 4–1–1 Juice Production vs. Natural Gas Consumption

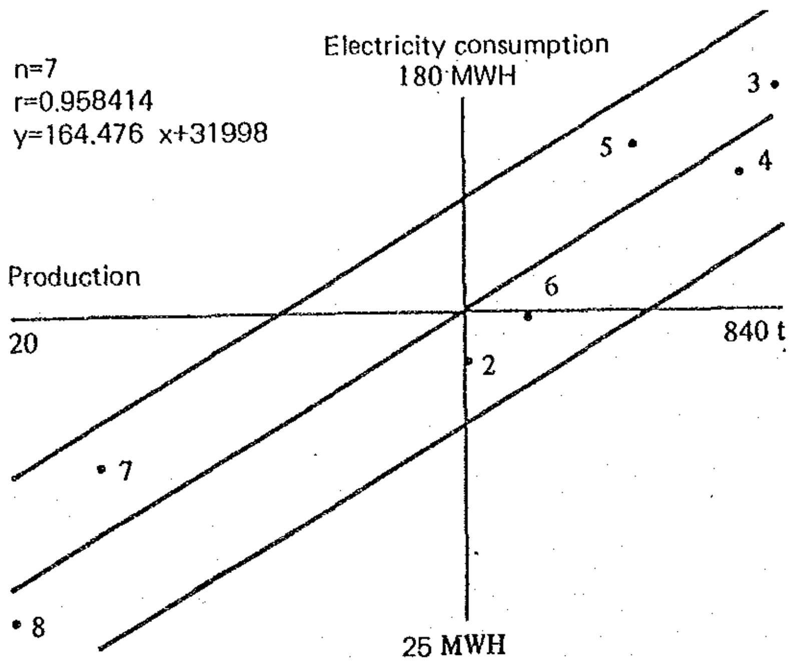


Figure 5–1–2 Juice Production vs. Electric Power Consumption

Actual data should be plotted each month. If a large deviation from the regression line is found, it is necessary to immediately check for the cause, and take appropriate steps to remove the cause.

(11) Factory Layout

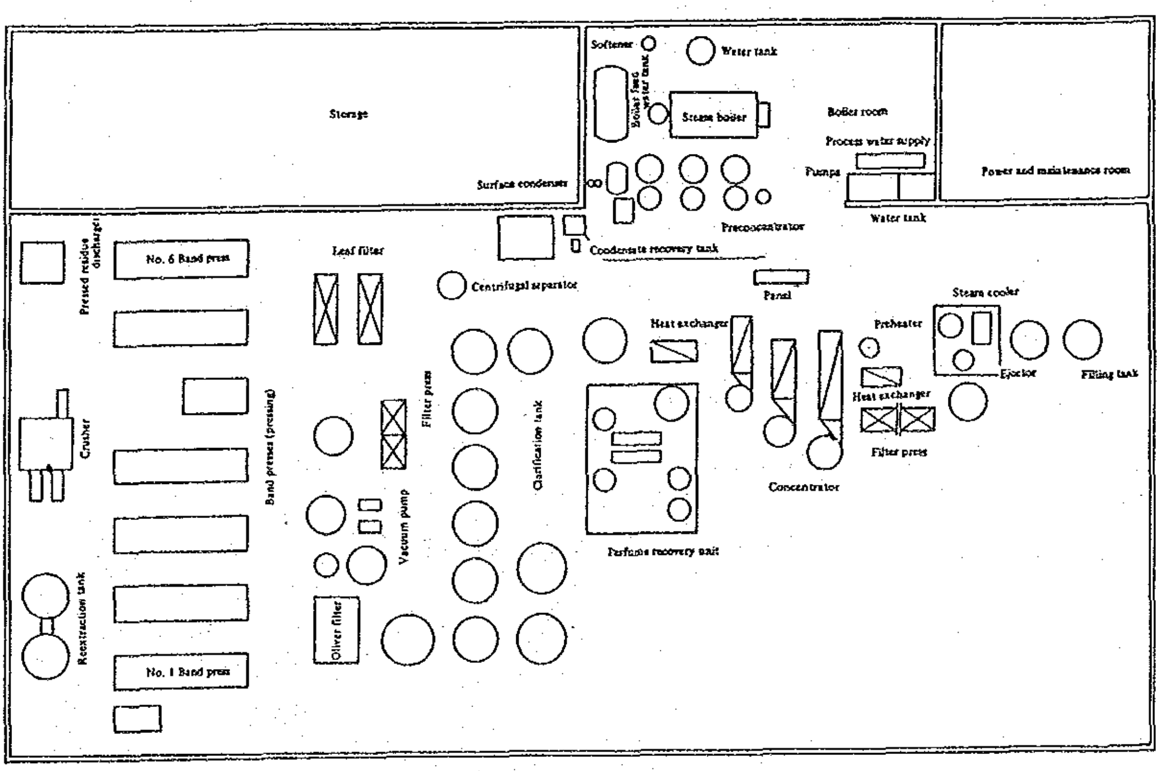
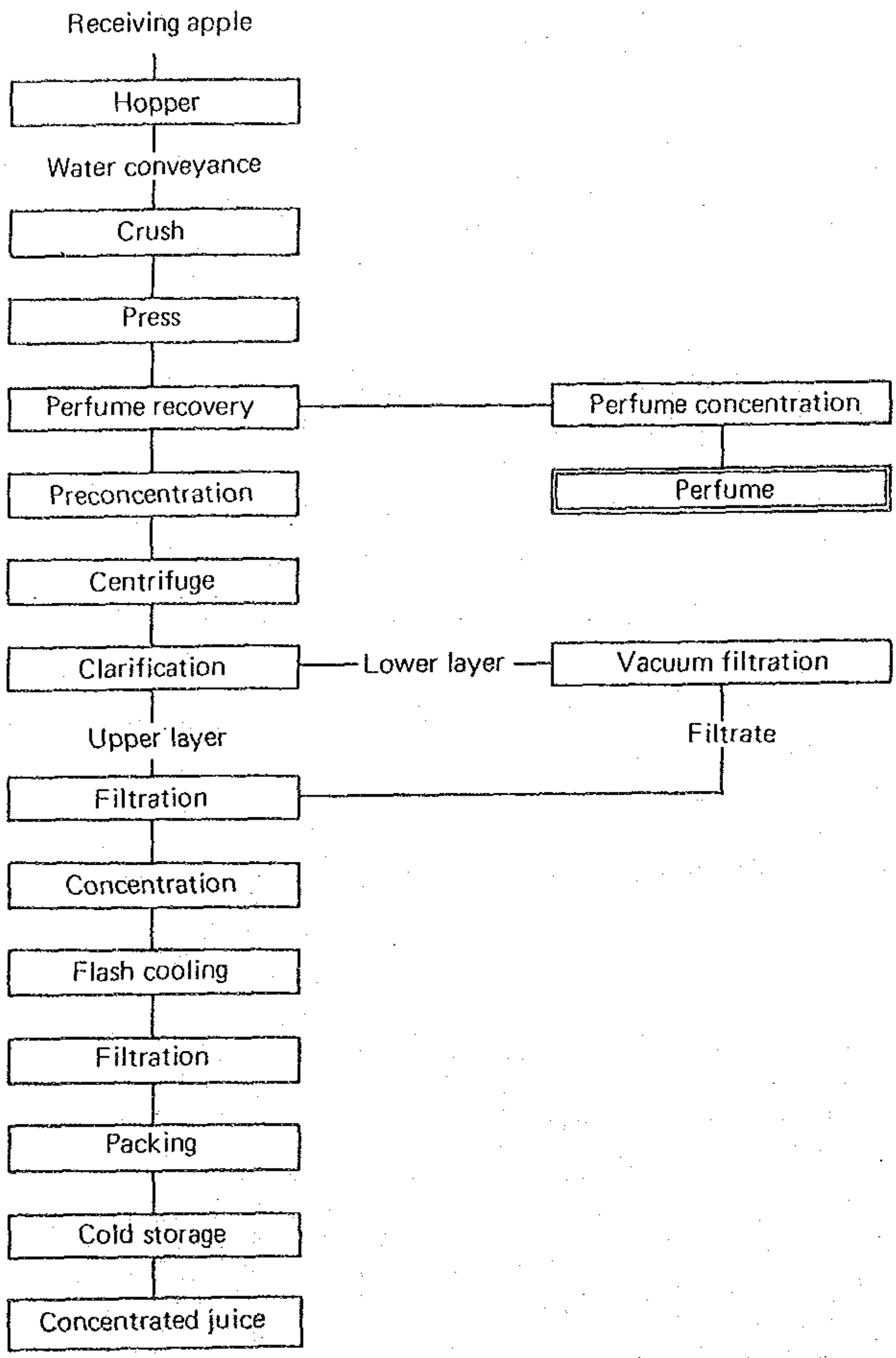


Figure 5–1–3 Equipment Layout

(12) Production process



Fiugre 5–1–4 Process Flowsheet

(13) One line Diagram

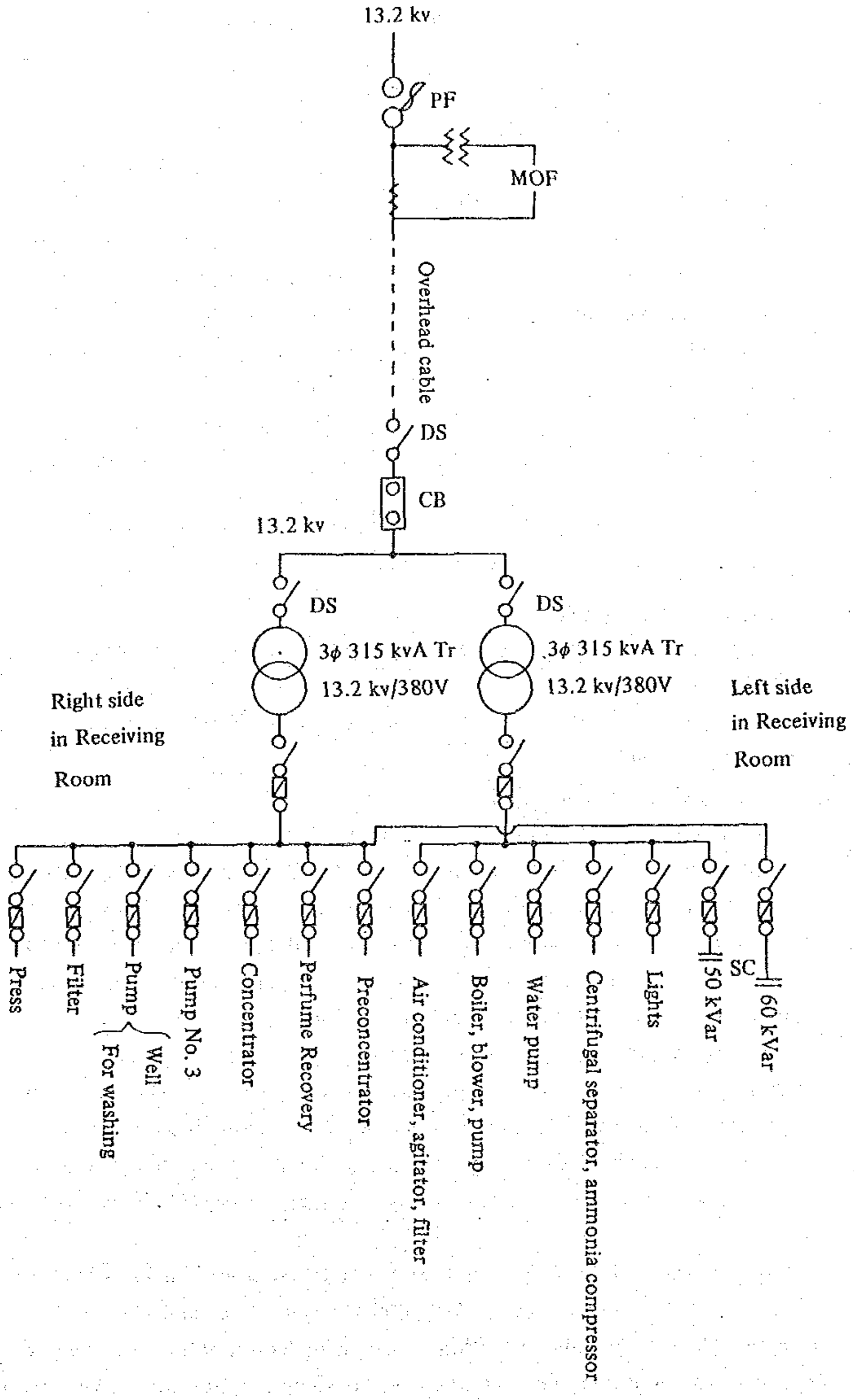


Figure 5–1–5 One line Diagram

(14) Major equipment

Table 5–1–6 Major Equipment

Name	Number	Specification
Crusher	1	50 Hp, Hammer Crusher
Press	2 X 3	Band Press
Perfume Evaporator	1	Monotubular, Jacket, Thin Film
Preconcentrator	1	Triple Effect, Surface Condenser
Centrifugal Separator	1	Continuous, 50 HP
Vacuum Filter	1	Oliver Type $15m^2$, Vac. Pump 30 HP X 2
Filter	2	Leaf
Filter Press	2	600 X 600, 700 X 700 mm
Concentrator	1	Triple Effect, Barometric Condenser
Boiler	1	10 t/h, 10 kg/cm^2
Transformer	2	13.2 kV/380V, 315 kVA

(15) Factory operating time

Production equipment: 20 hours/day X 120 days/year = 2400 hours/year

Boilers and other auxiliary equipment: 24 hours/day X 120 days/year = 2880 hours/year

5.1.2 Energy Management

(1) Energy Conservation Target

There was not set target for energy conservation.

The factory is located in the northern part of Patagonia, which is an energy producing area where preferential, low energy prices such as shown in Tables 5–1–4 and 5–1–5 are applied for regional development and industrialization. The energy expenses of the factory are lower than other factories in terms of percentage to cost according to the factory, gas accounting for 2.2% and electricity for 1.2%.

In response to the apple growers who own the factory, top priority is given to fully processing the apples that are brought into the factory over a specific period. Because the degree of squeezing apples is changed according to the crops, juice yield is not constant.

From these points of view, energy consumption is not regarded as an important item of management, and this is the reason why no target was set to improve energy conservation.

As shown in Table 5–1–3, however, energy consumption has been gradually increasing, and the factory pays US$100,000 for natural gas and electricity, an amount large enough to deserve due attention. Large energy consumption also means excess heat applied to the produced juice so that energy consumption must also be watched from the standpoint of quality control.

The first step to be taken for cost reduction is to determine the each individual factors constituting the cost and then set a target for improvement. In the case of this factory, which changes the degree of squeezing from year to year, it would be better to set a energy consumption target for each cases of juice/apple yield.

(2) Determining Energy Consumption

To improve the equipment and operations, it is essential to process data on production, quality, energy, etc. and accurately identify the existing conditions of the factory. Without data showing the relationships of operating conditions, production, quality, and energy consumption, it is not possible to pinpoint the problems and draw up a remedical plan for how to make improvements. If such data change in value, or if deviations occur from the planned values or design values, a clue to improvement could be obtained by checking for the cause. Therefore, measuring instruments should be installed at necessary points, their readings should be recorded and periodically processed to obtain the necessary information.

The factory records monthly energy consumption based on the numerical data printed on the slips that are sent from the gas and electric power companies according to the service meter readings. As it is, energy consumption can be known only afterward. Daily energy management involving appropriate measures based on actual energy consumption data can hardly be expected because such data is available only afterward. Just measuring energy consumption and showing it to the operators can stimulate a voluntary action for energy saving on the part of the operators.

This factory consumes heat energy as steam so that steam consumption can be determined by installing an integrating meter for water feed rate on the boiler water piping and recording it every hour. The recordings should be compared in terms of equipment, operating conditions, and production to determine the causes of energy waste. If the daily total amount of water supply and the gas consumption at the meter on the receving end are recorded in a boiler logbook, and are refered each other, boiler efficiency variations can be estimated.

It is strongly recommended that a boiler logbook be prepared and kept because it can be used for determining cleaning intervals from assumed uncleanliness of the heating surfaces based on data for variations of exhaust gas temperature, checking condensate recovery variations from water supply temperature over a long period of time, and is effective for not only energy conservation itself but also equipment maintenance.

The electric service meters are under the control of the electric power company, and therefore cannot be accessed, so install integrating meters on two low-voltage distribution boards and record electric power consumption daily.

(3) Engineer Education and Employee Training

Employees willing to make improvements cannot do so if they have no knowledge of how. It is important therefore to train the employees through training courses, for example.

The factory has only two engineers, so no special courses for their education. However, their technical level is improved by sending the engineers to the seminars provided by universities or associations, or through exchange of technical information with the U.S. customers

It must be noted that the factory undertakes a joint research on the ways of improving production techniques and the methods of measuring juice characteristics with four other juice companies at an INTI branch (CIATI), and has access to the latest technical information from abroad. In view of insufficient exchange of technical information in the whole juice industry, it is desirable that such an attempt as this joint research be spread across the country.

Most of the factory employees are temporarily hired for the operating period only. Therefore, there may not be sufficient time allowed for their training. It is important therefore to give them general precautions on steam leaks, saving of steam for sterilization, etc.; teach the way of handling energy through actual factory operations; call their attention to observe the work standard and keep the work place in order, and thus make them aware of the importance of energy conservation.

(4) Equipment Management

The factory operating period is about 100 to 120 days a year, and the facilities are kept in good order and clean because the factory processes food. According to the factory, electric parts are replaced as planned.

However, steam leaks from valves and faulty traps were found. Faulty valves and traps cannot be identified while the factory is out of operation, so it is necessary to put serial numbers on all the valves and traps, prepare a management logbook, file data on faults and repairs, and maintain the equipment while the factory is not run so that satisfactory factory operation may be started again. It is also necessary to file design calculation data, drawings, and modification history for the main facilities, as well as electric wiring diagrams because it will help make improvement in the future and deal quickly with accidents.

5.1.3 Problems with Use of Energy and Remedial Measures

5.1.3.1 Preconcentrator

(1) Specifications and Use of Preconcentrator

(a) The preconcentrator is a triple effect evaporator installed to boost the production capacity in 1986, and is used for the preconcentration of juice after perfume recovery. The design specifications of the preconcentrator are as follows:

Feed juice rate:	14,800 kg/hour
Feed juice brix:	9.2
Evaporation:	4,800 kg/hour
Concentrated juice:	10,000 kg/hour
Concentrated juice brix:	13.6
Steam used by first stage evaporator:	2,700 kg/hour
Concentrated juice temperature:	50°C
Evaporation ratio:	1.78

(b) Flow sheet

See Figure 5–1–6

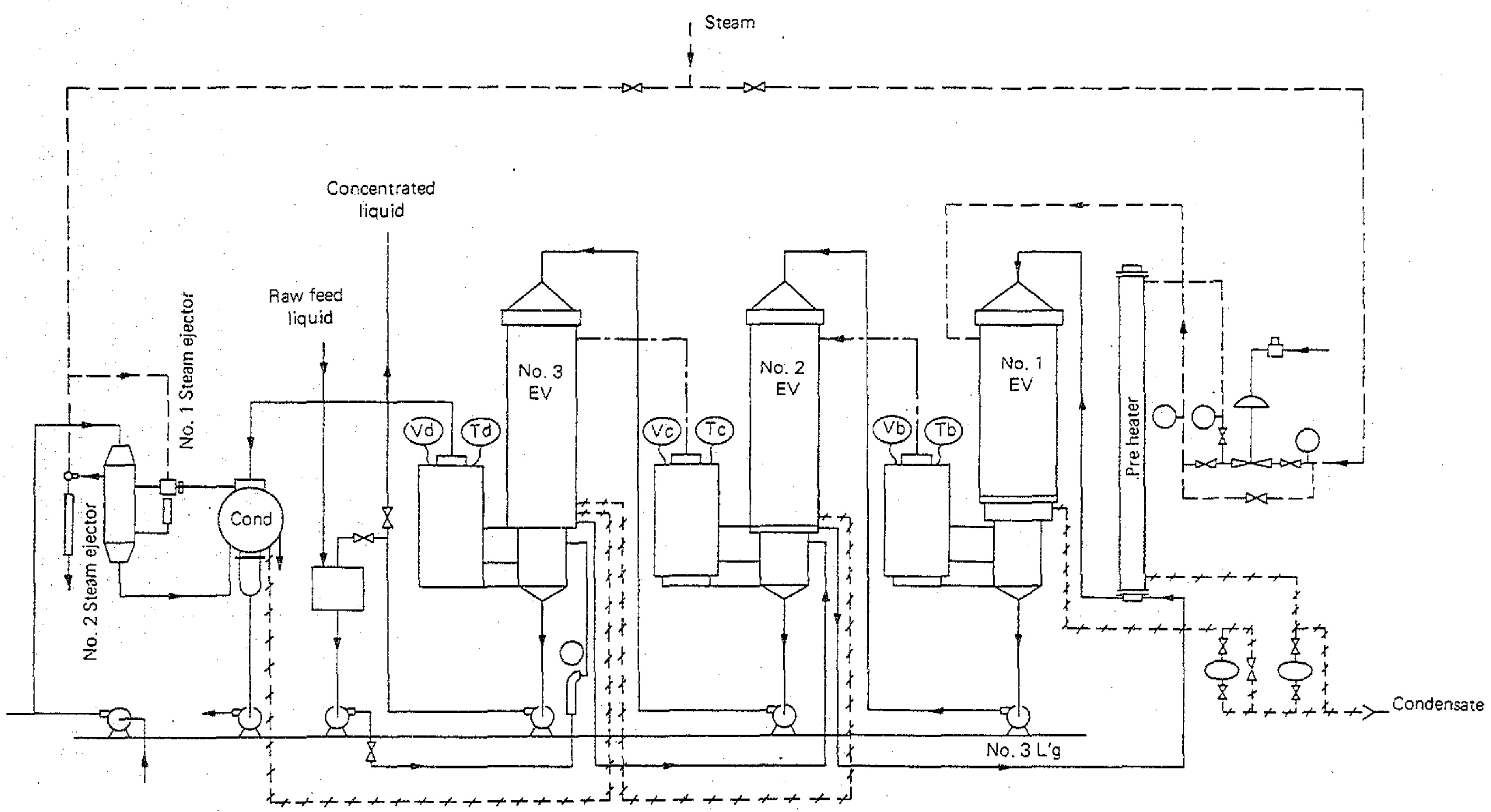


Figure 5–1–6 Preconcentrator

(c) Use

The preconcentrator is cleaned with water for four hours before start of operation daily for the purposes of the maintenance of the heating surface and sanitation management. Both the preconcentrator and concentrator are disassembled and cleaned once a month. In special cases, they are cleaned by circulating an alkaline solution.

(2) Heat Balance

(a) Measured values

To determine heat balance, the diagnostic measuring instruments that had been brought from Japan and the measuring instruments available in the factory were used to measure the steam consumption rate, juice flow rate, temperature and pressure at each stage, juice brix, and equipment surface temperature. Of the measured values, those in time zones in which temperature, etc. were relatively stable are shown in Table 5–1–7.

Table 5–1–7 Measured Values

Time	12:00	12:15	12:30	12:45	13:00	16:30	16:45	17:00	Average
Preheater inlet juice temperature	67.4	69.0	68.0	68.2	67.2	071.2	71.5	70.9	69.2
Steam temperature	106.3	107.7	108.3	105.9	105.5	106.5	105.1	107.7	106.6
First stage evaporator temperature	78.8	77.9	80.2	82.0	80.4	82.0	79.2	82.7	80.5
Second stage evaporator temperature	66.5	65.9	66.1	66.7	66.1	68.0	69.2	71.6	67.5
Third stage evaporator temperature	56.7	56.3	56.9	57.0	56.3	61.0	59.2	60.2	58.0

Steam pressure: 0.504 kg/cm^2

Steam consumption (including steam for preheater): 1,288 kg/hour

Juice flow rate: 13,900 liters/hour, 14,317 kg/hour

Juice brix: 10

The steam consumption rate was determined by measuring the amount of condensate. The ultrasonic flow meter is not effective for reading accurate juice flow rate, so it was determined by reading the rotameter in the factory. Juice brix was assumed to be 10.

(b) Heat radiation calculation

The amount of heat radiated from the surfaces of the evaporators was calculated from the measured surface temperatures. In calculating the above, the emissivity was taken as 0.4 because the evaporators are made of stainless steel, and the room temperature as 27°C without winds. The outer surface of the top cover was taken as an upward plane surface and the lower cone as a downard plane surface, and the others were taken as vertical plane surfaces in calculating the amount of heat radiation.

Table 5–1–8 Heat Radiation from Preconcentrator

Part	Surface area	First stage evaporator		Second stage evaporator		Third stage evaporator	
	m^2	Temperature	Heat radiation	Temperature	Heat radiation	Temperature	Heat radiation
Top cover	0.730	91°C	388 kcal/h	87	357	57	148
Calandria cylinder	5.737	47	666	92	2,966	57	1,102
Condensate heat exchanger	1.844	91	935	92	952	57	354
Lower cylinder	1.909	91	968	75	662	57	367
Lower cone	0.546	91	139	75	97	57	55
Evaporator	5.513	91	2,795	76	1,979	57	1,059
Joint *	5.698	91	2,889	76	2,046	57	1,094
Total	8,800				9,100		4,200
Grand total	22,100 kcal/h						

Note *: The surface area of one evaporator is 16.279 m^2, 35% of which was added as joint duct surface area.

Only the calandria cylinder of the first stage evaporator is heat-insulated, and its outer face plate is made of stainless steel. The heat insulation is about 30 mm thick.

(c) Heat balance

On the basis of the measurements thus obtained, the conditions for material balance and heat balance for each stage were calculated.

1) Material balance

Table 5–1–9 Material Balance

	Juice Flow	Juice Brix	Evaporation rate
Input	14,317 kg/h	10.0	#1 957 kg/h
#1 ~ #2	13,360 kg/h	10.7	#2 1,215 kg/h
#2 ~ #3	12,146 kg/h	11.8	#3 1,383 kg/h
Output	10,763 kg/h	13.3	

2) Heat balance

Table 5–1–10 Heat Balance

No.	Heat input		Heat output	
1	Steam Juice	686.5 Mcal/h 921.4	Vapor Juice Heat Loss	604.3 Mcal/h 994.8 8.8
	Total	1,607.9		1,607.9
2	Vapor Juice	604.3 994.8	Vapor Juice Heat Loss Condensate	760.8 752.2 9.1 77.0
	Total	1,599.1		1,599.1
3	Vapor Juice	760.8 752.2	Vapor Juice Heat Loss Condensate	860.8 566.1 4.2 82.0
	Total	1,513.0	Total	1,513.0

Note Heat of Vaporrization

Steam	533 kcal/kg
#1 Vapor	551.0 kcal/kg
#2 Vapor	558.8 kcal/kg
#3 Vapor	564.5 kcal/kg

3) Heat transfer coefficient of calandria

#1	812 kcal/(m² h°C)
#2	1,418 kcal/(m² h°C)
#3	2,498 kcal/(m² h°C)

4) Evaporation ratio

$$\text{Evaporation Ratio} = \frac{14{,}317.0\ \text{kg/h} - 10{,}763.0\ \text{kg/h}}{1{,}288\ \text{kg/h}} = 2.759$$

5) Observations of heat balance

The heat balance table shows that heat of input juice accounts for a large percentage of the heat input. Therefore, it is important for saving steam to prevent juice temperature from lowering during the process from the end of perfume recovery till the entry of juice into the preconcentrator.

The No. 2 and No. 3 evaporators show a reasonable heat transfer coefficient of calandria, but the No. 1 evaporator shows a rather low heat transfer coefficient, indicating that its heating surface is stained. More attention should be paid to cleaning the No. 1 evaporator because it is the first vessel to receive juice and is liable to be stained.

The evaporation ratio was satisfactory. Generally, the evaporation ratio of a triple effect evaporator is said to be about 2.4 to 2.8.

5.1.3.2 Concentrator

(1) Specifications of Concentrator

(a) The concentrator concentrates juice to a brix of about 70 after separating and starch from the huice. It is a part which is preheated by a plate heat exchanger using the hot water generated by steam heating, and another part which is preheated by steam using a double tube heat exchanger for sterilizing. The concentrating section is a triple effect type, and the heat exchanger is a plate type. Concentrated juice is cooled by reduced pressure flashing in the vessel cooled by an ammonia refrigerator, and is filtered again in the final stage before it is put into containers. The concentrator uses a barometric condenser for its vacuum system, while the preconcentrator uses a surface condenser.

(b) Flow sheet

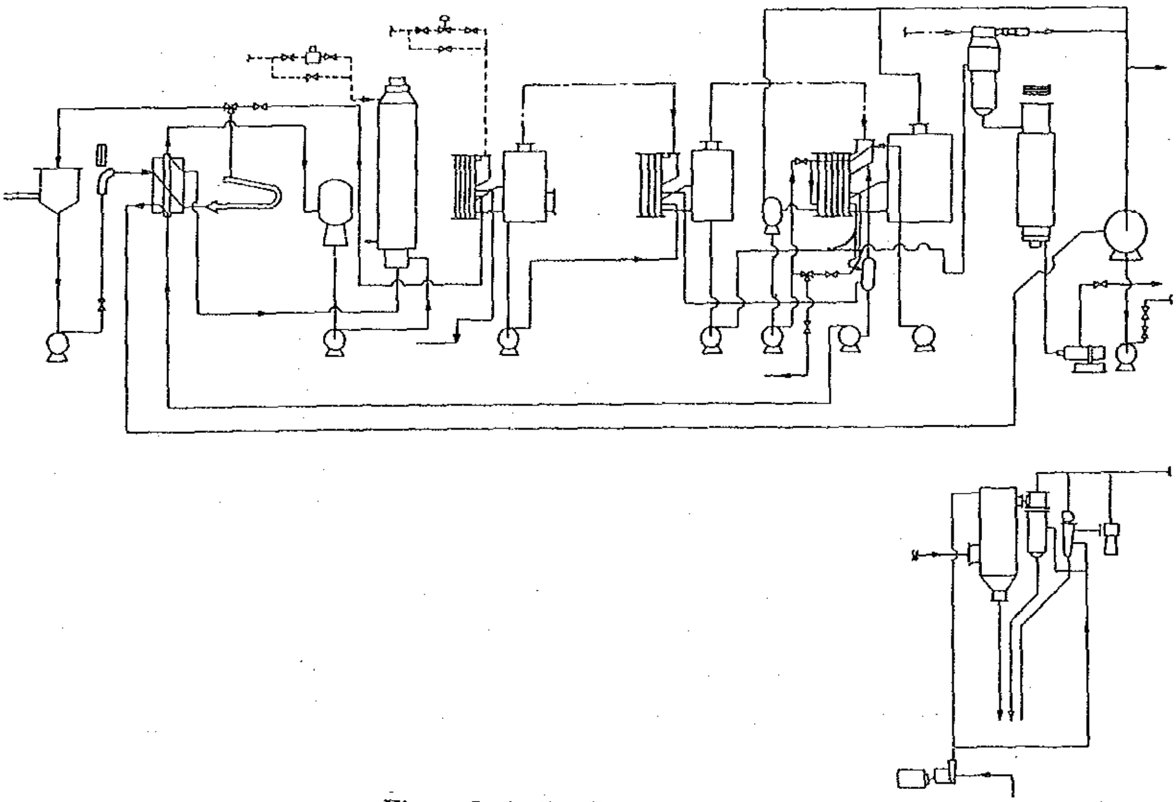


Figure 5–1–7 Concentrator

(c) Use

As in the case of the preconcentrator, the concentrator is cleaned with water for four hours before start of operation each day for the purposes of the maintenance of the heating surface and sanitation management

(2) Heat Balance

(a) Measured values

The concentrator was measured similar to the preconcentrator. The measuring results are shown in Table 5–1–11.

Table 5–1–11 Measured Values

Time	Juice temperature entering first stage evaporator	First stage evaporator temperature	Second stage evaporator temperature	Third stage evaporator temperature	Discharged condensate temperature
14:45	106.2	98.7	83.7	45.6	83.7
15:00	108.2	97.5	83.9	43.3	81.9
15:15	104.0	95.5	79.5	46.2	80.5
15:30	104.2	96.2	79.1	44.5	80.8
16:00	108.0	100.2	86.9	43.9	84.3
16:15	103.8	84.3	83.2	43.1	79.8
16:30	99.5	92.1	79.1	41.9	79.5
16:45	105.8	94.1	79.2	40.5	81.0
17:00	108.9	88.9	76.4	39.3	75.9
Average	105.4	95.3	81.2	43.1	80.8

Steam pressure:	(Preheater):	3.2 kg/ cm^2
	(First stage evaporator):	1.0 kg/ cm^2
Juice flow rate:		9,428 l/h
		9,805 kg/h
Juice brix	Input	13.2
	Output	71.5
Heater heating surface	#1	W 590 mm x H 1520 mm x 136 = 65.82 m^2
	#2	W 590 mm x H 1520 mm x 144 = 69.70 m^2
	#3	W 590 mm x H 1520 mm x 240 = 116.16 m^2

The steam consumption rate could not be measured because it exceeded the upper limit of the measuring instrument, and therefore was calculated instead. The juice flow rate was determined by reading the rotameter in the factory. Measured temperatures are shown in Table 5–1–11. As shown temperature variations were rather large.

(b) Heat radiation calculation

As in the case of the preconcentrator, the amount of heat radiation from the concentrator was calculated.

Table 5–1–12 Heat Radiation from Concentrator

Side	First stage evaporator			Second stage evaporator			Third stage evaporator		
	Temper-ature °C	Surface area m^2	Heat radia-tion kcal/h	Temper-ature °C	Surface area m^2	Heat radia-tion kcal/h	Temper-ature °C	Surface area m^2	Heat radia-tion kcal/h
Upward	97	1.898	1,134	83	1.929	862	47	3.081	373
Downward	97	1.992	572	83	1.025	435	47	3.177	200
Vertical	97	13.894	7,920	83	14.147	6,027	47	23.222	2,694
		17.782	9,600		18.101	7,300		29.480	3,300

The surface areas in the above table include the plate heat exchangers, evaporating section, and connecting pipes, but not the plate mounting bases and clamps.

(c) Heat balance

On the basis of the measurements thus obtained, the conditions for material balance and heat balance for each stage were calculated.

1) Material balance

Table 5–1–13 Material Balance

	Juice Flow	Juice Brix	Evaporation rate
Input	9,805 kg/h	13.2	#1 2,502 kg/h
#1 ~ #2	7,303 kg/h	17.7	#2 2,678 kg/h
#2 ~ #3	4,625 kg/h	28.0	#3 2,818 kg/h
Output	1,809 kg/h	71.5	

2) Heat balance

Table 5–1–14 Heat Balance

No	Heat input		Heat output	
1	Steam Juice	1,278.1 Mcal/h 938.0	Vapor Juice Heat Loss	1,594.8 Mcal/h 609.6 9.6
	Total	2,214.0		2,214.0
2	Vapor Juice	1,594.8 609.6	Vapor Juice Heat Loss Condensate	1,692.0 302.0 7.3 203.2
	Total	2,204.4		2,204.4
3	Vapor Juice Condensate	1,692.0 302.0 203.2	Vapor Juice Heat Loss Condensate	1,736.3 38.9 3.3 418.5
	Total	2,197.1		2,197.1

Note: Heat of Vaporrization

Steam	526 kcal/kg
#1 Vapor	542.1 kcal/kg
#2 Vapor	550.6 kcal/kg
#3 Vapor	573.5 kcal/kg

Steam consumption: 2,426 kg/h

3) Heat transfer coefficient of heat exchangers

#1	785 kcal/(m^2 h°C)
#2	1,380 kcal/(m^2 h°C)
#3	333 kcal/(m^2 h°C)

4) Evaporation ratio

The heat balance shown above applies to the first stage evaporator and downstream, not to the preheater and sterilizer. To calculate the evaporation ratio for all of the above, it is necessary to determine the steam consumed by the preheater and sterilizer.

Temperature of juice entering preheater:	32.6°C
Temperature of juice leaving preheater:	105.4°C
Juice flow rate:	9,805 kg/h
Juice specific heat:	0.9
Steam pressure:	3.2 kg/cm^2
Latent heat of steam evaporation:	508.5 kcal/kg
Preheater heat radiation loss:	Assumed as 5%

$$\frac{9{,}805 \text{ kg/h} \times (105.4 - 32.6°\text{C}) \times 0.9}{508.5 \text{ kcal/kg} \times 0.95} = 1{,}330 \text{ kg/h}$$

Therefore, the evaporation ratio will be as follows:

$$\text{Evaporation ratio} = \frac{9{,}805 \text{ kg/h} - 1{,}809 \text{ kg/h}}{2{,}426 \text{ kg/h} + 1{,}330 \text{ kg/h}} = 2.129.$$

5) Observations of heat balance

The individual stages are relatively well balanced in the evaporation rate, and have an evaporation ratio close to a common value, though it is slightly lower. All the heat exchangers, however, showed a rather low heat transfer coefficient, indicating that they might possibly be stained or clogged up.

A heat image of the third effect evaporator heat exchanger is attached hereto. As shown, only the temperature of the part near the inlet is high.

Figure 5–1–8 Concentrator Plate Heat Exchanger

5.1.3.3 Problems and Remedial Measures

(1) Reducing Heat Radiation

(a) Preconcentrator

The calandria cylinder of the first effect evaporator is heat-insulated, but all the others are exposed, causing heat radiation loss. The main body, evaporating section, and vapor duct must be heat-insulated.

The effects of heat insulation are calculated below.

If a heat insulation with rock wool (heat conductivity $\lambda = 0.0382$ kcal/mh°C) 25 mm thick is provided, the surface temperature can be lowered to 40°C. Apart from the parts that are already heat-insulated and that are too complicated to be heat-insulated, the heat insulation to the surface temperature of 40°C will reduce heat radiation as calculated below.

Table 5–1–15 Reduction of Heat Loss by Heat Insulation (kcal/h)

	Heat-insulated area	First stage evaporator		Second stage evaporator		Third stage evaporator	
	m²	Before heat insulation	After heat insulation	Before heat insulation	After heat insulation	Before heat insulation	After heat insulation
Calandria cylinder	5.737	Insulated		2,966	390	1,102	390
Lower cylinder	1.909	968	130	662	130	367	130
Lower cone	0.548	139	21	97	21	55	21
Evaporating section	5.513	2,795	375	1,979	375	1,059	375
Joint duct	5.698	2,889	387	2,046	387	1,094	387
Total	19.403	6,791	913	7,750	1,303	3,677	1,303
Reduction of heat loss by heat insulation		5,878		6,447		2,374	
Overall heat radiation after heat insulation		2,900		2,600		1,800	

Note: Surface temperature after heat insulation is to be 40°C.

For heat radiation before heat insulation, see Table 5–1–8.

The heat insulation of the preconcentrator will reduce heat loss by about 15,000 kcal/h in total, but the third stage evaporator will not produce much effect in reducing heat loss because its temperature is low.

Using the amounts of heat radiation from the first and second stage evaporators after their heat insulation and the same material balance and heat balance equations, steam consumption was calculated, assuming that juice flow rate and other conditions would be the same. The answer was 1,269 kg/h

Thus, the amount of steam saved by the proposed heat insulation will be:

1,288 kg/h – 1,269 kg/h = 19 kg/h

From the heat balance of the boiler, fuel consumption per kilogram of steam (at a steam pressure of 8 kg/cm²) will be 0.0807 m³/kg-steam.

Therefore, the annual saving of fuel will amount to:

0.0807 m³/kg-steam x 19 kg/h X 2,880 = 4,415 m³/year

For your reference, the time required to recover the investment is calculated as follows, using heat insulation cost and fuel price.

The area that needs heat insulation is as shown below.

First stage evaporator	13.666 m²
Second stage evaporator	19.403 m²
Total	33.069 m²

If the unit cost of heat insulation with rock wool 25 mm thick is 50 U$S/m² (provided that the external plate is made of aluminum 0.7 mm thick),

50 U$S/m² x 33.069 m² = 1,653 U$S.

Because the cost of natural gas is 0.041 U\$S/m^3, the annual saving will amount to:

0.041 U\$S/m^3 x 4,415 m^3/year = 181 U\$S/year.

Thus, the time required to recover the investment will be:

1,653 U\$S ÷ 181U\$S/year = 9.1 years

(b) Concentrator

It is difficult to heat-insulate the plate heat exchanger because it must be disassembled from time to time to clean it. The parts to be heat-insulated are the evaporating section, vapor ducts and pipings.

As in the case of the preconcentrator, reduction of heat loss by heat insulation with rock wool 25 mm thick (heat conductivity λ = 0.0382 kcal/(mh °C) except for the third stage evaporator whose temperature is low and the parts of complex shape was calculated as follows:

Table 5–1–16 Reduction of Heat Loss by Heat Insulation (kcal/h)

Side	First stage evaporator			Second stage evaporator		
	Heat-insulated area	Before heat insulation	After heat insulation	Heat-insulated area	Before heat insulation	After heat insulation
Upward	1.334m^2	797	95	1.334	596	95
Downward	1.430	410	54	1.430	307	54
Vertical	11.000	6,270	748	11.083	4,721	754
Total	13.764	7,477	897	13.847	5,624	903
Reduction in heat loss	6,580			4,721		
Total heat radiation after heat insulation	3,000			2,600		

Note: Surface temperature after heat insulation is to be 40°C.
For the amount of heat radiation before heat-insulation, see Table 5–1–12.

Using the amounts of heat radiation from the first and second stage evaporators after their heat insulation and the same material balance and heat balance equations, steam consumption was calculated, assuming that juice flow rate and other conditions would be the same. The answer was 2,407 kg/h

Thus, the amount of steam saved by the proposed heat insulation will be:

2,426 kg/h – 2,407 kg/h = 19 kg/h

From the heat balance of the boiler, fuel consumption per kilogram of steam (at a steam pressure of 8 kg/cm^2) will be 0.0807 m^3/kg-steam.

Therefore, the annual saving of fuel will amount to:

0.0807 m^3/kg-steam x 19 kg/h X 2,880 h = 4,415 m^3/year

The time required to recover the investment in heat insulation is calculated as follows.

The area that needs heat insulation is as shown below.

First stage evaporator	13.764 m^2
Second stage evaporator	13.847 m^2
Total	27.611 m^2

If the unit cost of heat insulation with rock wool 25 mm thick is 50 U$S/$m^2$ (provided that the external plate is made of aluminum 0.7 mm thick),

50 U$S x 27.611 m^2 = 1,381 U$S.

Because the cost of natural gas is 0.041 U$S/$m^3$, the annual saving will amount to:

0.041 U$S x 4,415 m^3/year = 181 U$S/year

Thus, the time required to recover the investment will be:

1,381 U$S ÷ 181 U$S/year = 7.6 years.

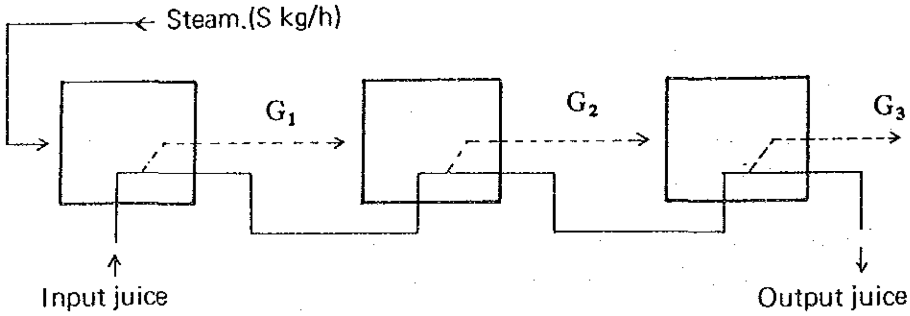
(c) Simple heat insulation method

This factory uses low-priced gas so that the economic advantage of heat insulation will decrease. In such a case, the simple method of covering the equipment with a hood made of lightweight sheet and thus heat-insulating it with the layer of hot air kept under the hood may be used to produce a considerable heat insulation effect.

(2) Saving Steam by Recycling Generated Steam

One of the methods of energy conservation for multi effect evaporator is to recycle the generated low-pressure vapor using a steam ejector, and thus save the steam.

(Present)



(Improvement by Steam Recycling)

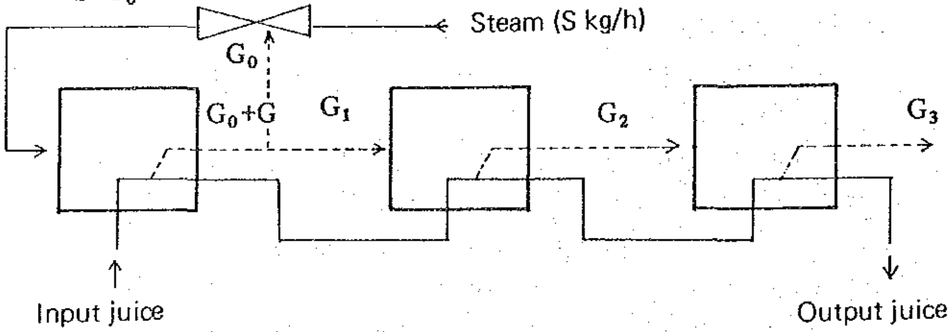


Figure 5–1–9 Multiple Effect Evaporator

Generally, part of the vapor generated in the first stage evaporator is pressurized by a steam ejector using heating steam, and circulated back to the first stage evaporator.

Theoretically, a triple effect evaporator may need only one-third of the amount of steam used by a single effect evaporator. If this method is used, however, the first effect evaporator will apparently serve as a double effect evaporator and the overall system will be equivalent to a quadruple effect evaporator, requiring only one-quarter of the steam now needed as expressed by the following equation.

Steam required by a triple effect evaporator:

If $S \doteqdot G_1 \doteqdot G_2 \doteqdot G_3$,

$S/(G_1 + G_2 + G_3) = S/3 \quad S = 1/3.$

Steam required for recirculation:

If $S \doteqdot G_0$,

$S/[(G_0 + G_1) + G_2 + G_3] = S/4 \quad S = 1/4.$

This factory reduces steam of 8 kg/cm^2 to 0.5 kg/cm^2 using a reducing valve, and uses the reduced-pressure steam for the preconcentrator. When drawing the vapor of 390 mmHg generated in the first stage evaporator with a steam ejector by use of that pressure difference, 1/3.1 of the steam can be drawn in. If the vapor generated in the first tage evaporator is to be recycled as much as 1/3.5 of the steam, the amount of steam producing the same juice flow rate and the same degree of concentration as in the heat balance calculation is calculated to be about 1,186 kg/h, which means the possibility of a 8% saving of steam over the present steam consumption. A steam saving of 170 kg/h can also be realized for the concentrator.

(3) Steam Ejector

(a) Change from steam ejector to water ejector

If the evaporation temperature of the final evaporator is about 45°C, the steam ejector can be changed to a water ejector to circulate water (30°C) through the cooling tower. Generally, the required amount of energy will fall to one-fifth.

Particularly, the steam ejector in the No. 2 stage of the preconcentrator should be considered in this regard because exhaust steam is discharged indoors.

(b) Change from steam ejector to vacuum pump

A motor-driven vacuum pump consumes about one-third as much energy as a steam ejector, but change from a steam ejector to a vacuum pump alone will not bring about so much cost advantage. It may be practical to consider such a chance when making major renovations of the equipment.

(c) Pulsation of extracted steam from the second steam ejector of preconcentrator

The extracted steam from the second steam ejector of the preconcentrator was observed to be pulsating. Variation of vacuum pressure can adversely affect the stability of operation.

The probable cause of this pulsation is faulty discharge of condensate from the No. 1 barometric condenser which cools the extracted steam from the No. 1 stage steam ejector. If that is the case, it is necessary to attach a condensate extraction nozzle to the bottom of the condenser as shown in Figure 5–1–10, and extract condensate using a centrifugal pump.

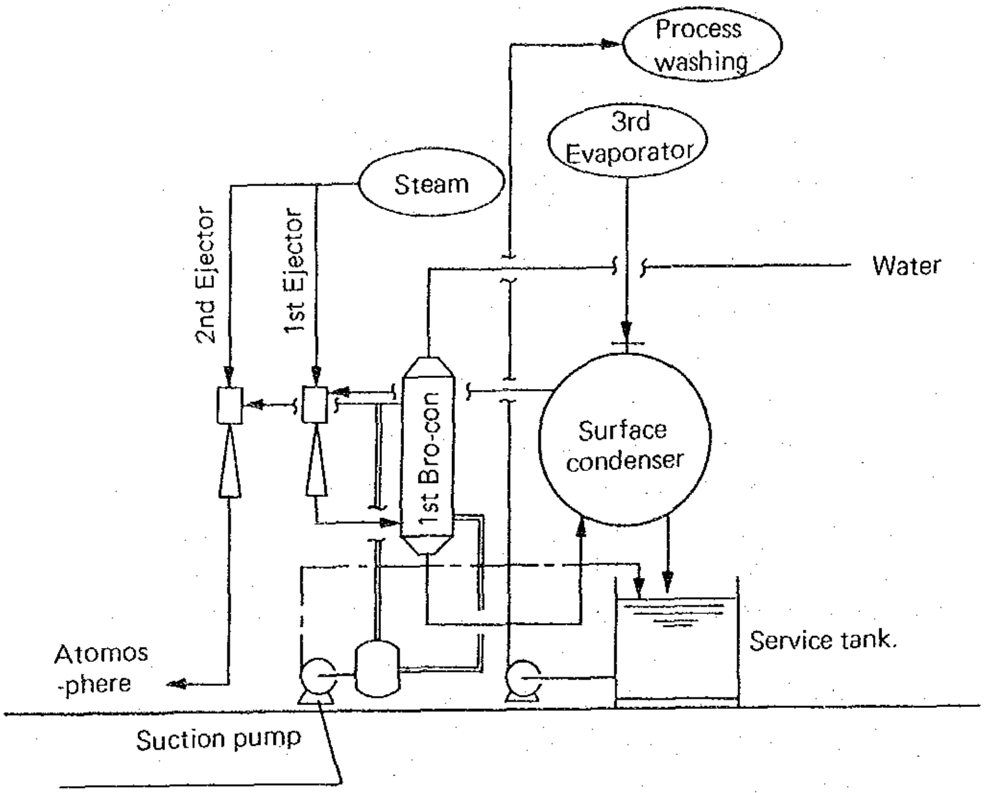


Figure 5–1–10

(d) Pulsation of barometric condenser of concentrator

The degree of vacuum in the barometric leg in the lower part of the barometric condenser for the concentrator was pulsating at intervals of a few minutes, causing variation of the temperature and pressure of the evaporators accordingly and thus disturbing the stability of operation. The seal was broken as a result with incidental overflow of water to excess. (3,000 ℓ/cycle)

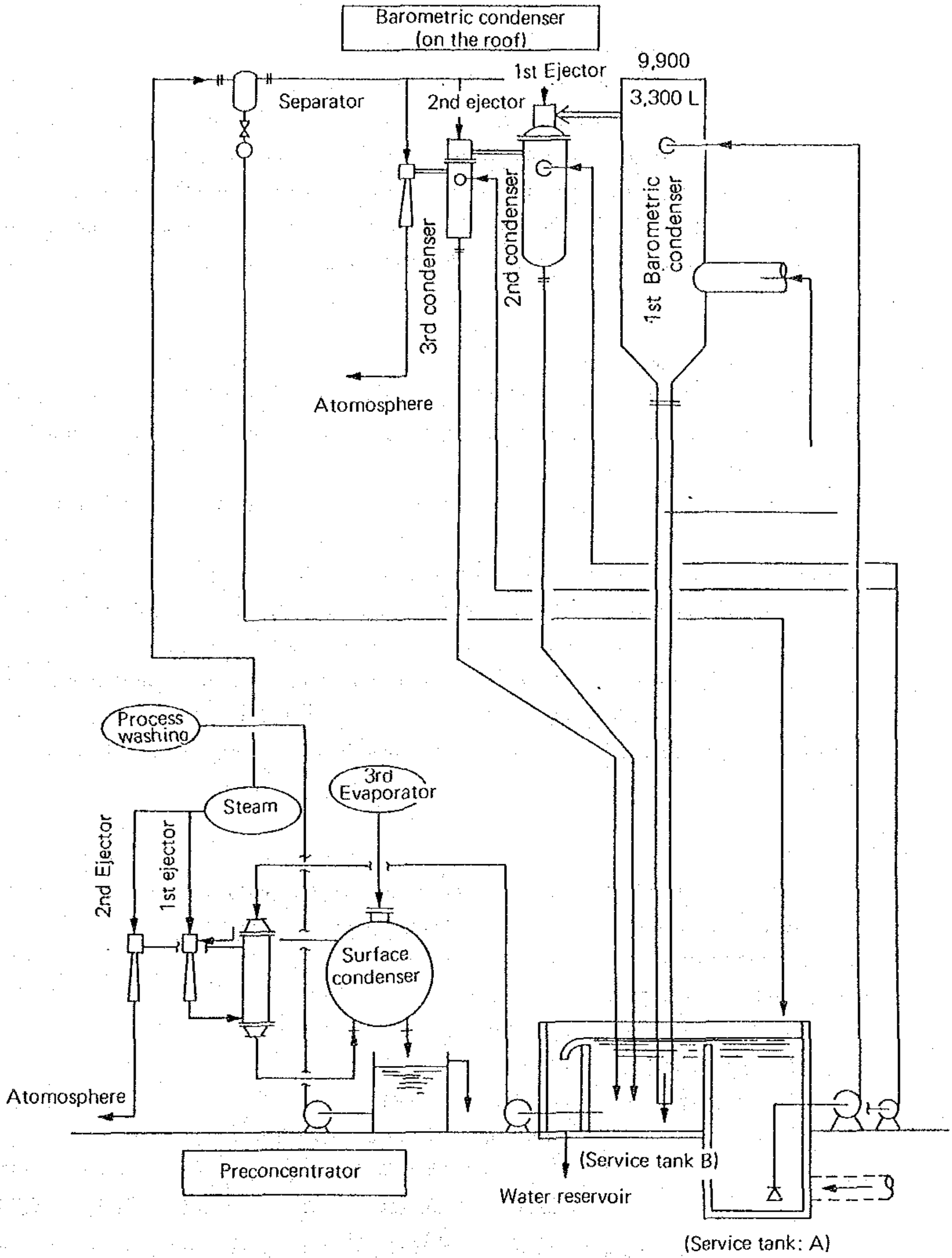


Figure 5–1–11 Flow Sheet of Vacuum Line

The probable cause is a broken tray in the No.2 barometric condenser, or blocking by scale or slime, or an enlarged hole in the steam ejector nozzle due to wear (pulsation occurs if the nozzle hole is enlarged by more than 10% of the design value.)

Generally, barometric condensers and steam ejectors must be checked and cleaned inside at least once every two years, and nozzles worn by 5% or more must be replaced with new ones.

(e) Daily management

Management instruments, that is, thermometers and pressure gauges for the barometric condensers and steam ejectors, must be installed to determine the present operating condition. Check recorded operation data about once every month, and prepare graphs, if possible, by plotting the data so that anything abnormal can be detected in time. Particularly, equipment degradation and air leaks can be detected early by recording the time required to reach the specified degree of vacuum after the start of operation and managing the trends of that time.

(4) Installing Steam Trap

The plate heat exchanger for the first stage evaporator of the concentrator uses neoprene packing, and the steam trap was removed for reasons that the steam would leak if the steam pressure was high.

Therefore, the steam was discharged without condensation, resulting in loss of the most of the heat possessed by the steam. The heat transfer coefficient on the dry surface is low relative to heat transfer with condensation, resulting in a lowered heating capacity.

It is suggested that a steam trap of mechanical type (for example, float type) which operates well even if differential pressure is low be selected and installed.

It may be noted that steam is used better at lower pressure. Considering that the first effect evaporator has an ample heating surface, it would be better to lower the steam pressure (to less than 1 kg/cm^2) within the range in which a temperature difference can be ensured.

5.1.3.4 Boiler

The steam supplied from the boiler is used as an energy source for the perfume recovery unit, preconcentrator, and concentrator, and plays an important role in the production process.

(1) Boiler specifications

Type:	3-pass flue and smoke tube boiler				
Evaporation rate:	10 tons/h				
Steam pressure:	10 kg/cm^{2}G (rated)				
Fuel:	Natural gas (H1 = 9,274 kcal/Nm^3)				
	CH_4 = 88.36%		C_2H_6 = 5.67%		C_3H_8 = 2.40%
	i-C_4H_{10} = 0.35%		n-C_4H_{10} = 0.73%		i-C_5H_{12} = 0.20%
	n-C_5H_{12} = 0.18%		C_6H_{14} = 0.10%		N_2 = 1.52%
	CO_2 = 0.49%				
Heating surface:	260 m^2				
Year of manufacture:	1976				
Structure:	As shown in Figure 5–1–12				

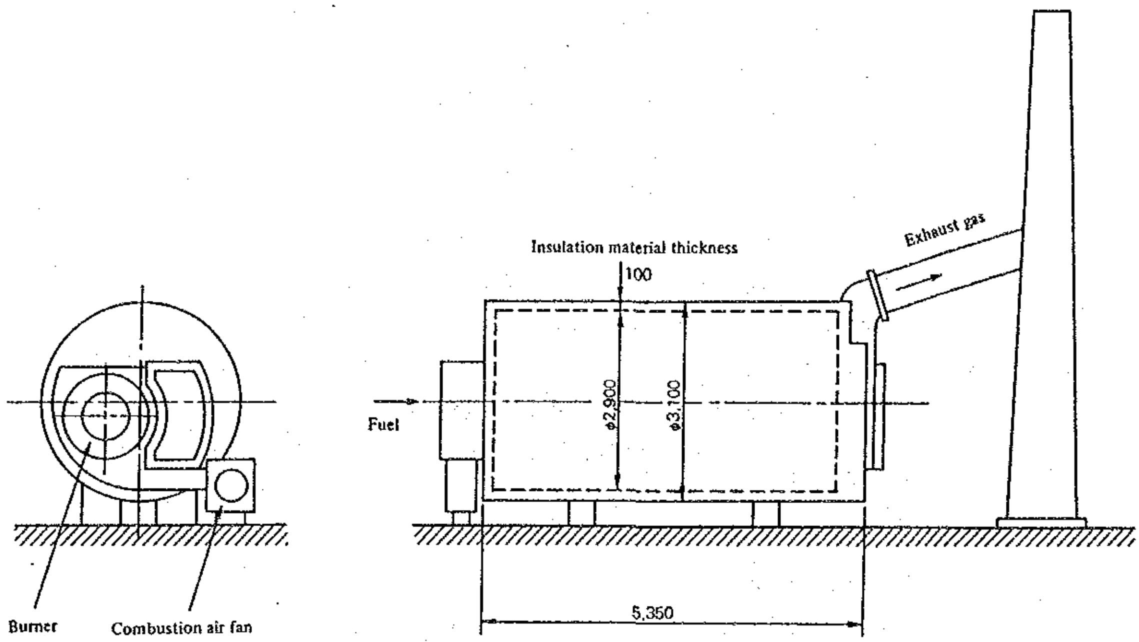


Figure 5–1–12 Boiler Structure

(2) Survey Items and Collected Data

The boiler was surveyed twice, once on March 15, 1988 and the other time on March 18. On March 18, data could not be collected because of power failure.

The survey involved measurements by both of the instruments that had been brought by the Japanese team and the meters mounted on the boiler, and observation of operating condition.

(a) The data collected by use of the instruments and meters are as follows. The measuring points are shown in Figure 5–1–13.

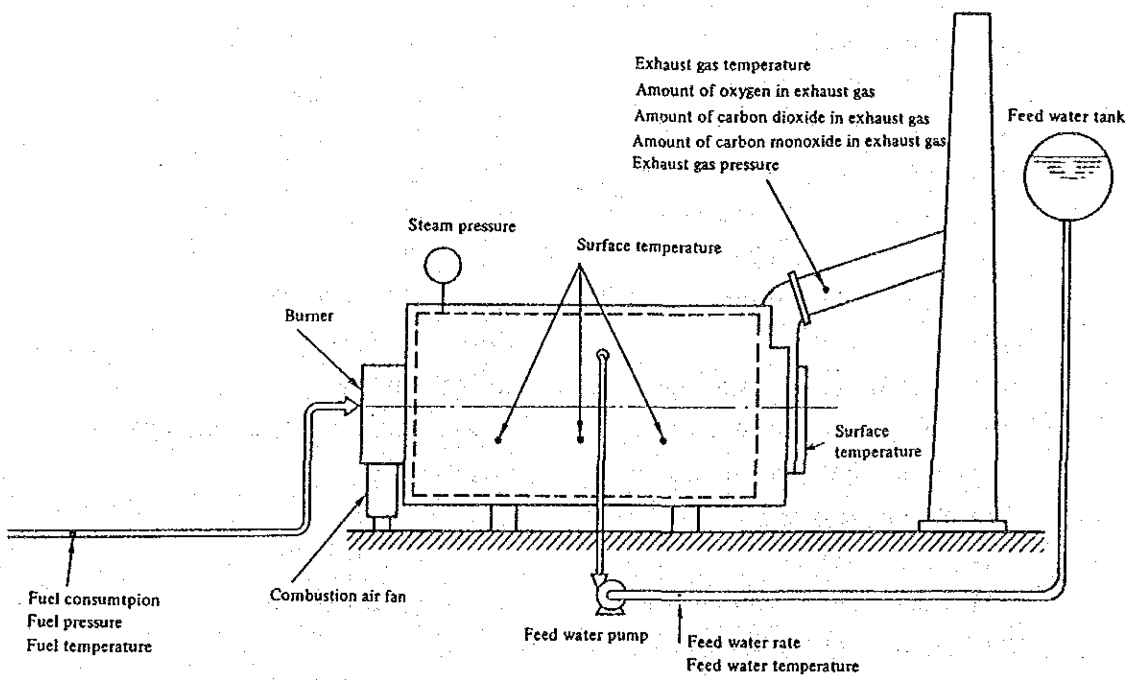


Figure 5–1–13 Boiler Measuring Points

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

(b) Observation items are as follows:
1) Combustion
2) Control method of combustion and water supply
3) Boiler casing and piping heat insulation
4) Steam leaks
5) Equipment maintenance

(3) Boiler Heat Balance

(a) Boiler heat balance was determined on the basis of data for 14:00 to 15:30 on March 15. The details of the data are as follows:

1)	Kind of fuel:		Natural gas
2)	Fuel consumption	(Ef)	281 m^3/h at 1.80 kg/cm^2 G, 23°C
3)	Fuel consumption (Standard state)	(Efn)	725.7 Nm^3/h
4)	Heating value (low level)	(H1)	9.274 kcal/Nm^3
5)	Fuel specific gravity (Air = 1.0)	(Sgf)	0.634
6)	Fuel specific heat	(Cp)	0.39 kcal (Nm^3°C)
7)	Fuel temperature	(Tf)	28°C
8)	Ambient temperature	(To)	30°C
9)	Combustion air temperature	(Ta)	33°C
10)	Fuel air specific heat	(Cp')	0.31 kcal (Nm^3°C)
11)	O_2 % in dry exhaust gas	(O_2)	7.9% (Figure 5–1–15)
12)	CO_2 % in dry exhaust gas	(CO_2)	6.2% (Figure 5–1–16)
13)	CO% in dry exhaust gas	(CO)	0 (Fiugre 5–1–17)
14)	Exhaust gas specific heat	(Cpg)	0.33 kcal (Nm^3°C)
15)	Exhaust gas temperature	(Tg)	206°C
16)	Exhaust gas pressure	(Pg)	-3.8 mmH_2O
17)	Blow water	(Fb)	0 m^3/h
18)	Feed water rate (Volume)	(Fwv)	9.077 m^3/h
19)	Feed water rate (Weight)	(Fww)	9.077/0.00101259 = 8,964 kg/h
20)	Feed water temperature	(Tw)	52°C
21)	Steam pressure	(Ps)	8 kg/cm^2 G
22)	Steam enthalpy	(h")	661.93 kcal/kg
23)	Feed water enthalpy	(h')	51.98 kcal/kg
24)	Amount of theoretical combustion air	(Ao)	10.47 Nm^3/Nm^3 – fuel

25) Amount of theoretical wet exhaust gas (Go) 11.55 Nm^3/Nm^3 – fuel

26) Air ratio (m) 1.60

27) Actual amount of wet exhaust gas (G) 17.83 Nm^3/Nm^3 – fuel

(b) Heat input

Heat input per Nm^3 of fuel was calculated.

1) Heat of comustion (H1)

$H1 = 9{,}274$ kcal/Nm^3

2) Sensible heat of fuel (Qs)

$Qs = Cp \times (Tf - To) = 0.390 \times (28 - 30) = -0.78$ kcal/Nm^3

3) Sensible heat of combustion air (Qa)

$Qa = Cp' \times m \times Ao \times (Ta - To) = 0.31 \times 1.60 \times 10.47 \times (33 - 30) = 15.58$ kcal/Nm^3

4) Heat input total (Qi)

$Qi = H1 + Qs + Qa = 9{,}274 - 0.78 + 15.58 = 9{,}288.80$ kcal/Nm^3

(c) Heat output

Heat output per Nm^3 of fuel was calculated.

1) Heat content of steam (Qv)

$$Qv = \frac{Fww}{Ffn} \times (h'' - h') = \frac{8.964}{725.7} \times (661.93 - 51.98) = 7534.23 \text{ kcal/Nm}^3$$

2) Heat taken away by exhaust gas (Qg)

$Qg = G \times Cpg \times (Tf - To) = 17.83 \times 0.33 \times (206 - 30) = 1{,}035.57$ kcal/Nm^3

3) Heat radiated from boiler casing (Qr)

$$Qr = \frac{1{,}400 \times 7.5 + 1{,}500 \times 7.5 + 150 \times 50}{725.7} = 40.31 \text{ kcal/Nm}^3$$

Average temperature and surface area of front plate: 131°C, 7.5 m^2

Average temperature and surface area of rear plate: 137°C, 7.5 m^2

Average temperature and surface area of shell plate: 47°C, 50.0 m^2

4) Other heat loss (Qm)

$Qm = 678.69$ kcal/Nm^3

5) Heat output total (Qo)

$Qo = Qv + Qg + Qr + Qm = 7{,}534.23 + 1{,}035.57 + 40.31 + 678.69 = 9{,}288.80$ kcal/Nm^3

(d) Heat balance table

The above are summarized as shown in Table 5–1–17

Table 5–1–17 Boiler Heat Balance

Heat input			Heat output		
Item	kcal/Nm³	%	Item	kcal/Nm³	%
Combustion heat of fuel	9,274.00	99.84	Heat content of steam	7,534.23	81.11
Sensible heat of fuel	-0.78	-0.01	Heat taken away by exhaust gas	1,035.57	11.15
Sensible heat of combustion air	15.58	0.17	Heat radiated from boiler casing	40.31	0.43
			Other heat loss	678.69	7.31
Total	9,288.80	100.00	Total	9,288.80	100.00

(4) Problems and Remedies

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

One of the methods of reducing the amount of heat taken away by exhaust gas is to reduce the amount of exhaust gas itself. This can be achieved by adjusting combustion air for fuel to the proper amount. The ratio of the actual amount of air to the amount of air theoretically required for burning fuel is called for air ratio, which can usually be obtained by measuring the amount of oxygen in exhaust gas. The present amount of oxygen in exhaust gas is 7.9% and the air ratio is 1.60. If the amount of oxygen in exhaust gas is reduced to 4.5%, th air ratio will be 1.27, which will result in reducing the amount of exhaust gas by about 20%.

Reducing the amount of air can be attained by the adjustment of the opening of the air intake damper for the combustion air fan. This adjustment does not require installation of additional devices so that no direct investment is needed.

Table 5-1-18 Reducing the Amount of Heat Taken Away by Exhaust Gas by Improving the Air Ratio

No.	Item		Unit	Present (a)	Improved (i)
1	Amount of oxygen in exhaust gas		%	7.9	4.5
2	Air ratio	m		1.60	1.27
3	Amount of theoretical combustion air	Ao	Nm^3/Nm^3	10.47	10.47
4	Amount of theoretical exhaust gas	Go	Nm^3/Nm^3	11.55	11.55
5	Actual amount of air	A	Nm^3/Nm^3	16.75	13.30
6	Actual amount of exhaust gas	G	Nm^3/Nm^3	17.83	14.67
7	Exhaust gas temperature	tg	°C	206	206
8	Heat taken away by exhaust gas	Qg	$kcal/Nm^3$	1,035.57	852.03

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

$$S = 1 - \frac{Hi - Qga}{Hi - Qgi} = 1 - \frac{9,288.8 - 1,035.57}{9,288.8 - 852.03} = 0.0217 = 2.17\%$$

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

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

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

The amount of yearly saving can be calculated from the annual fuel consumption of 1,529,000 m^3 as follows:

1,529,000 m^3/year x 0.0217 x 0.04 US$/$m^3$ = 1,327 US$/year

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

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

The factory recovers condensate, and feed water temperature is from 50°C to 60°C so that a further rise in feed water temperature by waste heat recovery is not so significant. If a further rise in feed water temperatur is desired, it would be better to study ways of increasing the efficiency of condensate recovery.

The boiler's exhaust gas temperature is 206°C so that it is not normally necessary to lower exhaust gas temperature any more. However, because the fuel is natural gas, it does not contain sulfur compounds or other substances that are corrosive to metals, and exhaust gas temperature can be further lowered. Therefore, fuel saving by preheating combustion air is studied.

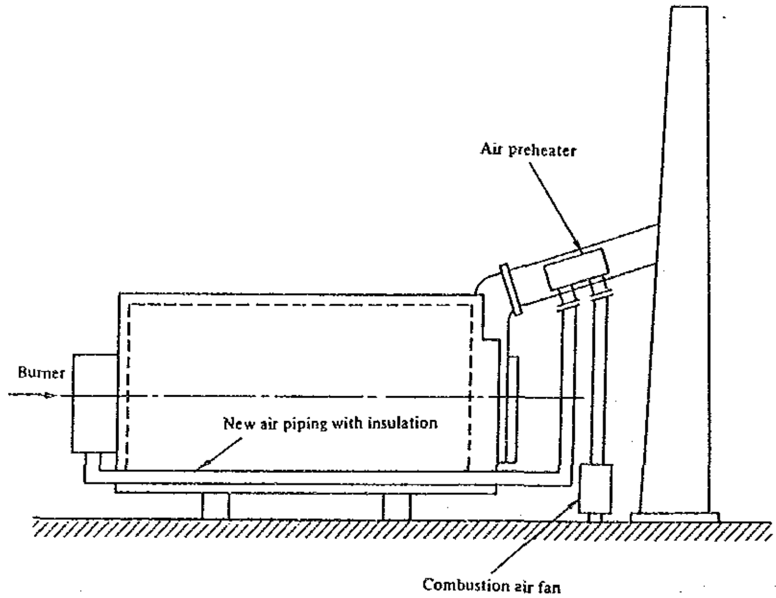


Figure 5–1–14 Position of Installing Air Preheater

The fuel saving rate (S) can be calculated by the following equation.

$$S = \frac{P}{Hi - Qg + P}$$

where P: Heating value brought in by preheated air (kcal/Nm^3);

Hi: Amount of heat input per Nm^3 of fuel (kcal/Nm^3);

Qg: Amount of heat taken away by combustion gas (kcal/Nm^3).

If combustion air preheated to 70°C after improving the air ratio, fuel saving will amount as follows:

$$P = 1.27 \times 10.47 \times 0.31 \times (70 - 33) = 152.51 \text{ kcal/Nm}^3$$

$$S = \frac{152.51}{9.288.8 - 852.03 + 152.51} \times 100 = 1.84\%$$

The amount of fuel saving calculated from the annual fuel consumption of 1,529,000 m^3 is as follows:

1,529,000 m^3/year X 0.0184 X 0.04 US$/m^3 = 1,125 US$/year

It costs about US$20,000 to install an air preheater in Japan. Before making this modification, therefore, it is necessary to carefully study economic effects.

(c) Reducing the heat radiated by boiler casing, etc.

As for heat radiation from the boiler casing, the shell is well heat-insulated with a surface temperature of 45 to 50°C. However, the heat insulation of the front plate around the burner and smoke tube rear plate is not quite satisfactory because their surface tempeature is 130 to 150°C. The front plate and rear plate are lined with a thin insulating material perhaps because they have to be opened when cleaning the smoke tube. If they are lined with a thicker insulating material to lower their surface temperature to 80°C, dissipated heat can be reduced as follows:

$$(1{,}800 - 600)\ \text{kcal/h·m}^2 \times 7.5\ \text{m}^2 \times 2 = 18{,}000\ \text{kcal/h}.$$

The resulting amount of fuel saving per annum will be as follows:

$$\frac{18{,}000\ \text{kcal/h}}{9{,}288.8\ \text{kcal/m}^3} \times 120\ \text{days/year} \times 24\ \text{h/day} \times 0.04\ \text{US\\$/m}^3 = 223\ \text{US\\$/year}$$

If the front and rear plates are lined with a thicker insulating material at the next maintenance time, there will be little increase in expenses.

(d) Control of the air ratio during combustion at high and low rate

The boiler used two combustion positions – high and low – and the combustion characteristics at these positions are as Figure 5–1–15, 16 and 17.

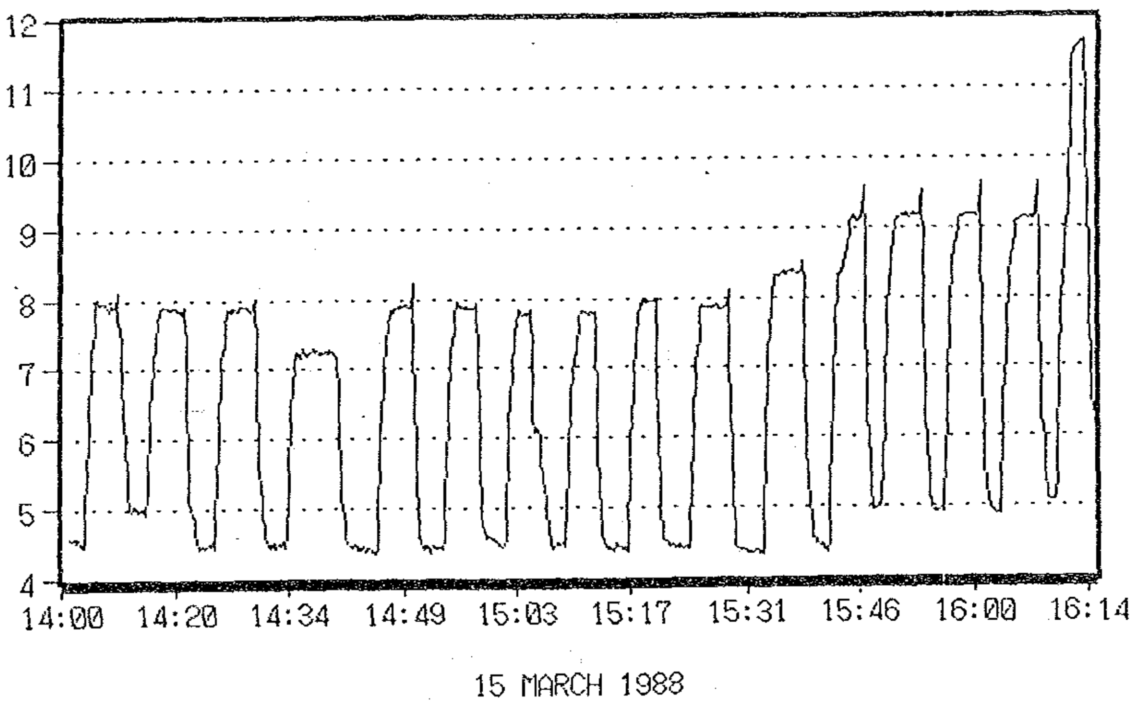


Figure 5–1–15 Amount of Oxygen in Exhaust Gas (%)

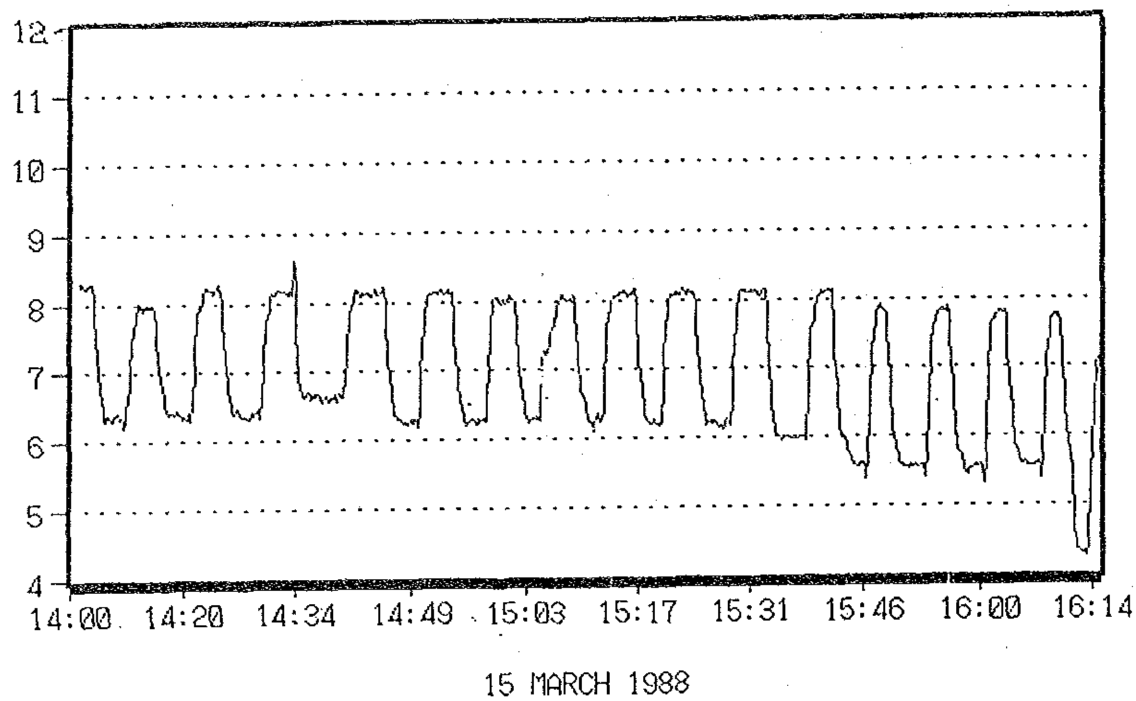


Figure 5–1–16 Amount of Carbon Dioxide in Exhaust Gas (%)

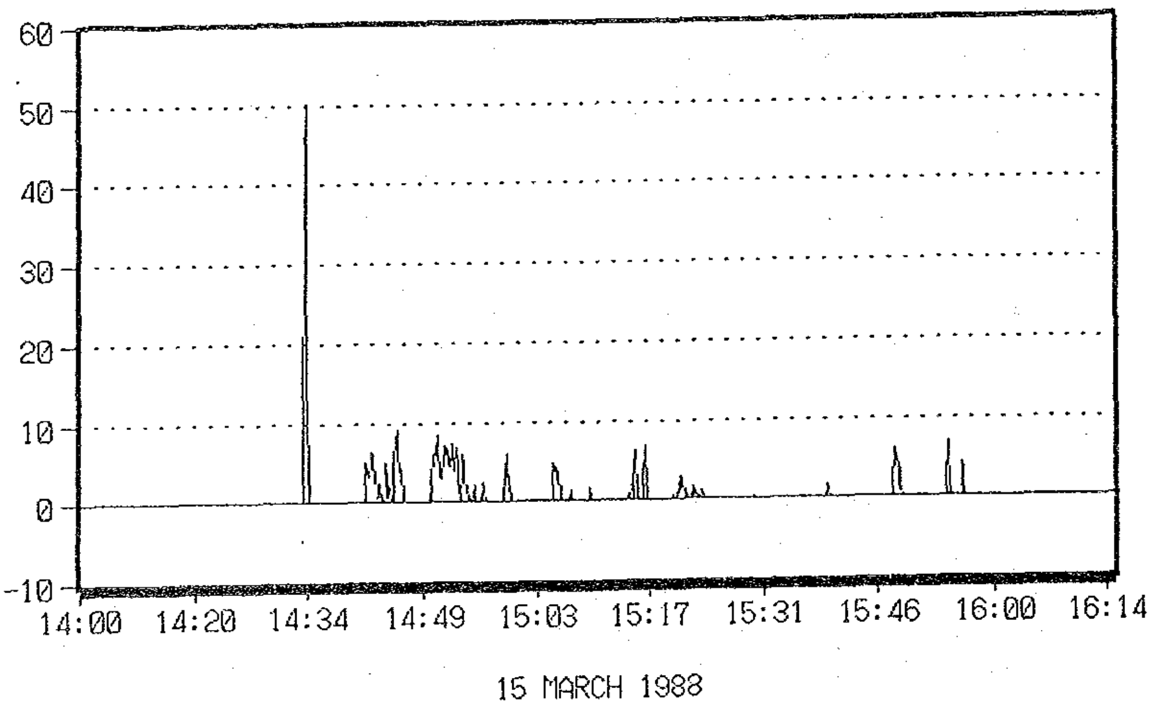


Figure 5–1–17 Amount of Carbon Monoxide in Exhaust Gas (PPM)

Table 5–1–19 Characteristics at High/Low Combustion

Item	High	Low
Exhaust gas temperature	215 to 220°C	195 to 205°C
Oxygen concentration in exhaust gas	4.5 to 6%	8 to 12%
Carbon dioxide concentration in exhaust gas	7 to 8%	4.5 to 6%
Carbon monoxide concentration in exhaust gas	0 to 500 ppm	0 ppm
Exhaust gas pressure	-5 mmH2O	-3 mmH2O

As shown in Table 5–1–19, oxygen concentration is high during low combustion, so energy can be saved by reducing the amount of combustion air. The combustion control method such as used for this boiler is common, and oxygen concentration in exhaust gas during low combustion is normally 5 to 6%, which is considerably lower than the oxygen concentration in exhaust gas from the boiler in this factory. It is recommended that the damper on the intake side of the combustion air fan be slightly closed to reduce the amount of combustion air. Carbon monoxide was found during high combustion, so it is necessary to enforce careful management by adjusting the burner tip, etc. to ensure perfect combustion of the fuel. If gas is used as fuel, oxygen concentration of about 3% in exhaust gas normally means no generation of carbon monoxide.

(e) Feed water quality management

The quality of feed water and boiler water was as shown in Table 5–1–20.

Table 5–1–20 Quality of Feed Water and Boiler Water

Measurement	Feed water			Boiler water		
	Temperature	pH	Electric conductivity	Temperature	pH	Electric conductivity
First time	46.4°C	8.22	14.83 mS/cm	49.6°C	11.13	>20 mS/cm
Second time	50.8°C	7.72	19.85 mS/cm	49.5°C	11.13	>20 mS/cm
Reference value	25°C	7 – 9	–	25°C	11 – 11.8	<4.5 mS/cm

Both the feed water and boiler water showed abnormally high electric conductivity, which means the water contains a large amount of impurities and causes to shorted boiler life.

If the electric conductivity of feed water is high, boiler water will also have high electric conductivity. Therefore, feed water quality must be thoroughly controlled. This factory employs a water softener to improve water quality and condensate recovery. To identify the cause of the abnormally high electric conductivity of feed water, it is necessary to check both the performance of the water softener and the quality of condensate.

Water quality adjustment by boiler water blow will not only be ineffective in this case but also cause energy loss.

5.1.3.5 Steam Line

(1) Steam leaks

(A) Evaluation of present state

(a) There were very many steam leaking points over the entire steam line. Steam leaking points are indicated by the mark * in the piping diagram of Figure 5–1–18. Large leaking points are indicated by double marks **.

(b) Maintenance is performed altogether in the period of non production. Information on current leaking points and the degree of leakage may be lost before maintenance time, making proper maintenance impossible.

It is suggested that serial numbers be marked on the existing leaking points and detailed information be recorded in a book for later use in repair.

(c) Loss from leaks

Quantitative evaluation of the amount of existing steam leaks is difficult, but approximate values can be obtained as follows: Assuming that total of all the existing leaking point clearances correspond to a hole 5 mm in diameter, according to use the Figure 5–1–19 the amount of leaking steam at a steam pressure of 1 kg/cm^2G can be calculated to be 22 kg/h. If coefficient of discharge is 0.8, the actual rate of blowing steam will be about 17 kg/h. If annual operation time is 2,880 h, annual steam loss will amount to 49 tons.

Blowout from leaking points will be faster than sound velocity, naturally causing wear and further increase in leakage.

The boiler safety valve and the rotary shaft of the perfume recovery evaporator must be repaired as soon as possible. Otherwise, repair expenses will increase.

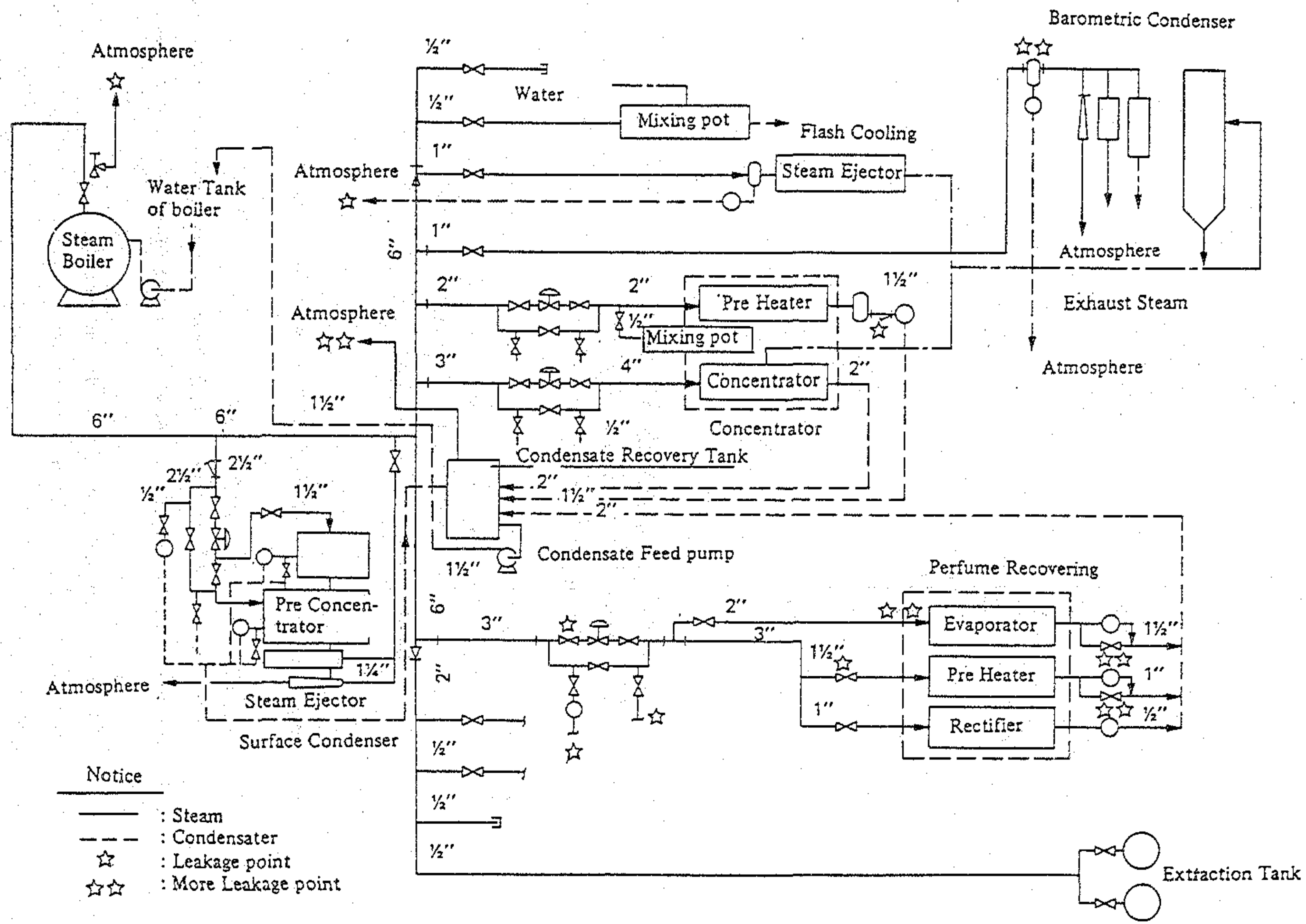
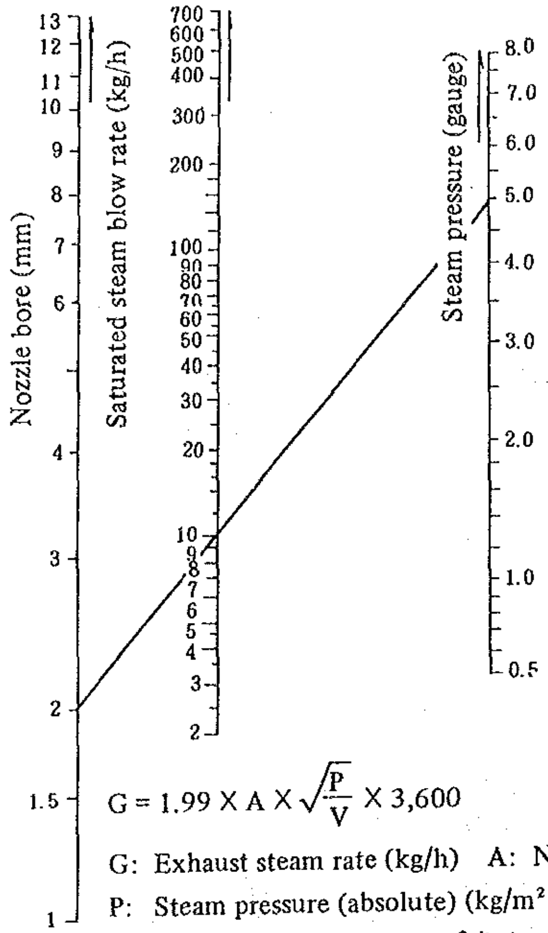


Figure 5–1–18 Steam & Condensate Flow Sheet



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

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

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

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

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

Figure 5–1–19 Nozzle Diameter and Steam Injection Rate

(2) Amount of Heat Radiation from Bare Parts

A) The piping, valves, and flanges up to the first valve of each unit that were bare but should normally be heat-insulated were measured to determine their heat dissipation area.

B) The following are common parts that are not heat-insulated.

(a) The valve and flange of the pressure regulating valve unit, and the connecting pipes around them.

(b) Steam pipes connected to the two ejectors of concentrator and all the outdoor pipes

C) The bare heat dissipating parts of the piping can be classified by function as follows: 58% pipes; 31% valves; 11% flanges and others. See Table 5–1–21.

D) In reference to the heat radiation area shown in Table 5–1–21, heat loss from the piping and the effect of heat insulation were calculated. The results are shown in

Table 5–1–21 **Survey Results of Bare Parts of Steam Pipes (Surface area calculated according to ECC Energy Conservation Data Sheets.)**

Process	Type	Size (B)	Actual Quantity Pipe(m)	Actual Quantity Quantity	Length (m) @	Length (m) Total length	Surface area(m^2) Per meter	Surface area(m^2) Total	Remarks
Preconcentrator	Pipe	6	4.5	–	–	–	0.518	2.33	
		2½	2	–	–	–	0.239	0.48	
		1½	3.5	–	–	–	0.152	0.53	
	Globe valve	4	–	1	1.20	1.20	0.359	0.43	
		2½	–	2	1.16	2.32	0.239	0.55	
	Reducing valve	2½	–	1	1.54	1.54	0.239	0.37	
	Flange	6	–	1	0.44	0.44	0.518	0.22	
		3	–	1	0.42	0.42	0.280	0.12	
	Subtotal							5.03	
Perfume recovery	Pipe	3	1.5				0.280	0.41	
		2	5				0.190	0.95	
		1½	10				0.152	1.52	
	Globe valve	3		3	1.31	3.93	0.280	1.10	
		2		1	1.22	1.22	0.190	0.23	
		1½		1	1.31	1.31	0.152	0.20	
	Reducing valve	3		1	1.53	1.53	0.280	0.43	
	Flange	3		2	0.42	0.84	0.190	0.16	
	Subtotal							5.01	
Concentrator	Pipe	4	9				0.359	3.23	
		3	1				0.280	0.28	
		2	1				0.190	0.19	
	Globe valve	3		3	1.31	3.93	0.280	1.10	
		2		3	1.22	3.66	0.190	0.69	
	Reducing valve	3		1	1.	1.53	0.280	0.43	
		1½		1	1.	1.58	0.152	0.24	
	Flange	4		1	0.39	0.39	0.359	0.14	
		3		2	0.42	0.84	0.280	0.23	
		2		1	0.44	0.44	0.190	0.08	
	Subtotal							6.61	

Process	Type	Size (B)	Actual Quantity Pipe(m)	Quantity	Length (m) @	Total length	Surface area(m²) Per meter	Total	Remarks
Ejector	Pipe	1	16				0.106	1.70	
	Valve	1		1	0.62	0.62	0.106	0.56	
	Flange	1		2	0.53	1.06	0.106	0.11	
	Pot	1		1				0.04	
	Subtotal							2.41	
Barometric condenser	Pipe	1	26				0.106	2.77	
	Valve	1		1	0.62	0.62	0.106	0.06	
	Flange	1		2	0.53	1.06	0.106	0.11	
	Pot	1		1				0.04	
	Subtotal							2.98	

Table 5–1–22 Reduction in Radiating Heat Rate

Process	Bare area m²	Internal steam pressure kg/cm² (G)	Ambient temperature °C	Radiating heat rate kcal/h	Radiating heat rate after heat insulation kcal/h	Reduction in radiating heat rate kcal/h
Preconcentration	5.03	1	30	5,833.5	548.6	5,284.9
Perfume recovery	5.01	3	30	8,513.5	867.0	7,646.5
Concentration	6.61	1	30	8,051.8	754.4	7,297.4
Ejector	2.41	5	30	4,417.2	533.4	3,883.8
Barometric condenser	2.98	5	20	7,368.9	878.9	6,490.0
Total	22.04			34,184.9	3,582.3	30,602.6

(Note) Glasswool insulation thickness (mm)

Steam pressure/pipe diameter	1	1½	2	2½	3	4	6
1 kg/cm²		30	30	40	40	40	40
3″		30	40		40		
5″	30						

Reduction in radiating heat calculated in terms of fuel where Latent heat of steam evaporation = 485.4 kcal/kg ($8kg/cm^2$ G)

$$30{,}602.6 \times \frac{1}{485.4} \times 120 \times 24 \times 0.0807 = 14{,}653\ m^3/year$$

(3) Steam Trap Management

(A) Management Problems

(a) Perfume recovery

Two of the three sets of steam heaters have each bypass pipe connected to their steam trap (1½B, 1B), and these two sets were in operation with their bypass valoes open. This results in outflow of a large amount of steam, running through the condensate tank into the atmosphere and abnormally rising the temperature of hot water in the condensate tank. This makes recovery into the boiler feed water tank difficult.

(b) Concentrator

The first tage evaporator was in operation without its steam trap.

As in the case mentioned in Item (a) above, a large amount of uncondensed steam was discharged into the atmosphere.

More than 80% of the heat possessed by steam is latent heat of vaporization, and its discharge in uncondensed form produces a large loss. Unless heat transfer with condensation is used, the heating surfaces will be dry and the heat transfer coefficient will fall.

(B) Estimation of Exhaust Heat Loss

(a) Steam loss is estimated from the exhaust flow velocity through the outdoor exhaust pipe connected to the condensate tank.

Conditions: Inside condensate tank

Temperature: 101 ~101.5 ℃

Pressure: 400 ~600mmAq

Exhaust velocity (estimated): 4"–50m/s, 2"–30m/s

Results: Exhaust steam rate = 4"–1t/h, 2"-150kg/h

Annual steam loss

1,150 kg/h X 2,400 h/year = 2,760 tons/year.

(C) Measures to Prevent Steam Trap Bypass

(a) Closing the steam trap bypass

Replace the steam traps with ones of proper capacity which have been well maintained. When steady operation is achieved, close the bypass. Instruct the employees that opening the bypass will not help heating.

(b) Steam trap sizing normally requires about 3 times the condensate discharge amount in steady operation because a large amount of condensate must be quickly discharged at startup.

(D) General Management of Steam Traps

(a) The life of steam traps is generally 3 to 5 years, subject to variation depending on the type. The valve and valve seat become worn with use over a long period of time so the steam is discharged together with condensate. Consider the steam traps as expendables, and replace them with new ones periodically.

(b) Generally, check the steam traps for their function about once every year, and prepare a record of their data.

Leaks inside the steam traps can be detected from sound by an experienced worker. An ultrasonic diagnostic meter called a trap tester may also be used for this purpose.

(4) Study of Condensate Recovery

(A) Problems of Existing Recovery System

A condensate recovery flowchart is shown in Figure 5–1–20.

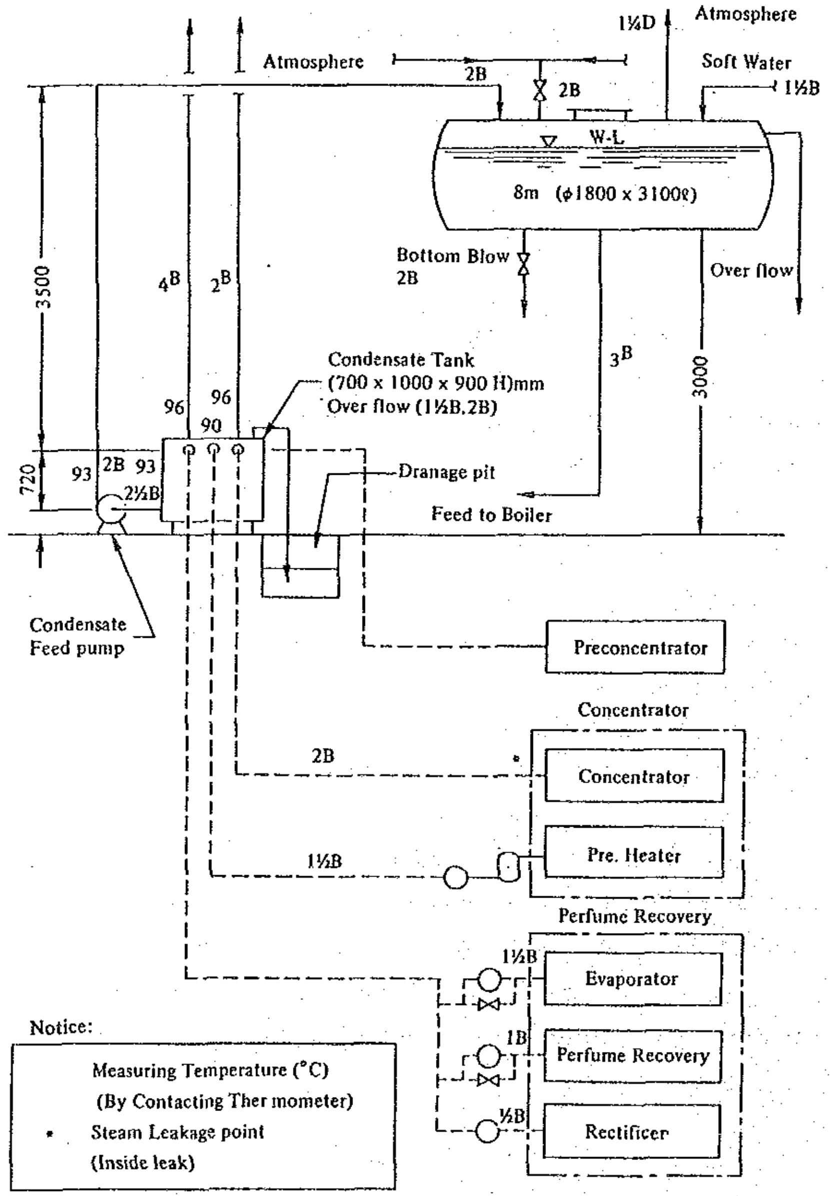
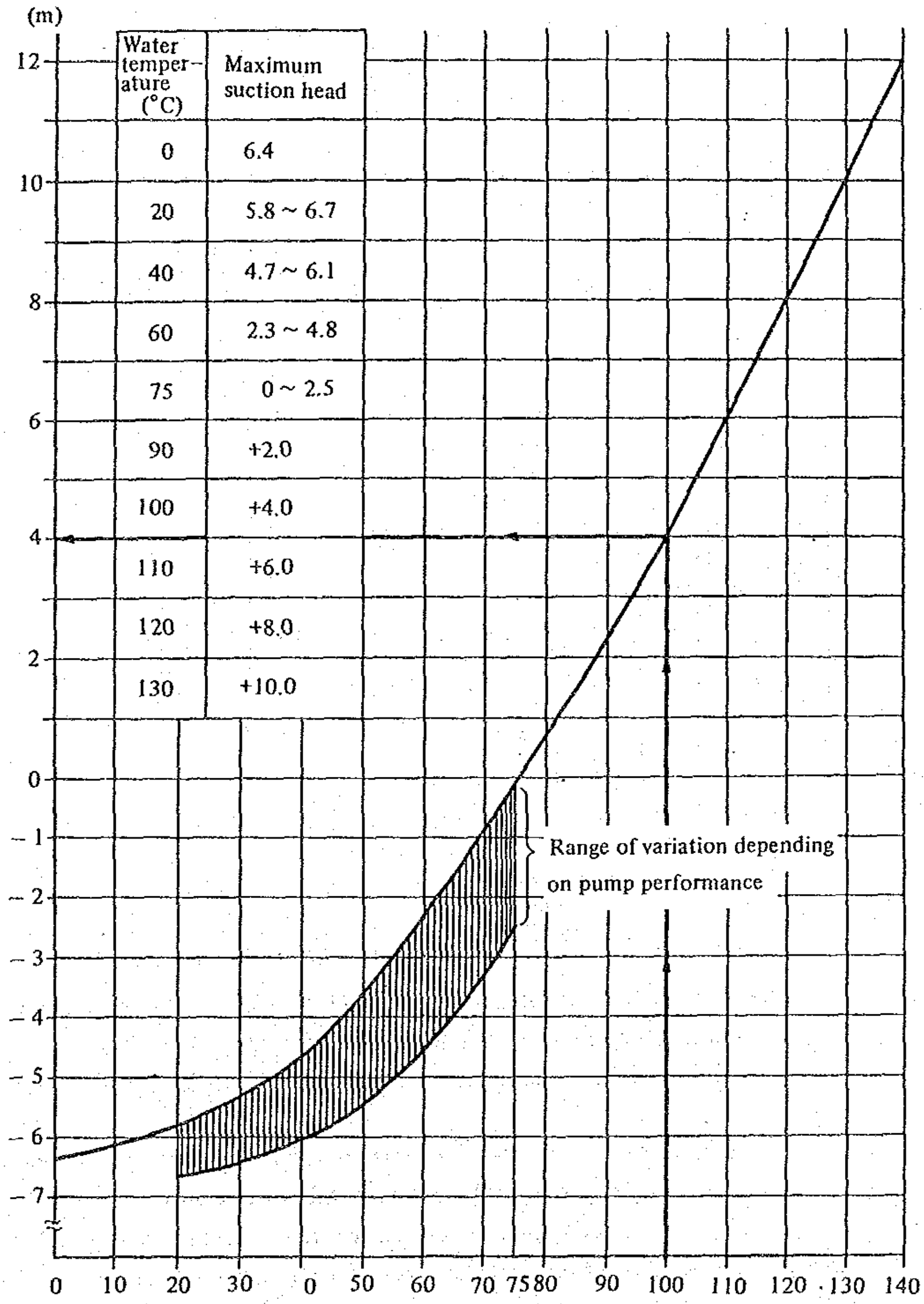


Figure 5–1–20 Condensate Recovery System

The existing recovery system cannot recover the condensate collected from the evaporator, etc. into the boiler feed water tank at high temperature. The reason is that, if the condensate nearly at the boiling point is drawn into the pump from an open condensate tank, a cavitation will occur, making it impossible to pump up.

The relationship between condensate temperature and the required net positive suction head is shown in Figure 5–1–21.



Water temperature (°C)	Maximum suction head
0	6.4
20	5.8 ~ 6.7
40	4.7 ~ 6.1
60	2.3 ~ 4.8
75	0 ~ 2.5
90	+2.0
100	+4.0
110	+6.0
120	+8.0
130	+10.0

Figure 5–1–21 **Water temperature and Required Net Positive Suction Head (Source: Boiler Operation Handbook by Sangyo Publishing Company)**

Because the steam trap bypass valves are open, the steam is blown into the condensate tank, making condensate recovery difficult.

(B) Improvement of Condensate Recovery System

(a) If a condensate recovery pump using an ejector is employed, no net positive suction head is necessary. However, if the condensate tank and pump remain in use as they are, lowering the temperature of the condensate in the condensate tank to 75°C or below by a method such as shown in Figure 5–1–22 will enable continuous, steady recovery of the condensate into the boiler feed water tank.

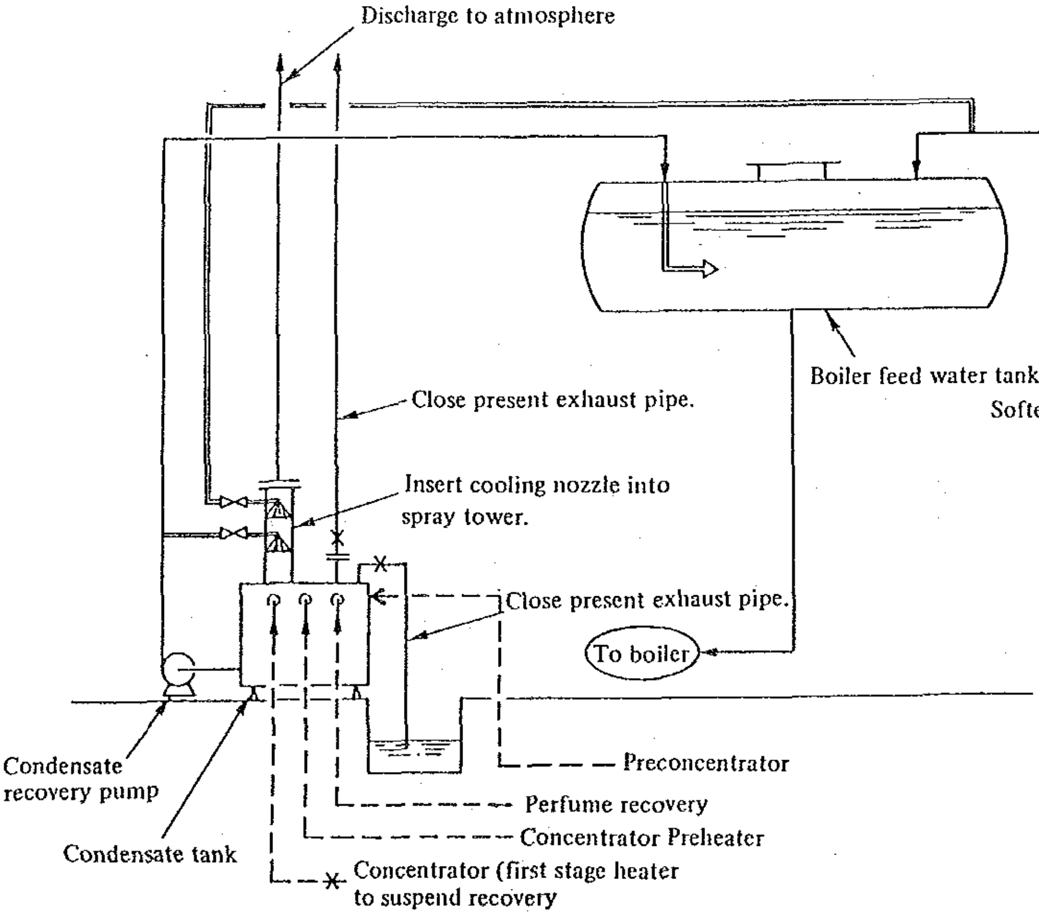


Figure 5–1–22 Condensate Recovery Method (Example for Reference)

This method also permits recovery of the flash steam that is generated at the point of condensate discharged from the processes.

The amount of flash steam generated in each process is shown in Table 5–1–23.

(b) Maintain the steam traps to prevent steam leak into the condensate line.

(C) Recovery of Condensate from Concentrator heater to Boiler

In each of the plate type heat exchanger, the concentrate may leak into the condensate, so recovery of condensate into boiler feed water should be avoided. This may be the cause of the unsatisfactory quality of the present boiler feed water.

Table 5–1–23 Flash Steam Recovery Rate

	Steam consumption	Working steam pressure	Saturated water enthalpy	Generated flash steam ratio	Generated flash steam rate
	T/H	kg/cm² G	Kcal/kg	%	kg/H
Preconcentrator	2.0	0.5	111.2	2.06	41.2
Perfume recovery	2.0	0.5	111.2	2.06	41.2
Concentrator preheater	0.5	3.2	145.5	8.42	42.1
Concentrator	(1.5)	1.0	120.3	3.75	(56.2)
Total except figures in parentheses	4.5				124.5

Note: Under atmospheric condition, saturated water enthalpy is 100.1 kcal/kg and latent heat of steam 539.0 kcal/kg.

5.1.3.6 Water Supply System

(1) Determining Water Consumption

The factory uses ground water and surface water which is subject to change from season to season, and has one each shallow well and deep well. In addition, the factory receives a small quantity of city water for drinking and part of the production process.

Because water intake tends to be short, the factory is implementing a water supply reinforcement plan involving another deep well and a new cooling tower to circulate cooling water.

Along with this plan, it is necessary to promote rational use of water. For this purpose, minimum water intake and maximum water consumption must be quantitatively determined.

Possible water intake is measured by pouring water into the water storage tank while maintaining a water level and measuring volume increase over a specific time. Because the concrete water tank may be often found cracked, it is necessary to check it for leakage on a day off beforehand.

The simplest way of determining water consumption is to estimate it from the total quantity of water discharged. An instantaneous flow rate can be measured by using a triangular weir in the ditch at the point of discharging water. Technical data on triangular weir is shown in Table 5–1–24.

It is estimated from the quantity of water discharged that the factory was consuming about 60 to 70 m^3/h when it was surveyed.

(2) Feed Water Line

The present feed water lines are arranged more or less by use, but still leave room for improvement.
(See Figure 5–1–23.)

(1) The water discharged after cooling the preconcentrator (52 m^3/h) is not sufficiently used, and much water overflows from the service tank.

(2) The water used to cool the perfume recovery unit, juice cooler, and vacuum filter pump can be recovered for reuse. Figure 5-1-24 shows an example of piping improvement plan. The points of overflow are limited, flow rate variations of the individual pipelines are absorbed, and management is made easier. The simplified pipeline configuration also permits removal of a pump and helps reduce electric power consumption.

Although accurate water consumption at present could not be determined, the amount of water that can be saved by this improvement plan was calculated for your reference as follows:

Recovery and reuse of water discharged ater cooling preconcentrator. . . . . 10 to 20 m^3/h
Recovery and reuse of water discharged after cooling perfume recovery
unit, etc. . . . . 10 m^3/h
Total . . . . 20 to 30 m^3/h

Table 5–1–24

Flow through weir

Triangle Weir

From Strickland's formula

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

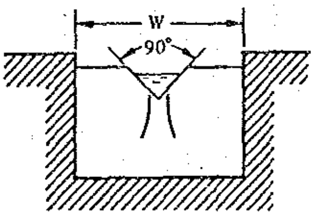
However, the following conditions must be met $\theta = 90°$, H>50mm, W>7H, D>3H.

where Q: Flow rate (m^3/min);

H: Water depth from top of weir (m);

W: Water channel width (m);

D: Height from bottom of water channel to top of weir (m);



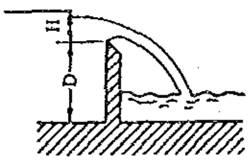
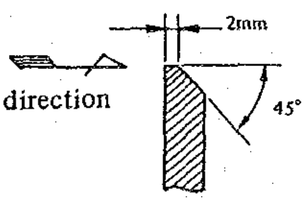


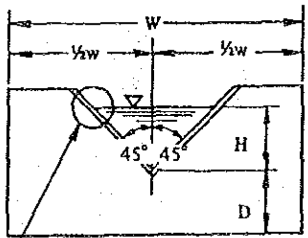
Table of Rectangular Triangle Weir Flow Rate (m^3/min)

H(mm)	0	1	2	3	4	5	6	7	8	9
50	0.0478	0.0530	0.0527	0.0553	0.0579	0.0605	0.0633	0.0662	0.0690	0.0720
60	0.0751	0.0782	0.0814	0.0847	0.0881	0.0914	0.0950	0.0986	0.1022	0.1060
70	0.1099	0.1137	0.1178	0.1219	0.1261	0.1302	0.1346	0.1390	0.1443	0.1481
80	0.1528	0.1575	0.1625	0.1675	0.1724	0.1775	0.1828	0.1882	0.1935	0.1989
90	0.2046	0.2103	0.2161	0.2219	0.2278	0.2339	0.5401	0.2462	0.2524	0.2590
100	0.2656	0.2722	0.2788	0.2857	0.2927	0.2997	0.3067	0.3139	0.3214	0.3288
110	0.3362	0.3437	0.3516	0.3595	0.3674	0.3754	0.383=	0.3819	0.4002	0.4086
120	0.4178	0.4258	0.4347	0.4436	0.4225	0.4614	0.4707	0.4892	0.4896	0.4900
130	0.5085	0.5184	0.5284	0.5385	0.5482	0.5585	0.5689	0.5794	0.5898	0.6004
140	0.6113	0.6222	0.6332	0.6441	0.6555	0.6670	0.6784	0.6899	0.7014	0.7135
150	0.7255	0.7375	0.7495	0.7618	0.7744	0.7869	0.7995	0.8121	0.8251	0.8383
160	0.8514	0.8645	0.8778	0.8915	0.9053	0.9190	0.9328	0.9496	0.9608	0.9752
170	0.9897	1.0040	1.0184	1.0303	1.0480	1.0630	1.0780	1.0940	1.1080	1.124
180	1.0390	1.1550	1.1720	1.1880	1.2040	1.2210	1.2370	1.2540	1.2700	1.287
190	1.3040	1.3210	1.3390	1.3560	1.3730	1.3910	0.4090	1.4280	1.4460	1.464
200	1.4810	1.500	1.519	1.537	1.556	1.575	1.594	1.613	1.633	1.652
210	1.672	1.692	1.712	1.732	1.752	1.772	1.783	1.814	1.835	1.856
220	1.877	1.898	1.920	1.941	1.963	1.984	2.007	2.029	2.051	2.073
230	2.096	2.119	2.142	2.165	2.188	2.211	2.234	2.253	2.281	2.304



Flow direction

Shape of cutout



The above flow rate formula applies to the following range.

W: 0.5 to 1.2m

H: 0.07 to 0.26m < W/3

D: 0.1 to 0.75m

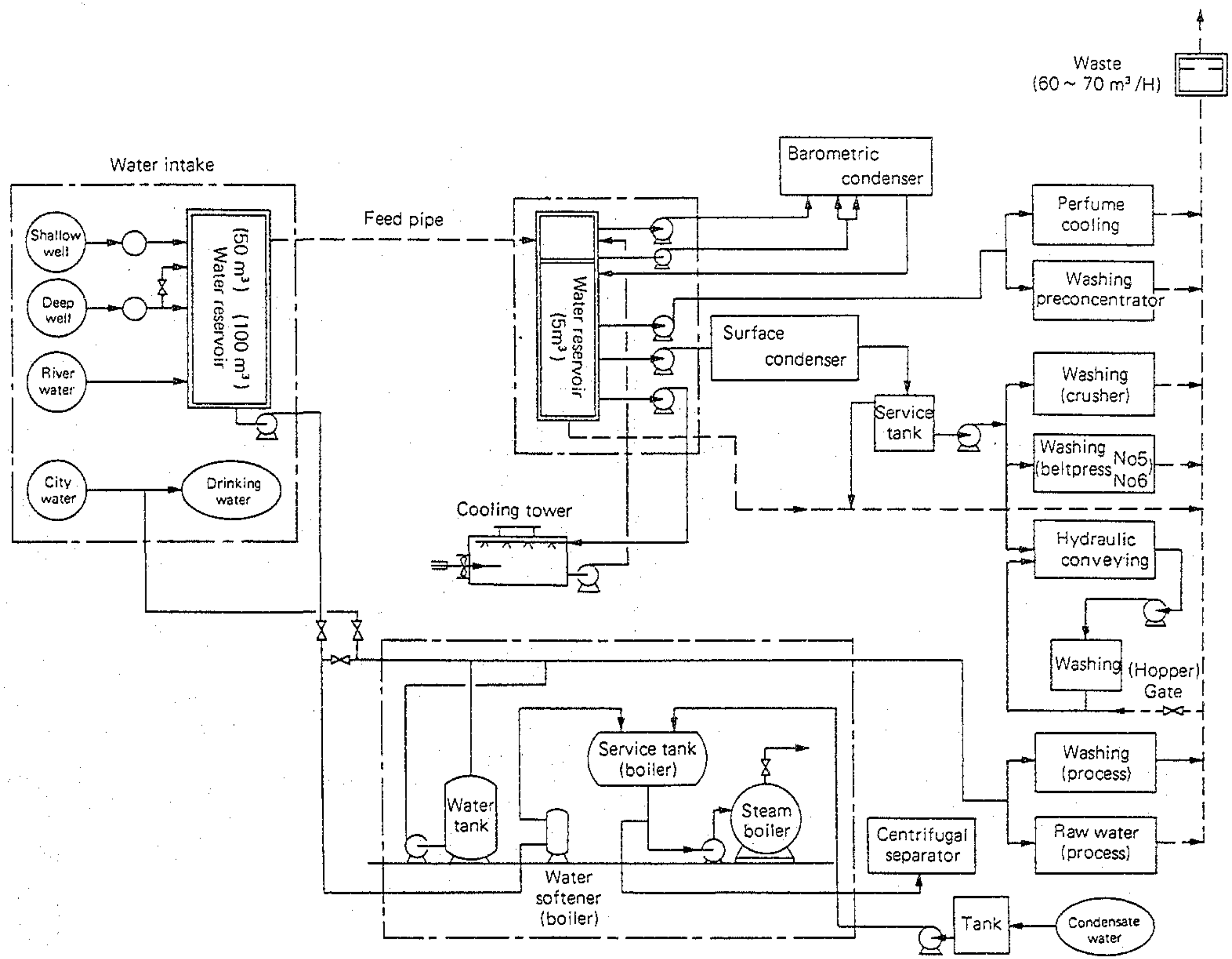


Figure 5–1–23 Water Flow Sheet

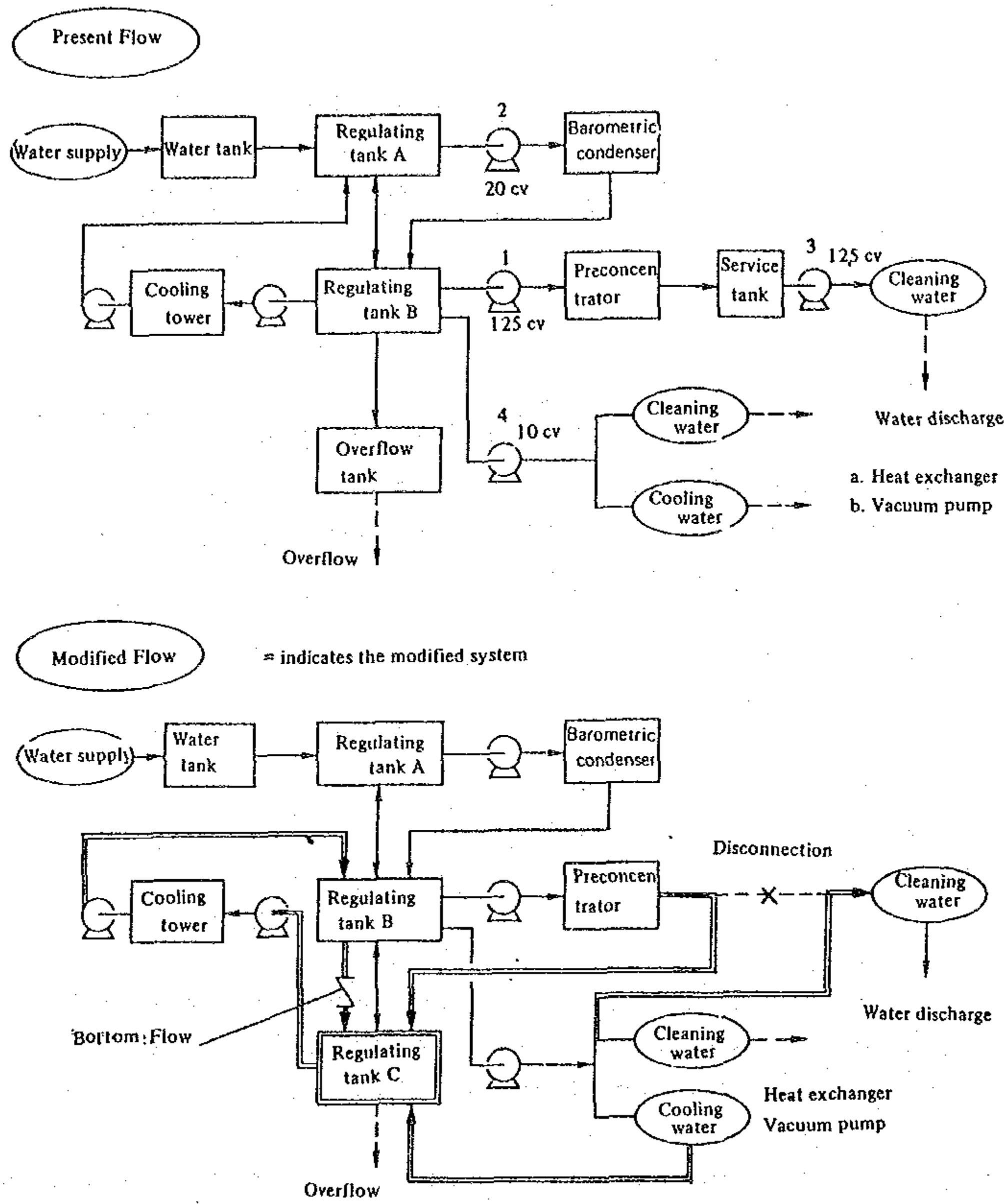


Figure 5–1–24 Proposed Improvement of Feed Water Piping

(3) Management of Cleaning Water for Press belts

The press belts are cleaned by spraying water through the holes drilled in the 2 pipes as shown in Figure 5-1-25, and water consumption and the way of water spray vary considerably from press to press.

The water flow rates were measured for No. 5 and No. 6 presses using an ultrasonic flow meter, and there was a difference of more than twice between them as shown below, indicating waste of water due to excessive water supply.

No. 5 press: 3.63 m^3/h
No. 6 press: 9.30 m^3/h

Because the cleaning water for the No. 1 to No. 4 presses directly gets into the material,

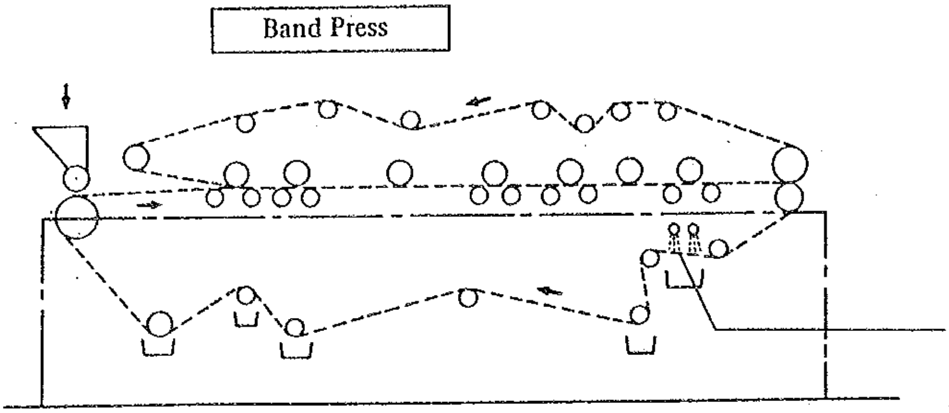


Figure 5–1–25 **Band Press Cleaning Method**

the excess water increases the concentration load to raise fuel consumption.

The following improvements are proposed to maintain steady, cleaning effects at all times except for the personal difference of the operators.

(1) Changing cleaning nozzles

Use flat spray nozzles of the following specifications to assure uniform cleaning of the belt surfaces.

Spray angle: 30 to 60°
Spray water rate: 6.5 to 15 liters/min
Spray pressure: 2 kg/cm^2

(2) Standardizing cleaning operation

Mount a pressure gauge on the secondary side of the cleaning water regulator valve for each press, draw a pressure mark corresponding to the proper water rate, and operate the regulator valve while watching the mark. Educate the operators to observe this method.

(4) Others

Apple juice was found spilled from the belt presses on the floor. Apples are pressed into juice by consuming electricity so that reducing loss of apple juice will lead to energy conservation.

The cooling water piping was partly in contact with the hot part of the exhaust gas flue. This is another point requiring improvement.

5.1.3.7 Power Receiving and Distributing and Electrical Facilities

(1) Power Receiving Facilities

Electric power is received from an overhead line of 13.2 kV, and a supply integrating wattmeter and reactive powermeter are installed at the power receiving point, which is connected to the switchgear in the transformer room with an overhead line about 100 meters long. The transformer room has two transformers of 3-phase, 315 kVA, each of which steps down the received power to 380 V. The loads are mostly the motors that drive the centrifugal separator, press, etc. Both transformers are used during the juice production period that begins in January, while only one of them is kept in operation during the maintenance period that follows the production period.

A 60 kVar condenser is connected to the low-voltage end of the right transformer and a 50 kVar condenser to the low-voltage end of the left transformer as viewed facing the entrance to the transformer room.

(2) Measurement Made

The following were measured using Watt-Power Factor Meter (Models PFM-1000, PFMA-5210, and PFM-1000P), clip-on AC power meter, and 12-channels Hybrid recorder.

1 Overall factory load (Figure 5–1–26)

2 Load on the low-voltage main line of the left side transformer (Figure 5–1–27)

3 Load on the low-voltage main line of the right side transformer (Figure 5–1–28)

4 Each branch load on the secondary side (Table 5–1–25)

5 Pump motor load (Table 5–1–26)

(3) Problems of Electric Power Management

(1) Drawings and data are not maintained.

(a) The wiring diagrams used in building the factory were available, but not one line diagrams. One line diagrams such as shown in Figure 5-1-5 should be available so that the overall electrical system can be easily understood.

(b) No motor list was available so that it was unknown whether interchangeable motors were available and whether spare motors were available.

(c) Many of the motor-driven machines are uncertain of their specifications.

(2) Meters are insufficient. Apart from the supply meters, a voltmeter, ammeter, and power factor meter for the 13.2 kV line were not available. Thus, the electricity used in the factory could be measured only on the secondary side for daily management.

(3) There is room for improving the power factor.

(a) Table 4-1-27 shows the electric power charges paid last year. Argentina has an electric power charge system which charges penalties if the power factor (cos ϕ) is less than 85% and gives incentives if it is 85% or more. This factory pays penalties during the juice production period, when the load is high and the power factor low.

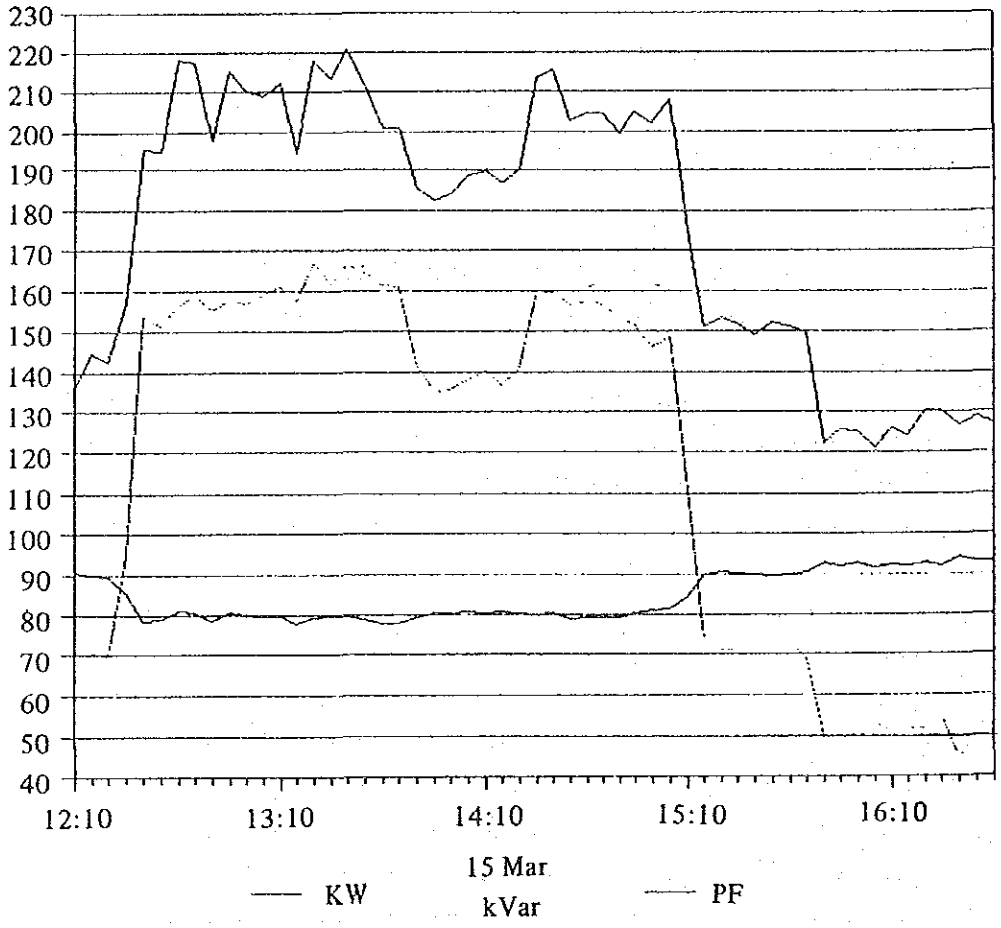
Note:

$$\tan\phi = \frac{\text{Monthly reactive electric power}}{\text{Monthly electric power}}$$

$$\cos\phi = \frac{1}{\sqrt{1 + \tan^2\phi}}$$

(b) Figures 5–1–26, 5–1–27, and 5–1–28 show the transformer loads.

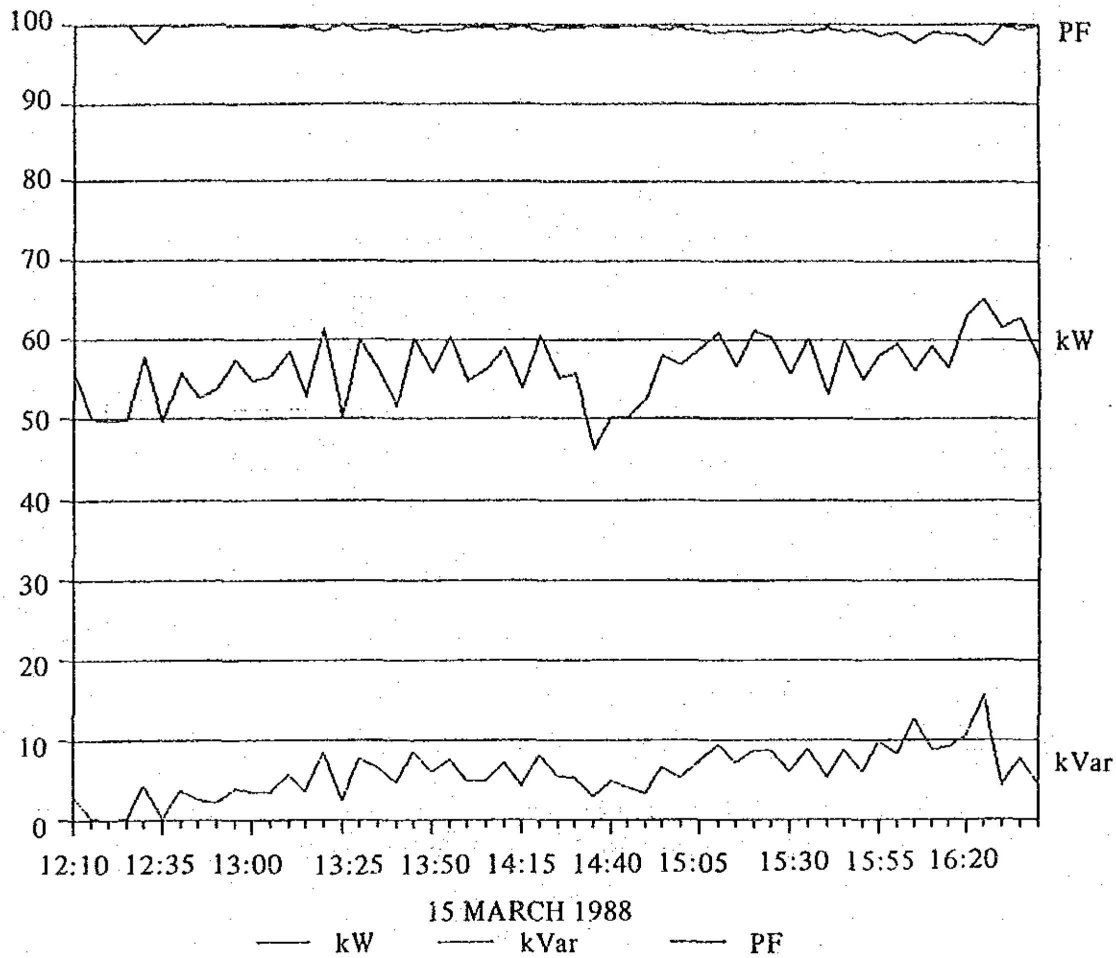
The transformer on the left as viewed from the entrance to the transformer room has a light load so that reactive power is absorbed by the 50-kVar condenser and the power factor is higher (more than 90%), while the transformer on the right as viewed from the transformer room entrance shows a power factor drop to less than 80% when the load exceeds 100 kW because the 60-kVar condenser cannot sufficiently absorb reactive power.



TOTAL

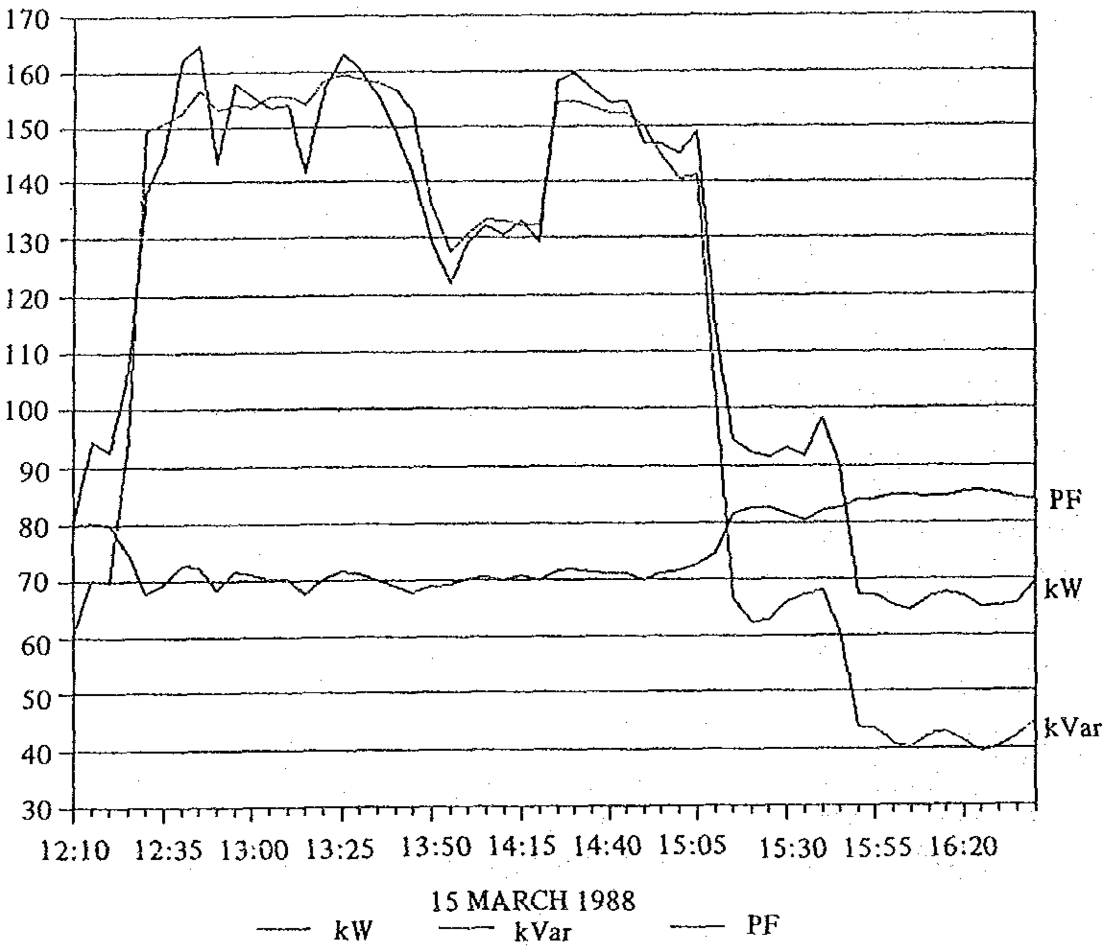
	kw	kvar	P.F.
AVG	176.3	116.1	83.5

Figure 5–1–26 Total Power Receiving



12:30 – 16:50	kw	LEFT kvar	P.F.
AVG	56.5	5.8	99.5

Figure 5–1–27 Power Transformer (Left side)



RIGHT

	kw	kvar	P.F.
AVG	119.88	110.21	73.6

Figure 5–1–28 Power Transformer (Right side)

Table 5-1-25 Power Consumption of Branches (1)

Date	Time	Branch		kW	kVar	P.F.
Mar. 16	11:00-12:55	Crasher	Avg	55.11	93.92	50.61
	13:15-14:25		Avg	42.96	88.34	43.73
			Max	58.1	97.3	53.0
			Min	37.2	84.7	37.4
	11:10-14:25	Vacuum filter	Avg	20.25	16.50	77.51
			Max	20.5	16.9	78.1
			Min	20.1	16.3	76.7
	11:10-14:25	Well pump, etc.	Avg	8.19	7.23	74.97
			Max	8.7	7.5	76.7
			Min	7.6	7.1	72.9
	11:10-13:30	No. 3 Pump	Avg	34.55	26.50	79.35
			Max	38.9	29.7	83.9
			Min	33.0	22.2	78.0
	11:10-14:25	Concentrater	Avg	12.76	15.11	64.50
			Max	13.8	16.1	67.4
			Min	9.1	14.4	53.7
	11:10-14:25	Preconcentrater	Avg	17.24	17.80	69.56
			Max	18.3	18.6	72.1
			Min	13.9	17.3	60.8

Power Consumption of Branches (2)

Date	Time	Branch		kW	kVar	P.F.
Mar. 17	10:30-14:35	Filter agitator	Avg	3.99	4.17	69.15
			Max	9.0	11.2	85.3
			Min	1.7	1.2	53.2
	10:30-14:35	Boiler pump	Avg	10.90	8.29	79.60
			Max	19.5	12.7	84.5
			Min	3.9	3.7	69.5
	10:30-14:35	Well pump	Avg	11.34	10.53	73.28
			Max	11.5	10.8	74.8
			Min	11.2	10.1	72.3
	10:30-14:35	Ammonia equipment	Avg	30.04	20.63	82.43
		Centrifuger	Max	33.5	22.7	86.2
			Min	24.3	14.8	80.2
	17:00-17:05	Lighting	Avg	12.5	8.5	82.7

Table 5–1–26 Measured Output Power of Pumps and Others in Factory

	Rated output power		Voltage		Current		Power factor		Power consumption	Speed		Remarks
	CV	kw	Rated	Measured	Rated	Measured	Rated	Measured	kw	r.p.m Rated	Measured	
Water Pump	12.5	9.2	380	375	22	15.45	0.84	0.625	6.28	1450	1462	3.298 kg/cm^2 0.833m^3/minute
Pump for Barometric Condenser	20	14.72	380	379	29	14.61	0.87	0.669	6.42	1450	1468	0.94m^3/minute
Water Pump for Preconcentrator	12.5	9.2	380	379	19	15.6	0.84	0.547	5.6	1450	1475	2.679 kg/cm^2 0.867m^3/minute
Process Cooling	10	7.36	380	381	15	11.5	0.86	0.938	7.12	1440	1469	
Water Conveyer	20	14.72	380	377	29.5	9.5	0.86	0.306	1.9	1420	1475	

Table 5–1–27 Electric Power Charge Payments (January – December 1987)

1987	Active power kwh	Reactive power kVar h	ton ϕ	Power factor cos ϕ	Basic charge	Energy charge	Power factor penalty and incentive	Net payment for electricity	Penalty and tax (18% of net payment)	Amount invoiced
1	6,120	10,728	1.75	0.496	A 586.96	A 186.66	A 255.29	A 1028.91	A 345.72	A 1374.63
2	99,648	72,648	0.72	0.812	627.44	2959.37	107.60	4276.21	1436.81	5713.02
3	180,144	137,448	0.76	0.796	639.58	5084.90	171.73	6571.75	2208.12	8779.87
4	154,440	116,424	0.75	0.8	639.58	4460.94	153.01	5846.59	1964.46	7811.05
5	163,224	118,728	0.72	0.812	651.73	4788.28	163.20	6207.53	2048.50	8256.03
6	113,472	84,456	0.74	0.804	1006.85	4279.71	151.47	6977.95	922.51	7900.46
7	70,560	–					–	4649.59	725.34	6211.41
8	24,336	2,880	0.11	0.994	947.23	1328.14	–119.46	2543.97	336.32	2880.29
9	8,712	0	0	1.	1254.88	645.49	–99.77	1800.60	280.89	2405.60
10	6,408	0	0	1.	1720.40	636.38	–123.75	2634.99	348.36	2983.36
11	5,688	0	0	1.	1720.40	569.61	–120.23	2559.87	338.49	2898.36
12	4,680	144	0.03	1.	1720.40	473.75	–115.19	2453.17	324.32	2777.49

Table 5-1-28 Standard Capacities of Installed Equipment

200-V single-phase induction motor

Rated output power kW	Condenser capacity			
	50Hz		60Hz	
	μF	kVA	μF	kVA
0.1 or less	20	0.25	20	0.30
0.2	20	0.25	20	0.30
(0.25)	30	0.38	20	0.30
0.4	30	0.38	30	0.45
(0.55)	40	0.50	30	0.45
(0.75)	40	0.50	40	0.60
(1.1)	50	0.63	40	0.60

100-V single-phase induction motor

Rated output power kW	Condenser capacity			
	50Hz		60Hz	
	μF	kVA	μF	kVA
0.1 or less	50	0.16	50	0.19
0.2	75	0.24	50	0.19
(0.25)	75	0.24	75	0.28
0.4	75	0.24	75	0.28
(0.55)	100	0.31	75	0.28
(0.75)	100	0.31	100	0.38
(1.1)	100	0.31	100	0.38

200-V three-phase induction motor

Rated output power kW	Condenser capacity			
	50Hz		60Hz	
	μF	kVA	μF	kVA
0.2 or less	15	0.19	10	0.15
0.4	20	0.25	15	0.23
0.75	30	0.38	20	0.30
(1)	30	0.38	20	0.30
(1.1)	30	0.38	20	0.30
1.5	40	0.50	30	0.45
(2)	50	0.63	40	0.60
2.2	50	0.63	40	0.60
(3)	50	0.63	40	0.60
3.7	75	0.94	50	0.75
(4)	75	0.94	50	0.75
(5)	100	1.26	75	1.13
5.5	100	1.26	75	1.13
7.5	150	1.89	100	1.51
(10)	200	2.51	150	2.26
11	200	2.51	150	2.26
15	250	3.14	200	3.02
18.5	300	3.77	250	3.77
(20)	300	3.77	250	3.77
22	400	5.03	300	4.52
(25)	400	5.03	300	4.52
30	500	6.29	400	6.03
37	600	7.54	500	7.54
(40)	600	7.54	500	7.54
45	750	9.43	600	9.05
(50)	900	11.31	750	11.31
55	900	11.31	750	11.31

400-V three-phase induction motor

Rated output power kW	Condenser capacity							
	400-V circuit				440-V circuit			
	50Hz		60Hz		50Hz		60Hz	
	μF	kVA	μF	kVA	μF	kVA	μF	kVA
0.2 or less	5	0.25	5	0.30	5	0.30	5	0.36
0.4	5	0.25	5	0.30	5	0.30	5	0.36
0.75	7.5	0.38	5	0.30	7.5	0.46	5	0.36
(1)	7.5	0.38	5	0.30	7.5	0.46	5	0.36
(1.1)	7.5	0.38	5	0.30	7.5	0.46	5	0.36
1.5	10	0.50	7.5	0.45	10	0.61	7.5	0.55
(2)	15	0.75	10	0.60	10	0.61	10	0.73
2.2	15	0.75	10	0.60	10	0.61	10	0.73
(3)	15	0.75	10	0.60	10	0.61	10	0.73
3.7	20	1.01	15	0.90	15	0.91	10	0.73
(4)	20	1.01	15	0.90	15	0.91	10	0.73
(5)	25	1.26	20	1.21	20	1.22	15	1.09
5.5	30	1.51	25	1.51	25	1.52	20	1.46
7.5	40	2.01	25	1.51	30	1.82	20	1.46
(10)	50	2.51	40	2.41	40	2.43	30	2.19
11	50	2.51	40	2.41	40	2.43	30	2.19
15	75	3.77	50	3.02	50	3.04	40	2.92
18.5	75	3.77	75	4.52	75	4.56	50	3.65
(20)	75	3.77	75	4.52	75	4.56	50	3.65
22	100	5.03	75	4.52	75	4.56	50	3.65
(25)	100	5.03	75	4.52	100	6.08	75	5.47
30	125	6.28	100	6.03	100	6.08	100	7.30
37	150	7.54	125	7.54	125	7.60	100	7.30
(40)	150	7.54	125	7.54	125	7.60	100	7.30
45	200	10.05	150	9.05	200	12.16	150	10.95
(50)	250	12.57	200	12.06	250	15.21	200	14.60
55	250	12.57	200	12.06	250	15.21	200	14.60

Table 5-1-29 Main Motors and Condensers

Use	Rated output power	Rated speed	Rated output power KW	Parallel-connected condenser 380V	Remarks
Ammonia compressor	40 CV	r.p.m. 1430	KW 29.4	125μF 6.28 KVA	Left
Boiler fuel pump	12.5	2910	9.2	50μF 2.51 KVA	Left
Boiler feed water pump	20	2910	14.7	75μF 3.77 KVA	Left
Water pump for condenser	12.5	1450	9.2	50μF 2.51 KVA	Right
Cooling water pump for roof barometric condenser	20	1420	14.7	75μF 3.77 KVA	Right
Perfume Cooling/Washing Pump	10	1440	7.36	40μF 2.01 KVA	Right
Hot water pump	12.5	2310	9.2	50μF 2.51 KVA	Right
Agitator	20	1450	14.7	75μF 3.77 KVA	Left
Vacuum pump	30	1450	22	100μF 5.03 KVA	Right
"	30	1450	22	100μF 5.03 KVA	Right
Pump for belt cleaning	20	2910	14.7	75μF 3.77 KVA	Right
Crusher	50	1450	36.8	150μF 7.54 KVA	Right
Pump for shallow well	20	1420	14.7	75μF 3.77 KVA	Left
Pump for apple conveyor	20	1420	14.7	75μF 3.77 KVA	Right
Centrifugal separator	50		36.8	150μF 7.54 KVA	Left
Total condenser capacity				63.58 KVA	KVA KVA 27.64 35.94

Note: The condenser capacities specified above refer to the capacities of condensers to be connected parallel to motors recommended in Technical Data 114 of the Japan Electrical Manufacturers' Association (pertaining to the selection of condensers for AC circuits, their installation, and maintenance precautions). The right column refers to the loads to be connected to the transformers on the right side as viewed from the transformer room entrance, and the left column to the loads to be connected to the transformers on the left side of the same.

(c) Table 5-1-25 shows the load on each branch.

Generally, the power factor is low because, for one thing, the motor load is small relative to the rated output power and, for another, the motors are mostly small sized. Particularly, the molienda (press) line's power factor is extremely low (about 50%).

(d) Remedial measures

The power factor can be improved by installing a condenser to absorb reactive power. If a condenser is connected to the load end, penalties will not longer have to be paid and, as current will decrease, cable resistance loss and transformer load loss will also decrease.

The condensers recommended in Technical Data 114 of the Japan Electrical Manufacturers' Association relative to rated motor outputs are shown in Table 5-1-28.

Table 5-1-29 shows numerical data on condensers to be connected in parallel to the main motors. It is recommended that condensers be connected to the crusher and pumps for the molienda line. Also connect a condenser of 60 kVar to the panel for the molienda line.

(e) Effect of improving the power factor by installing condenser

If a condenser of 60 kVar is connected to the panel for the molienda line and condensers amounting to 35.9 kVar in total are connected to the motors that are connected to the right transformer shown in Table 5-1-29, mean reactive power will decrease from 117.3 kVar to 35.2 kVar.

$$117.3 - (60 + 35.9) \times \left(\frac{370}{400}\right)^2 = 35.2\ \text{kVar}$$

Because the mean power is 175.6 kW, the power factor will be 98.9%.

$$\cos\phi_2 = \frac{175.6}{\sqrt{175.6^2 + 35.2^2}} = 0.980$$

(e-1) As a result, the factory will no longer have to pay the penalty of \$625.2 (\$737.7 including tax) that it now pays. Besides, the factory will be able to receive incentives amounting to \$468 a year including tax [119 x 12 x 1.18 = A1685 (\$468)], assuming the same rate of incentive it received in August last year.

(e-2) Transformer load loss will be reduced.

The transformer on the right has a high load and a low power factor, but when a condenser is connected to it, the mean reactive power of 107.8 kVar will decrease to 25.7 kVar as follows:

$$107.8 - (60 + 35.9) \times \left(\frac{370}{400}\right)^2 = 25.7\ \text{kVar.}$$

The mean apparent power will decrease as follows:

$$\sqrt{118^2 + 107.8^2} = 159.8\ \text{kVA} \rightarrow \sqrt{118^2 + 25.7^2} = 120.8\ \text{kVA.}$$

If the total load loss of the 315-kVA transformer is 4.6 kW, the load loss of the transformer will decrease as follows:

$$4.6 \times \left[\left(\frac{159.8}{315}\right)^2 - \left(\frac{120.8}{315}\right)^2\right] = 0.507\ \text{kW.}$$

If the factory operates for 120 x 24 = 2880 hours a year and pays \$0.035 (including tax) per kWh, the load loss will be reduced as follows:

$$0.035 \times 0.507 \times 2880 = \$51/\text{year}.$$

In addition, the resistance loss of the13.2-kV cable from the supply integrating wattmeter to the transformers, of the cable from the transformers to the low-voltage distribution board, and of the cables from the low-voltage distribution board to the local distribution board and motors will decrease. The amount of resistance loss reduced for the molienda line that carries high current is calculated below.

Mean power of the press line: 50.3 kW

Mean reactive power: 91.8 kVar

$$\text{Mean apparent power} = \sqrt{50.3^2 + 91.8^2} = 104.7\ \text{kVA}.$$

$$\text{Current } I_1 = \frac{104.7}{\sqrt{3} \times 0.37} = 163.4\ \text{A}.$$

The condensers to be connected to the molienda line, including those connected in parallel to the motors, can be expressed as follows:

$$(60 + 7.54 + 3.77 \times 2) \times (\frac{370}{400})^2 = 64.2\ \text{kVar}.$$

The mean apparent power after improving the power factor will be:

$$\sqrt{50.3^2 + (91.8 - 64.2)^2} = 57.4\ \text{kVA}.$$

The current will be:

$$I_2 = \frac{57.4}{\sqrt{3} \times 0.37} = 89.6\ \text{A}.$$

The cable are assumed to be 60 mm^2 in cross sectional area and 80 meters long. If the cable resistance is 0.311 ohm per kilometer, resistance loss will decrease as follows:

$$p = 3 \times (I_1^2 - I_2^2) \times \gamma \times t\,[\text{kWh}] = 3 \times (163.4^2 - 89.6^2) \times 0.311 \times \frac{80}{1000} \times 10^{-3} \times 120 \times 24 = 4014\,[\text{kWh}]/\text{y} \quad (3)$$

The above reduction in resistance loss will amount to: 0.035 x 4014 = \$140/year.

The power factor improvements mentioned above will bring about an annual saving of \$1244 as follows:

No more penalties:	\$625/year
Incentives:	\$468/year
Reduction in transformer load loss:	\$ 51/year
Reduction in calbe resistance loss:	\$100/year
Total	\$1244/year

(f) Expenses for the proposed improvements

The expenses for the proposed improvements are roughly calculated on the basis of the current prices in Japan as follows:

Item	Capacity	Quantity	Amount
Molienda line panel	20 kVar	3	$1320
Crusher motor	7.54 kVar	1	$120
Pump motor	3.77 kVar	2	$170
Installation			$390
Total			$2000

(g) Recovery of the investment

Since the annual saving from the proposed power factor improvements will amount to $1244, the investment of $2000 for the improvements can be recovered in one year and 7 months.

(4) The facotry uses fluorescent mercury lamps in general. It is suggested that they be replaced with lamps having higher luminous efficiency.

The factory itself now uses 24 400-watt fluorescent mercury lamps, and 2 fluorescent mercury lamps each in the warehouse and boiler room. We propose that the 24 fluorescent mercury lamps in the factory be replaced with 12 360-watt high-pressure sodium-vapor lamps, and the 2 fluorescent mercury lamps each in the warehouse and boiler room be replaced with one 360-watt high-pressure sodium-vapor lamp each. The total luminous flux of the 400-watt fluorescent mercury lamps is 22,000 lm compared with 47,500 lm for the 360-watt high-pressure sodium-vapor lamps, which will provide a light quantity of 2.16 times as much. Thus, the average illuminance will improve by 8%.

$$(47{,}500 \times 14) \div (22{,}000 \times 28) = 1.08.$$

Because the 28 400-watt fluorescent mercury lamps will be replaced with 14 360-watt high-pressure sodium-vapor lamps, power consumption will decrease by $(400 \times 28 - 360 \times 14) \times 10^{-3} \times (12 \times 120 + 3 \times 254) = 13{,}398$ kWh/year. The saving will amount to $0.035 \times 13{,}398 =$ \$469/year.

The expenses required for replacing the lamps are calculated on the basis of the current prices in Japan as follows:

$150 x 14 = $2100.

Therefore, it will take about 4 and a half years to recover the investment.

Remember that, when replacing the existing fluorescent mercury lamps, it is necessary to select a type of lamp which will permit use of the present stabilizers and to arrange the new lamps, which are fewer than the existing ones, not to make equipment shadows.

(5) The flow rates from the pumps are controlled with the valves, but this should be improved by applying pump rotating speed control. Table 4-1-26 shows pumps with small power consumption relative to the rated output power. The present survey could not measure the individual pumps over a long period of time. If the load is always small, the following steps will bring about a power saving.

Replacing with small -capacity pumps

Impeller cut

Reducing speed by means of pulley or reduction gear

If pumps are subject to much flow variation and operate under small load for a long time, keep the valve fully open, and control motor speed by changing the frequency of the power source by means of VVVF, instead of opening and closing the valve to control the flow rate. Motor power consumption can be réduced this way. Pump flow rate (Q) is directly proportionate to speed (N), head (H) is directly proportionate to the square of speed (N), and axial dynamic force (L) is directly proportionate to the cube of speed (N).

Therefore, if speed is reduced to one half to reduce the flow rate to one half, the axial dynamic force will be reduced to 1/8. In this case, there are various methods of controlling motor speed. A VVVF (variable voltage, variable frequency) inverter of power transistors is mostly used for this purpose.

5.1.3.8 Summary

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

Item		Possible annual amount of saving	%
Heat insulation of concentrator	Gas	8,800 m^3	0.6
Steam circulation of preconcentrator		19,800	1.3
Steam circulation of concentrator		32,900	2.2
Improvement of boiler air ratio		33,200	2.2
Heat recovery of boiler exhaust gas		28,100	1.8
Heat insulation of boiler		5,600	0.4
Prevention of leakage of steam pipe		3,300	0.2
Heat insulation of steam pipe		14,700	1.0
Total		146,400	9.6
Improvement of power factor		5,500 kWh	0.7
Improvement of lighting		13,400	1.6
Total		18,900	2.3

5.2 Results of Survey of Cannery

5. Survey of the Use of Energy in Model Factory

5.2 Results of Survey of Cannery

5.2.1 Summary of Factory

(1) Name of Factory: Ventura Mar del Plata S.A.C.I.F.I.M. (DARSENA)

(2) Type of Product: Food

(3) Location: Jose Hernandez 145 Mar del Plata, Prov. de Buenos Aires

(4) History of Factory

DARSENA is a cannery with a daily capacity for processing 28 to 30 tons of fish. Ventura is a company which owns fishing boats, refrigerator boats, cold storages, and fish meal plants, and operates a wide range of business related to fishing. DARSENA is one of the factories owned by it.

There are 11 canneries in Mar del Plata, of which DARSENA is one of the four medium.

Less than one half of its production is for its own market, while the rest is canned cod for distribution to the needy households produced at the request of the government. Argentine fishing is limited to summer only, and the factory depends on imported fish for the other half-year period. Export is completely impossible because of the high cost of import fish, cans and high wages. There are not many people at home consuming relatively expensive cans, and no significant recovery has been made since the sharp drop in consumption in 1978. For this reason, the factory began to produce other products such as dried fish.

Constructed in 1950, the factory has old production facilities except the boiler which was recently renewed to save fuel expenses by using natural gas in place of fuel oil. The unit cost per calory is estimated to be about 60% of that of fuel oil, and the factory expects to recover the investment in less than a year. The factory still uses fuel oil because gas piping has not be laid as yet.

The factory has about 150 employees, most of which are women workers for manual labor. One engineer and nine foremen take care of operation and maintenance.

(5) Employees

150 including the following:

One engineer

9 foremen	1 for boiler
	1 for autoclave
	2 for canning machines
	1 for packing
	1 for maintenance
	3 (women) supervisors

(6) Survey Period

March 21 to 25, 1988

(7) Japanese Team

Name	Assignment
Mitsuo Iguchi	Energy management

Teruo Nakagawa — Boiler and steam equipment
Kaoru Nakao — Food process
Takashige Taniguchi — Processed food conveyance, fluid vonveyance
Kenichi Kurita — Electric power facilities

INTI Members

Mr. Daniel Afione — Chief
Mr. Alberto Berset — Boiler and steam equipment
Mr. Arturo Verghelet — Assistance in thermal techniques
Mr. Marcelo Silvosa — Electric power facilities
Mr. Miguel Bermejo — Assistance in electrical techniques
Mr. Anibal Monzon — *Measurement and mobile unit driving*
Mr. Hector Citadino — Measurement and practical training

(8) Interviewees

Mr. Francisco Ventura — President
Mr. Mario Irribarren — Factory Manager
Mr. Alfredo Giovannoni — Maintenance Manager

(9) Production

Table 5–2–1 (Box)

Period	1984.8–1985.7	1985.8–1986.7	1986.8–1987.7
Tuna	33700	2600	34000
Mackerel	53500	39000	49500
Sardine	83500	32000	52500
Cod	8200	5300	17700
Shell etc.	4600	1200	2500
Cod for Charity	100000	112000	5800
Total ton	2088	1712	1103

Note:	Net Weight	Pieces a Box
Tuna	180 g/can	24
Mackerel	380	24
Sardine	170	30
Cod	380	24

(10) Energy Consumption

Table 5–2–2

	1983	1984	1985	1986
Fuel Oil kl	480	520	496	420
Elec. Power Mwh	240	250	247	200
City Water k t	53	60	62	43
Energy/Product				
Fuel Oil l/t			243	268
Elec. Power kwh/t			119	131
Energy Price	Oil		0.614 A/kg	0.15$/kg
	Electricity			0.06$/kWh

(11) Factory Layout

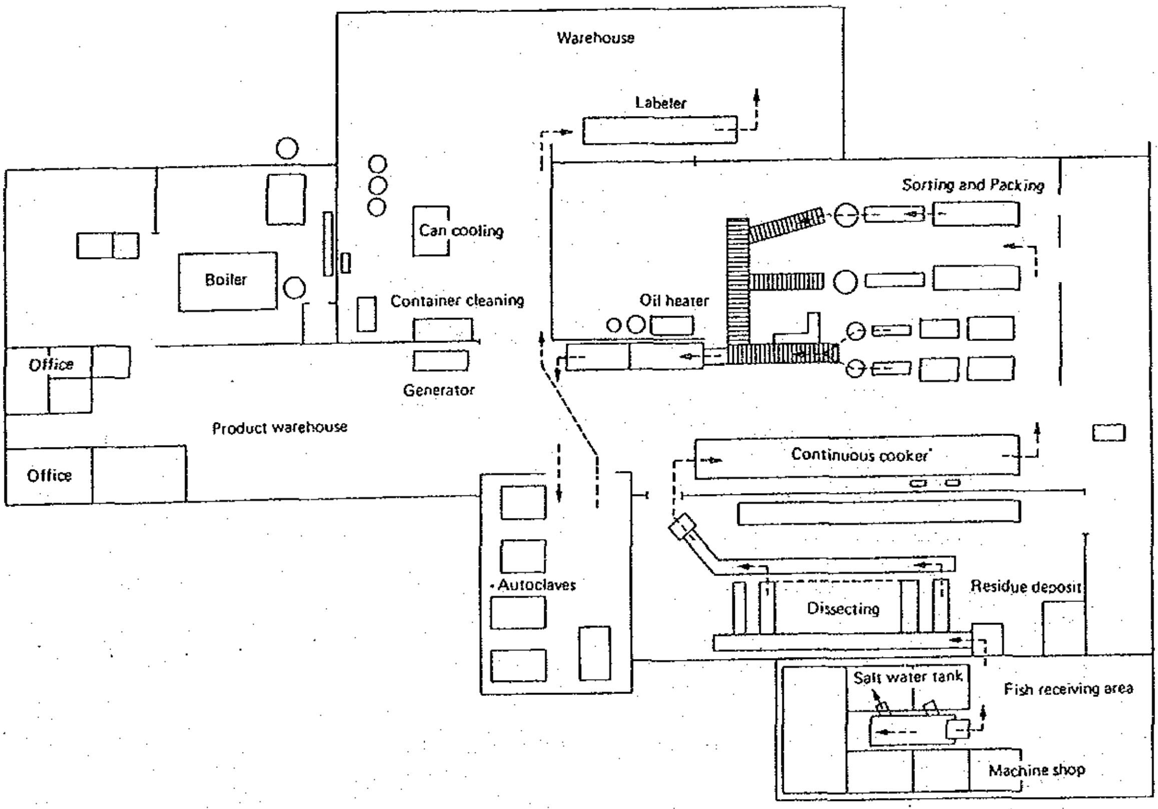


Figure 5–2–1 Plant Layout

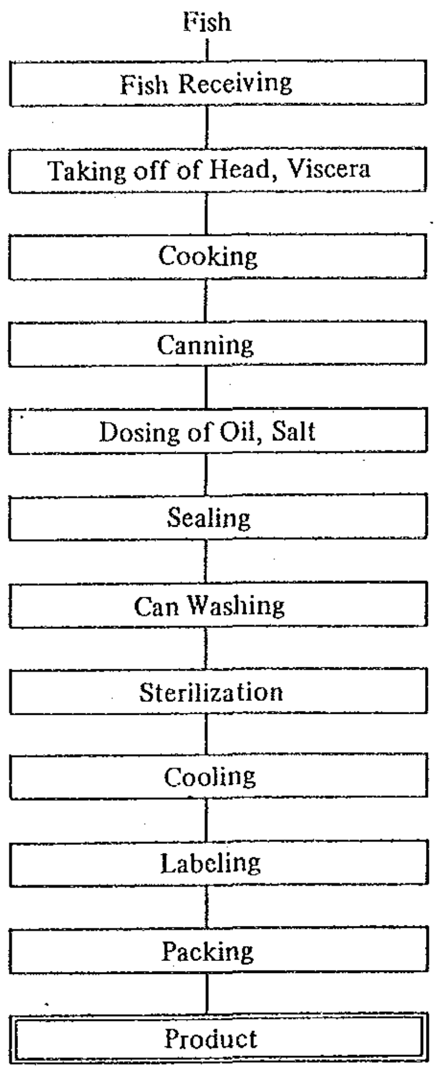


Figure 5–2–2 Production Process

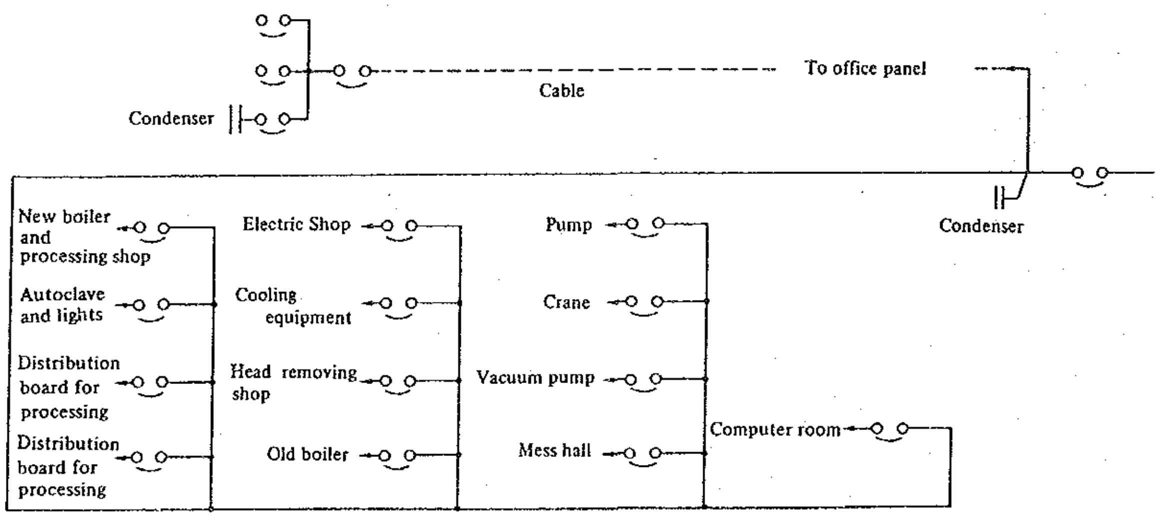


Figure 5–2–3 One Line Diagram

(14) Major Equipment

Table 5–2–3 Major Equipment

Name	Number	Specification
Cooker	3	2.2W X 2.2H X 3.81 (m)
Sterilizer	2	22.W X 2.2H X 2.5L (m)
Continuous Cooker	1	1.65W X 0.5H X 19.5L (m)
Can Washer	1	0.5W X 1.0H
Boiler	1	8t/h, 10 kg/cm^2
Room Airconditioner		
Ammonia Compressor	1	60 Hp

(15) Factory Operating Time

11 h/day X 5.5 days/week X 50 weeks/year = 3025 h/year

5.2.2 Energy Management

(1) Energy Conservation Target

Neither the company nor the factory has a set energy conservation target.

The factory manager is aware of and has a knowledge of the technical problems related to heat radiation from the equipment and pipings and the structure of the autoclave, and of their management methods. However, concrete steps for energy conservation have not been taken except for the renewal of the boiler to reduce costs by change of fuel because the factory considers that energy consumption is not so much with energy expenses account for only about 2% of the production cost and that a new investment cannot be justified at the present low rate of operation unless it will raise sales.

As pointed out later, however, there are some instances, for example, steam leakage from the continuous cooker, that can be remedied to prevent energy waste by taking precautions on the part of the employees without making a large investment. A system should be developed to enable the employees to voluntarily take remedial measures without instructions from the factory manager on each such occasion. It would be necessary first for the factory manager to have the employees be aware of the necessity of energy conservation and set a specific target for energy conservation, specifying monthly check on steam leakage, for example.

(2) Determining Energy Consumption Rate

The factory does not have fuel flow meters or integrating power meters to measure the energy consumption rates from time to time. Energy consumption rates are notified later to the factory manager by monthly reports prepared at the head office on the basis of purchase slips. Operating conditions, such as temperatures and pressures, are not recorded.

It is not possible, therefore, to perform daily management involving appropriate steps taken while keeping an eye on energy consumption. If energy consumption rapidly increases in a certain month, there is no data to check for the cause of it. There is neither a record of monthly energy consumption versus production so that energy consumption rates cannot be examined in long-range terms.

To improve the facilities and operation, it is essential to keep production, quality, energy, and other data in order and thus have accurate information on the factory. Unless data clearly showing the relationships of operating conditions, production, quality, and energy consumption are available, plans specifying points to be improved and how cannot be drawn up. If a certain value has changed, or if a deviation has occurred from a planned value or design value, the cause can be checked and a clue to improvement can be obtained. It is suggested that meters be installed where necessary and that their readings be recorded and periodically processed to obtain accurate information.

This factory consumes all heat energy as steam so that steam consumption trends can be determined by installing an integrating meter for feed water rate on the boiler feed water line and recording its readings every hour. Compare the recorded data with equipment operating condition, and production in order to identify the causes of waste. Change in boiler efficiency can be estimated by comparing the monthly totals of feed water and fuel consumption.

If boiler operating data is recorded daily in a journal, it may be used to assume the uncleanliness of the heating surfaces from exhaust gas temperature change and thus determine cleaning intervals, or to check other changes in long-range terms. A boiler journal should be kept by all means because it will be effective for not only direct saving of energy but also equipment maintenance.

Use separate power meters for the factory and office, and persons to be in charge of them respectively may keep an eye on electric power consumption and take appropriate steps.

(3) Education of Engineer and Training of Employees

The factory does not train the employees on its premises, but sends the engineer and foremen to the seminars held by the Mar del Plata University, INTI Fishery Research Center, INDEP (Fisheries Development Society), etc. However, most of the seminars are held in Buenos Aires, and it is hard for them to have an opportunity to take part in them.

The fish canning industry is not cooperative within the trade so there is no interest in exchanging technical information among the cannery operators. The engineers can hardly expect it as a means of improving technical level.

An engineer willing to voluntarily take steps for energy conservation cannot take action unless he has a knowledge of the required techniques or instances. Attending a seminar will encourage the engineer and rouse his interest in improvements. It is desirable, therefore, that persons be sent to outside seminars so that the knowledge acquired from such seminars may be transferred to other employees in the factory.

The person in charge of the boiler received a training course for qualifications conducted by the provincial ministry of sanitation, and had interest in improving boiler operation as can be witnessed from the fact that he attempted boiler heat balance calculation.

The employees in general are little involved in energy rate adjustment, but the foremen are providing advice on energy saving. The lights turning off at break time is well executed.

5.2.3 Problems with Use of Energy and Remedial Measures

5.2.3.1 Batch Type Cookers and Sterilizers

(1) Use of Cookers and Sterilizers

(a) Use of cookers

Large fishes, such as tunas and bonitos, are dissected and cleaned, then placed in iron net cases. About 60 net cases are placed on a single truck, and four to six trucks are placed in the cooker, where steam is directly introduced to cook the contents.

One iron net case weighs 3 kg, and holds 7 kg of fish in it. One truck weighs 30 kg. Thus, the total weight of trucks will be about 530 kg.

The cooker is a square, horizontal pressure vessel measuring about 2340 mm wide, 2110 mm high, and 3800 mm long. The factory uses three batch type cookers.

Steaming temperature is about 100 to 105°C and steaming time is about 2 and a half hours, which varies depending on fish size. It takes about an hour and 10 minutes for preparations (loading the material for steaming) and about 10 minutes to open the cooker and removing the trucks after steaming. Therefore, the time required to complete one cycle of operation will be about 3 hours and 50 minutes. Steam is injected into the cooker from the 20A pipes connected to the bottom of the cooker on both sides through nozzles 2.5 mm in diameter arranged in parallel.

Drains from the cookers that contain the fish soluble resulting from direct steam injection are disposed of.

The operation rate of the three batch type cookers is about 20% now, but will increase to about 120% in the period of about nine months from June through February when the cookers are used for 8 to 10 hours a day. The three cookers have a maximum capacity of processing about 40,000 kg of raw fish daily.

(b) Use of sterilizers

Cans out of the conveyor type continuous can washer are conveyed via the spiral guide into the containers on the trucks. Two to four trucks are placed together in a sterilizer, where steam is directly injected to sterilize the contents. One container holds 3,600 170-gram cans, 1,680 380-gram cans, or 3,380 180-gram cans.

The sterilizer is a square horizontal pressure vessel measuring 1860 mm wide, 1630 mm high, and 2600 mm long. Sterilizing temperature is about 110 to 120°C, and sterilizing time, including come-up time, is about 60 to 120 minutes. Two batch type sterilizers are now used. Steam pressure is regulated to about 1 ~ 1.5 kg/cm^2 using a valve.

After sterilizing, the containers out of the sterilizers are cooled by watering and blowing with a fan.

Condensate is not recovered now. It is assumed difficult to recover condensate because the sterilizers are used not only for sterilizing but also as cookers.

(2) Cooker Internal Heat Patterns

Temperature distribution in the cookers was measured during the steaming process. Steam conditions were as follows:

1) Fish: Cod

2) Quantity

Fish:	7 kg/case x 210 cases = 1,470 kg
Trucks:	30 kg/truck x 4 trucks = 120 kg
Iron net cases:	3 kg/case x 210 cases = 630 kg

3) Steaming time

Start:	11:14
Stop:	13:30
Steaming time:	2 hours 16 minutes
Come up time:	50 minutes
Net steaming me:	1 hours 26 minutes

4) Sensor positions for measuring temprature inside cookers

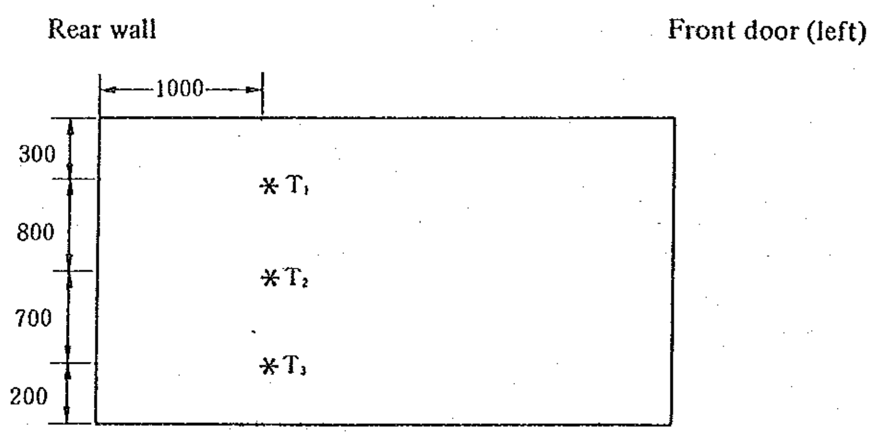


Figure 5–2–4 Sensor Positions for Measuring Temperature inside Cookers

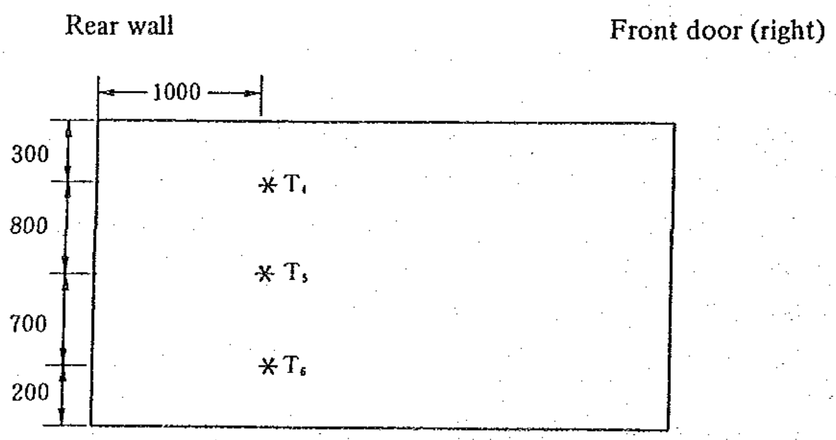


Figure 5–2–5 Sensor Positions for Measuring Temperature inside Cookers

5) Cooker internal temperature patterns

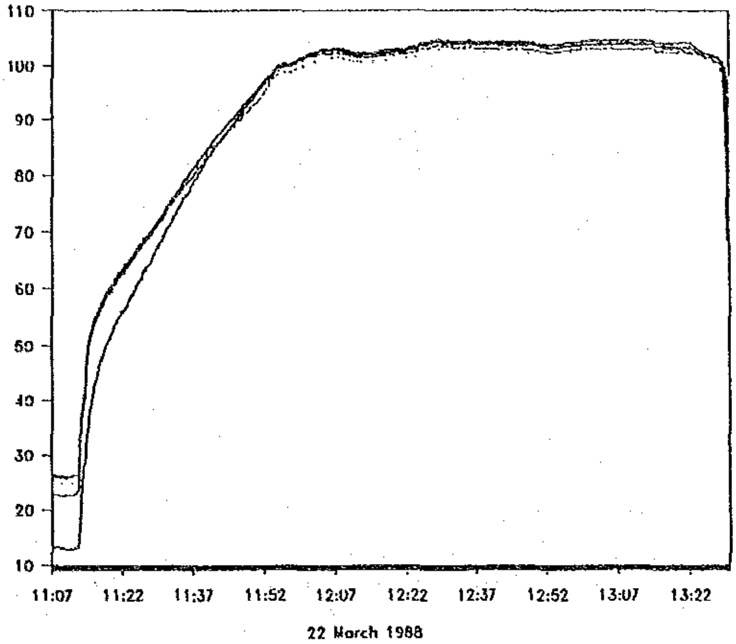


Figure 5–2–6 Inner Temperature of the Cooker

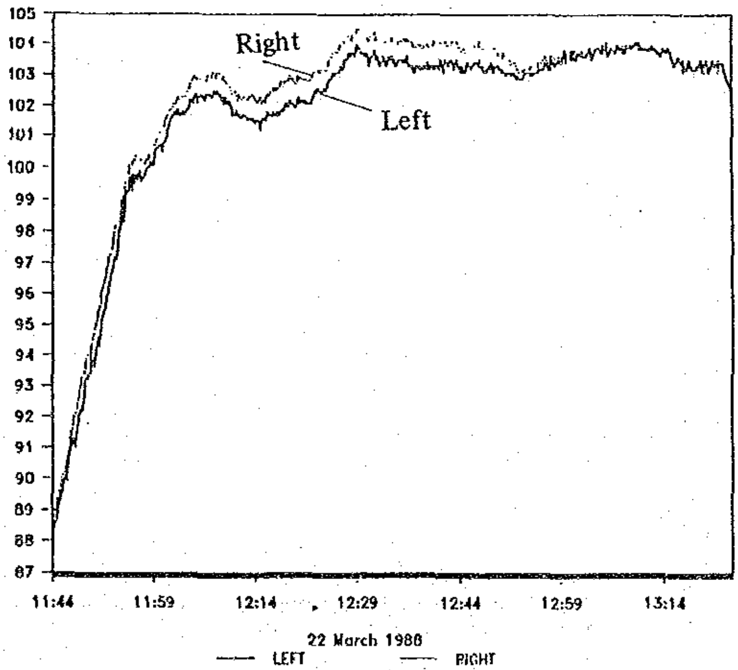


Figure 5–2–7 Inner Temperature of the Cooker (Upper part)

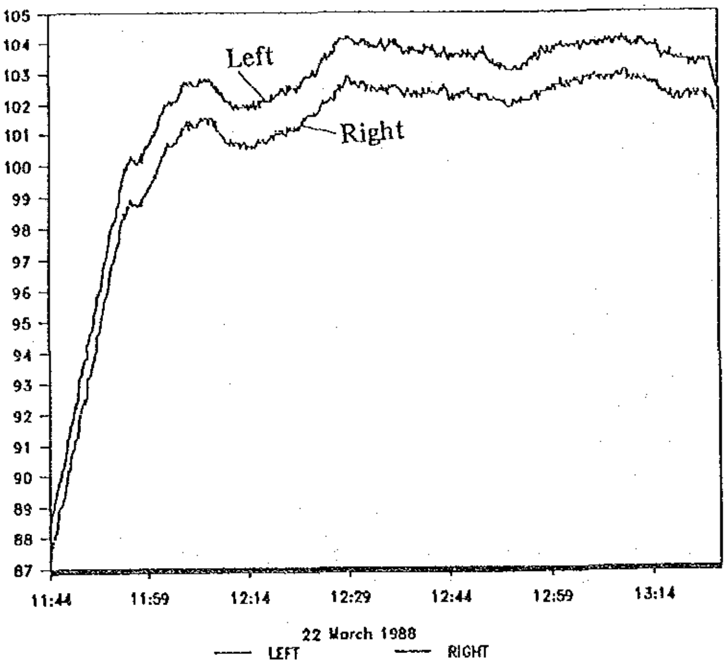


Figure 5–2–8 **Inner Temperature of the Cooker (Middle part)**

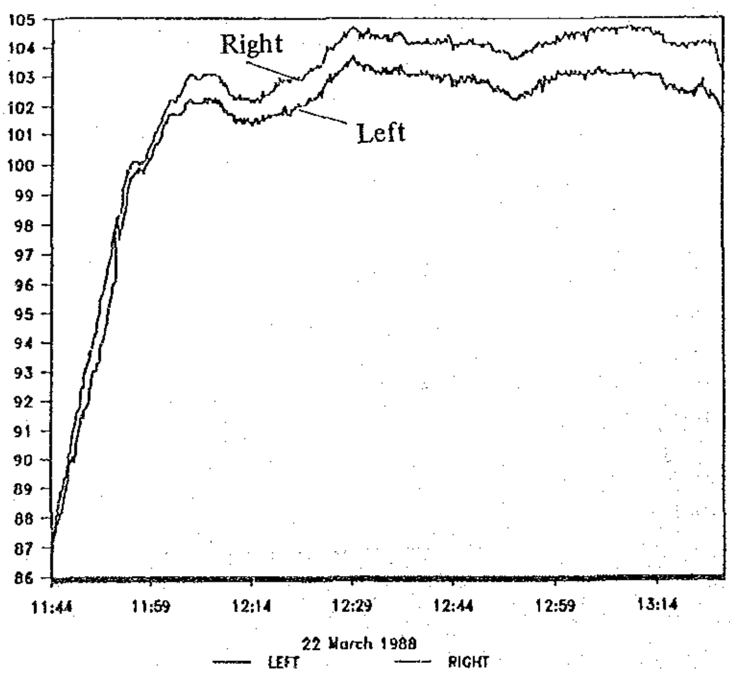


Figure 5–2–9 **Inner Temperature of the Cooker (Lower part)**

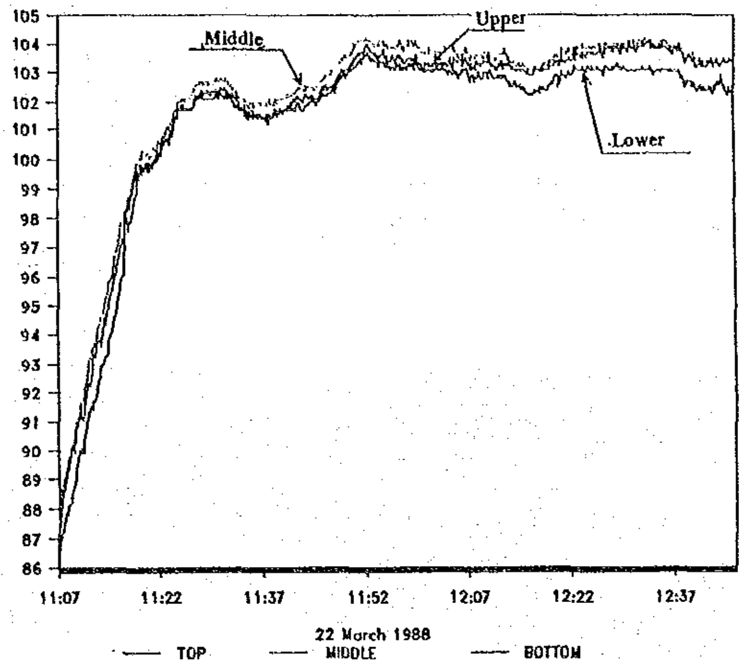


Figure 5–2–10 **Inner Temperature of the Cooker (Left side)**

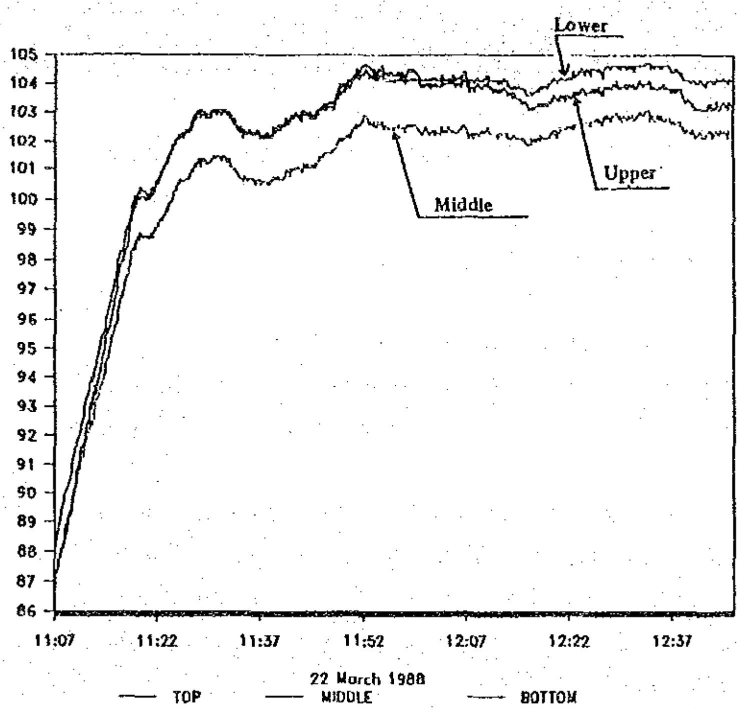


Figure 5–2–11 **Inner Temperature of the Cooker (Right side)**

The cooker internal temperature patterns show that the temperature rose to about 103°C at about 12:07, but fell to about 101°C at about 12:14. Temperature differences between the right and left were slight, less than about 0.5°C at upper level, and about 1°C at middle and lower levels. There was little difference in temperature distribution at upper, middle, and lower levels in the left. However, the temperature at middle level in the right was somewhat lower than that of upper or lower level.

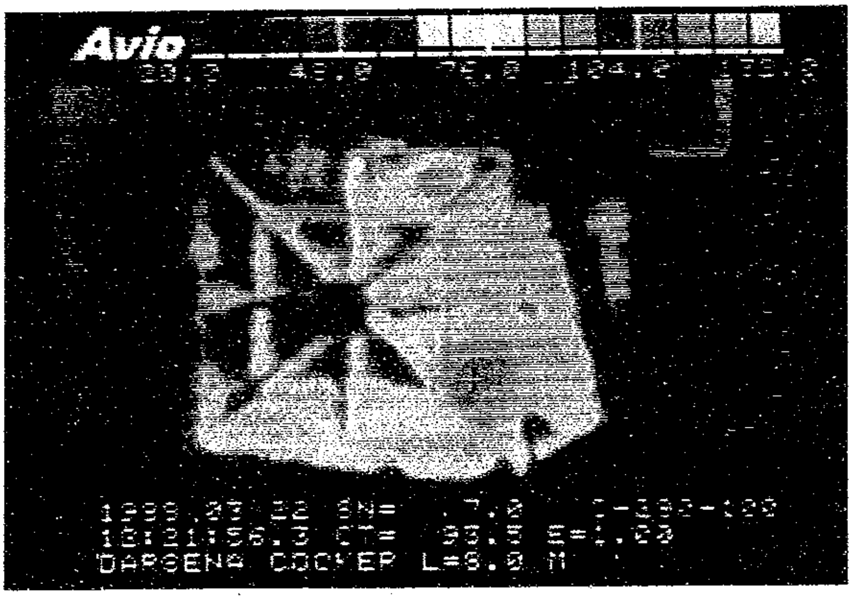


Figure 5–2–12 Thermal Picture of Cooker

Temperature differences were generally small. Come up time of 50 minutes should be shortened.

(3) Cooker Surface Temperature and Heat Radiation

Cooker surface temperature was measured, and the amount of heat radiated from the cookers for 2 hours and 16 minutes from start of steam injection to end of it was calculated.

The cookers are pressure vessels so their external surfaces are reinforced by welding H-shaped steel and flat bar. Thus, the total heat radiation surface must be calculated by adding the external surface area of the H-shaped steel and flat bar to the cooker surface area. The added heat radiation area per meter of H-shaped steel was 0.28 m^2 and that of flat bar was 0.20 m^2.

(a) Heat radiation area of each side of cooker

1) Right and left sides

Main body:	h 2,110 x L 3,800 = 8.02 m^2
H-shaped steel:	0.28 m^2 x h 2,000 x 9 lanes = 5.32 m^2
Flat Bar:	0.20 m^2 x L3,800 x 5 lanes = 3.80 m^2
Total:	17.14 m^2

2) Front

Main body:	h 2,110 x W 2,350 = 4.96 m^2
H-shaped steel:	0.28 m^2 x L 7,575 = 2.12 m^2
Flat bar:	0.20 m^2 x L 4,480 = 0.90 m^2
Total:	7.98 m^2

3) Rear

Main body:	h 2,110 x W 2,350 = 4.96 m^2
H-shaped steel:	0.28 m^2 x h 2,110 x 5 lanes ≒ 2.95 m^2
Flat bar:	0.20 m^2 x W 2,350 x 5 lanes = 2.35 m^2
Total:	10.26 m^2

4) Top

Main body:	W 2,350 x L 3,800 = 8.93 m^2
H-shaped steel:	0.28 m^2 x W2,110 x 9 lanes = 5.32 m^2
Flat bar:	0.20 m^2 x L 3,800 x 3 lanes = 2.28 m^2
Total:	16.53 m^2

(b) Surface temperature and heat radiation from each side of cooker

The temperatures of L_3, L_4, and L_5 were measured with a thermocouple, and the temperatures of the other parts with a pocket type surface thermometer. Calculations are based on an average room temperature of 27.9°C and no winds.

1) Right side

Table 5–2–4

Measuring time	11:34	12:04	12:34	13:00
Time passed	After 20 minutes	After 50 minutes	After 80 minutes	After 110 minutes
Right side (R1) (°C)	69	97	97	99
Right side (R2)	72	99	101	100
Right side (R3)	71	90	101	100
Right side (R4)	68	94	97	99
Right side (R5)	73	100	101	102
Average temperature	70.6	96.0	99.4	100.0
Heat radiation kcal/(m^2·h)	329	601	641	648

The amount of heat radiation for 2 hours and 16 minutes from the start of sending steam to the end of it was calculated as follows, provided that the emissivity of the cooker was assumed to be 0.5.

Amount of heat radiated for 20 minutes after start: $\frac{329 \text{ kcal}(m^2 h)}{2} \times 20/60 \text{ min} = 55 \text{ kcal}/m^2$

Amount of heat radiated for 30 minutes till 50 minutes after start $\frac{329 \text{ kcal}/(m^2 h) + \text{kcal}/(m^2 h)}{2} \times 30/60 \text{ min} =$ 233 kcal/m^2

Amount of heat radiated for 30 minutes till 80 minutes after start $\frac{601 \text{ kcal}/(m^2 h) + 641 \text{ kcal}/(m^2 h)}{2} \times 30/60 \text{ min} =$ = 310 kcal/m^2

Amount of heat radiated for 30 minutes till 110 minutes after start $\frac{641 \text{kcal}/(m^2 h) + 648 \text{ kcal}/(m^2 h)}{2} \times 30/60 \text{ min} =$ 322 kcal/m^2

Amount of heat radiated for the last 26 minutes:

$648 \text{ kcal}/(m^2 h) \times 26/60 \text{ min} = 281 \text{ kcal}/m^2$

Total amount of heat radiated: 1,201 kcal/m^2

2) Left side

Table 5–2–5

Measuring time	11:34	12:04	12:34	13:04
Time passed	After 20 minutes	After 50 minutes	After 80 minutes	After 110 minutes
Left side (L1) (°C)	63	99	101	99
Left side (L2)	73	100	100	101
Left side (L3)	76	92	95	95
Left side (L4)	74	94	95	94
Left side (L5)	78	99	100	101
Average temperature	72.8	96.8	98.2	98
Heat radiation $\text{kcal}/(m^2 \cdot h)$	241	479	494	492

Note: There was a clearance of about 300 mm between the left side of the cooker and the wall. The surface temperature of the wall was about 40 to 45°C. Calculations were made, assuming that room temperature was 40°C.

As same as the right side, the amount of heat radiated for 2 hours and 16 minutes from the start of sending steam to the end of it was calculated as follows. If the emissivity of the cooker surface is assumed to be 0.5 and that of the wall 0.9, the emissivity between the two will be 0.474.

Amount of heat radiated for 20 minutes from start = 40 kcal/m^2

Amount of heat radiated for 30 minutes till 50 minutes after start = 180 kcal/m^2

Amount of heat radiated for 30 minutes till 80 minutes

after start = 243 kcal/m²

Amount of heat radiated for 30 minutes till 100 minutes

after start = 247 kcal/m²

Amount of heat radiated for the last 26 minutes = 213 kcal/m²

Total 923 kcal/m²

3) Front

Table 5–2–6

Measuring time	11:34	12:04	12:34	13:04
Time passed	After 20 minutes	After 50 minutes	After 80 minutes	After 110 minutes
Front (F1) (°C)	57	91	96	96
Front (F2)	67	97	99	99
Front (F3)	62	94	99	99
Front (F4)	62	95	100	100
Average temprature	62.0	94.3	98.5	98.5
Heat radiation kcal/(m²·h)	248	581	630	630

As in the case of the right side, the amount of heat radiated for 2 hours and 16 minutes from the start of sending steam to the end of it was calculated as follows, provided that the emissivity of the cooker surfaces was assumed to be 0.5.

Amount of heat radiated for 20 minutes after start: = 41 kcal/m²

Amount of heat radiated for 30 minutes till 50 minutes

after start = 207 kcal/m²

Amount of heat radiated for 30 minutes till 80 minutes

after start = 303 kcal/m²

Amount of heat radiated for 30 minutes till 110 minutes

after start = 315 kcal/m²

Amount of heat radiated for the last 26 minutes = 273 kcal/m²

Total 1,139 kcal/m²

4) Rear

Table 5–2–7

Measuring time	11:34	12:04	12:34	13:04
Time passed	After 20 minutes	After 50 minutes	After 80 minutes	After 110 minutes
Rear (B1) (°C)	82	99	101	101
Rear (B2)	71	100	101	100
Rear (B3)	80	100	100	101
Rear (B4)	80	99	101	101
Average temperature	78.3	99.5	100.8	100.8
Heat radiation kcal/(m^2·h)	407	642	657	657

As same as right side, the amount of heat radiated for 2 hours and 16 minutes from the start of sending steam to the end of it was calculated as follows, provided that the emissivity of the cooker surfaces was assumed to be 0.5.

Amount of heat radiated for 20 minutes after start	= 68 kcal/m^2
Amount of heat radiated for 30 minutes till 50 minutes after start	= 262 kcal/m^2
Amount of heat radiated for 30 minutes till 80 minutes after start	= 325 kcal/m^2
Amount of heat radiated for 30 minutes till 110 minutes after start	= 329 kcal/m^2
Amount of heat radiated for the last 26 minutes	= 285 kcal/m^2
Total	1,269 kcal/m^2

5) Top

Table 5–2–8

Measuring time	11:34	12:04	12:34	13:04
Time passed	After 20 minutes	After 50 minutes	After 80 minutes	After 110 minutes
Top (S1) (°C)	76	96	96	96
Top (S2)	77	92	93	95
Top (S3)	75	97	92	93
Top (S4)	79	93	94	98
Top (S5)	78	93	96	97
Average temperature	77.0	94.2	94.2	95.8
Heat radiation kcal/(m² ·h)	516	752	752	776

As same as the right side, the amount of heat radiated for 2 hours and 16 minutes from the start of sending steam to the end of it was calculated as follows, assuming that the emissivity of the top was 0.8 because it was stained.

Amount of heat radiated for 20 minutes after start	= 85 kcal/m²
Amount of heat radiated for 30 minutes till 50 minutes after start	= 316 kcal/m²
Amount of head radiated for 30 minutes till 80 minutes after start	= 376 kcal/m²
Amount of heat radiated for 30 minutes till 110 minutes after start	= 382 kcal/m²
Amount of heat radiated for the last 26 minutes	= 335 kcal/m²
Total	1,495 kcal/m²

6) Bottom

Heat radiation from the bottom was disregarded

7) Total amount of heat radiated from cooker

Right side	1,201 kcal/m² x 17.14 m²	=	20,585 kcal
Left side	923 kcal/m² x 17.14 m²	=	15,820 kcal
Front	1,139 kcal/m² x 7.98 m²	=	9,089 kcal
Rear	1,269 kcal/m² x 10.26 m²	=	13,020 kcal
Total			83,226 kcal

Therefore, the amount of heat radiated per hour will be: 83,226 kcal x 60/136 min = 36,717 kcal/h

(4) Heat Balance

(a) Calculating cooker weight

H-shaped steel:	100 mm x 50 mm x 5/7; 9.3 kg/m x total length 94.085 m	= 875 kg
Flat bar:	100 mm x 12 mm; 9.42 kg/m x total length 70.03 m	= 660 kg
Steel plate:	12 mm; 94.2 kg/m² x 43.82 m²	= 4,128 kg
	Total	5,663 kg

(b) Cooker heat balance and quantity of steam

The heat required for steaming a batch of can be calculated as follows, assuming that the specific heat of material fish is 0.85 and the specific heat of the iron net cases, trucks and cookers is 0.117 and that reference temperature is 27.9°C.

	Weight	Specific heat	Final temperature	Heat	Percentage
Material fish steamed	1,470 kg	0.85	105°C	96,336 kcal	36.5%.
Iron net case	630 kg	0.117	105°C	5,683 kcal	2.2
Truck	120 kg	0.117	105°C	1,082 kcal	0.4
Cooker	5,663 kg	0.117	105°C	51,084 kcal	19.4
Heat radiation				83,226 kcal	31.5
Other unknown heat	10 %			26,379 kcal	10.0
Total				263,790 kcal	100.0

The 10% unknown heat was estimated from live steam discharge during the steaming process. Thus, the required heating value per hour will be:

263,790 kcal x 60/136 min = 116,378 kcal/h

If blow steam pressure is 0.4 kg/cm², the latent heat of evaporation will be 642.7 kcal/kg. Thus, the total required quantity of steam will be:

263,790 kcal ÷ (642.7 − 105) kcal/kg = 491 kg.

The amount of steam used per hour will be:

495 kg x 60/136 = 216 kg/h

The amount of steam used per kilogram of material fish will be 0.33 kg.

(5) Problems and Remedies

(5.1) Heat Radiation from Cooker Surface

The most effective way of saving steam for autoclaves is to reduce surface heat radiation by heat insulation. The autoclaves in this factory are not heat-insulated at all. As shown in the heat balance table, therefore, there is a heat loss of about 32%.

(a) Reduction of heat radiation by heat insualtion

Heat insulation with rock wool ($\lambda = 0.0382$ kcal/(mh°C) 25 mm thick will lower the surface temperature to 40°C. Spraying rock wool, for example, is recommended be cause of the ribs of H-shaped steel and band steel.