Report No. 5: Plastic & Chemical

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

— Siam Union Sahamitr Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Siam Union Sahamitr Co., Ltd. —

1. Outline of the Factory

Address	117 Thepark Rd. T. North Samrong A. Mueng Samutprakarn	
Capital	30 Million Bt	
Type of industry	Chemical	
Major products	Coconut oil, margarin and soap	
Annual product	Coconut oil 6,000 ton, Margarin 1,440 ton, Soap 1,900 ton	
No. of employees	150	
Annual energy consumption	Electric power	1,027.4 x 10^3 kWh
	Fuel	Bunker A 200 kℓ Bunker C 800 kℓ
Interviewees	Factory manager Mr. Banyat Technical adviser Mr. Wiboon.	
Date of diagnosis	July 14 ~ 15, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

This company was established 36 years ago with capitalization by the Thailand. The existing factory has passed sixteen years of its operation since the startup. It has thus far changed its owner three times.

In its early days, the company was also manufacturing crude coconut oil through its expression. At present, however, it is no longer in the expression work but is refining crude coconut oil purchased from other supply sources. Most of the final product coconut oil is put to its captive use, and the remainder sold on the local market.

Furthermore, the company is a general oil and fat product manufacturer who is producing margarine, soap and glycerine based on coconut oil as a starting material.

The company's production scale in the industry ranks third in coconut oil, second or third in margarine, fourth in glycerine and sixth in soap. The company is classed as one of the large manufacturers in overall gross sales in the oil and fat industry.

Their product price is sufficiently competitive on the international market, because all the raw materials are produced locally. Even byproducts are turned into finished products, so their productivity is high.

2. Manufacturing Process

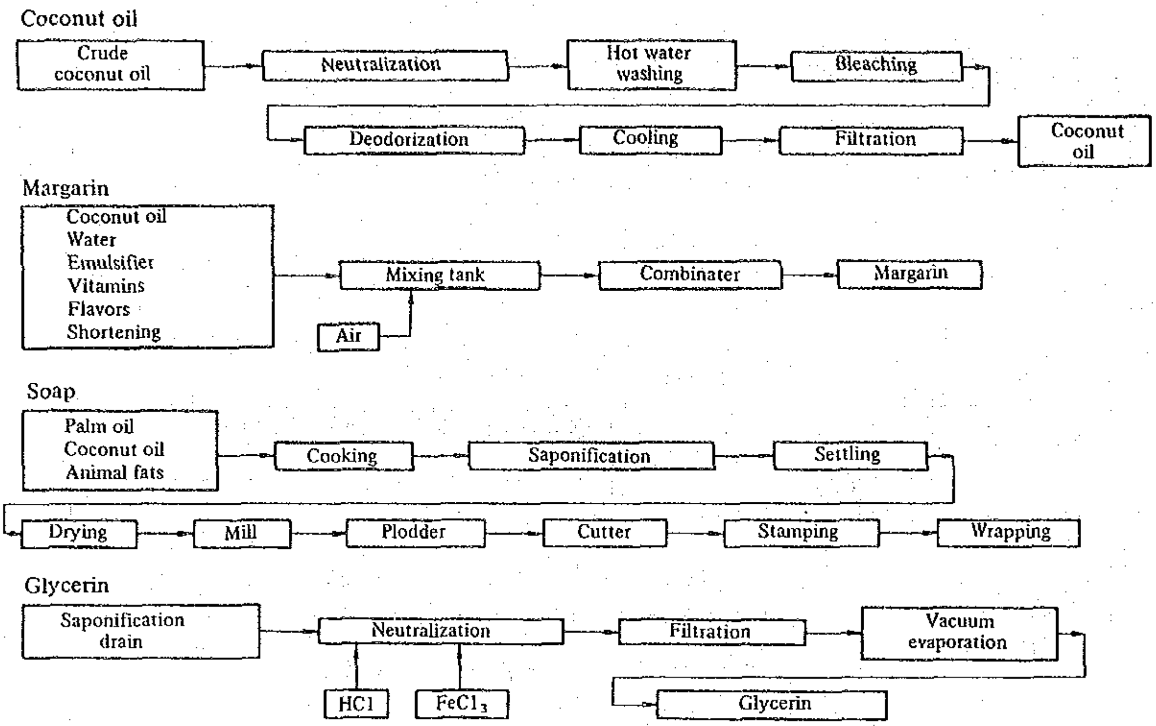


Fig. 5–1

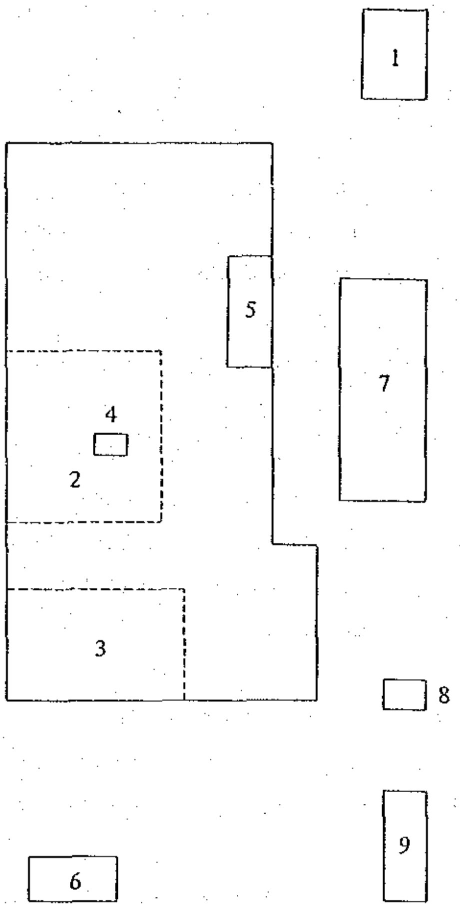
3. Major Equipment

3.1 Major Equipment

Table 5–1

Name	No. of units installed	Type, etc.
Coconut oil plant	1	Neutralizer 3 Decolorizer 3 Hot water washer 2 Deodorizer 2 Oil cooler 1 Essotherm heater 1
Soap plant	1	Kettle 6 Flash dryer 1 Mill 1 Plodder 1
Margarin plant	1	Mixing tank 1 Combinater 1 Chiller unit 1
Glycerin plant	1	Neutralizer 1 Distillation column 1 Evaporater 1
Boiler	3	9 t/h x 10 kg/cm^2 2 1.7 t/h x 14 kg/cm^2 1

3.2 Layout



1 Office
2 Coconut oil plant
3 Saponification plant
4 Boiler (10 t/h)
5 Margarin plant
6 Boiler (10 t/h)
7 Soap making plant
8 Boiler (1.7 t/h)
9 Glycerin plant

Fig. 5–2

4. State of Energy Management

4.1 Policy for Energy Conservation

The company is actively putting their effort to conserve energy with measures aimed at its realization. This year, the company has already invested 120,000 Bt for the insulation and condensate recovery. In addition, the company is scheduled to invest 100,000 Bt. Condensate equivalent to approx. 30% of the generated steam is now recoverable, yet the effect of investment has not quantitatively been confirmed. Incidentally, the definite payback time for investment in the energy conservation measures has not been set.

A new boiler (9 t/h) was put into active service a few months ago and the old boiler is now idle. Energy conservation due to the former's high operating efficiency is expected.

A conversion work for the existing batch-type coconut oil deodorization process to a continuous system is now underway. If completed, the waste heat which has not been utilized thus far can be recovered, hence a significant advantage will be expected.

4.2 Participation by All Employees

No voluntary activities such as QC circle exist now. Neither the work improvement suggestion system nor the commendation system is instituted. Improvement of the operation is regarded as a job by the staff members only and the general workers have no part in the activities for operational improvement.

The factory general manager appeals energy conservation only to the staff members at the meeting.

4.3 Control through Data

The fuel consumption of each kind is determined on a daily measurement of the stores in each tank, thus making available the figure of total fuel consumption for the whole factory. Further, the purchase quantities of fuel, raw material and secondary raw material are actually measured by a truck scale of the company to confirm the quantity of a delivery slip.

The company also determines a monthly electric power consumption by the whole factory for a month, referring to a bill submitted by the power company.

No steam flowmeter and no watt meter for each process are provided. Therefore, energy consumption per process cannot be grasped quantitatively. In order to exactly control energy at the factory where steam being used at many equipments, it is recommended that a steam flowmeter be installed specially on equipment which consumes a large quantity of energy such as saponification, bleaching and deodorizing.

4.4 Education and Training, Technical Leveling-Up of Employees

No energy conservation committee is yet organized. However, the employees discuss energy conservation problems at a weekly meeting centering around the factory general manager.

The company sends only boiler men to an external seminar once a year. It does not organize any visit to other manufacturers' factories for educational purposes. Further, joint activities and information exchanges have not taken place in the industry at all.

5. State of Fuel Consumption

5.1 State and Breakdown of Fuel Consumption

Heavy oil A		200 kl/year
Consumed for	(1)	boiler (1.7 t/h × 14 kg/cm^2)
		operated for 24 h/day × 90 days/year
	(2)	heating medium heater
		operated for 24 h/day × 300 days/year
Heavy oil C		800 kl/year

Consumed for boiler (9 t/h × 10 kg/cm^2) operated for 24 h/day × 300 days/year

5.2 Heat Balance of Boiler

No integrating feed water flowmeter and integrating steam flowmeter are provided. So it is difficult to determine an evaporation. However, assuming that the blow loss represents 0.5%, heat release and other loss 5%, the rough heat balance was calculated as shown in Table 5-2.

Table 5–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	1,085.70	99.7	Heat of steam	933.56	85.7
Sensible heat of fuel	3.47	0.3	Heat loss in exhaust gas	95.59	8.8
			Heat loss in blow water	5.56	0.5
			Heat release from boiler body, others	54.46	5.0
Total	1,089.17	100	Total	1,089.17	100

Elements for Calculation of Heat Balance

Type of Fuel		Heavy oil C
Fuel Consumption	(F)	110.0 kg/h
Calorific Value of Fuel (Low Value)	(Hl)	9,870 kcal/kg
Specific Gravity of Fuel	(SG)	0.952
Specific Heat of Fuel	(Cp)	0.45 kcal/kg°C
Temperature of Fuel	(Tf)	105°C
Reference Temperature	(To)	35°C
O_2% in Waste Gas	(O_2)	7.7%
Temperature of Waste Gas	(Tg)	190°C
Quantity of Blow Down Water	(B)	40 kg/h
Temperature of Blow Down Water	(Tb)	179°C
Quantity of Feed Water	(W)	1,538 kg/h
Temperature of Feed Water	(Tw)	40°C
Steam Pressure	(P)	9.0 kg/cm^{2}G
Evaporation (S=W − B)	(S)	1,498 kg/h
Enthalpy of Steam	(Es)	663 kcal/kg
Enthalpy of Feed Water	(Ef)	40 kcal/kg

Equation for Calculation of the Heat Balance

Input

Combustion heat of fuel (Qc) $1{,}085.70 \times 10^3$ kcal/h

$$Qc = F \times Hl$$

Sensible heat of fuel (Qs) 3.47×10^3 kcal/h

$$Qs = F \times Cp(Tf - To)$$

Output

Heat of steam	(Qv)	933.56×10^3 kcal/h
$Qv = S \times (Es - Ef)$		
Heat loss in exhaust gas	(Qe)	95.59×10^3 kcal/h
$Qe = F \times G \times 0.33(Tg - To)$		
Theoretical amount of air	(Ao)	
$Ao = 0.85\ Hl/1{,}000 + 2.0 = 10.39\ Nm^3/kg$		
Theoretical amount of exhaust gas (Go)		
$Go = 1.11\ Hl/1{,}000 = 10.96\ Nm^3/kg$		
Air ratio (m)		
$m = 21/(21 - O_2) = 1.58$		
Actual amount of exhaust gas	(G)	
$G = Go + Ao(m - 1) = 16.99\ Nm^3/kg$		
Heat loss in blow down water	(Qb)	5.56×10^3 kcal/h
$Qb = B \times (Tb - Tw)$		
Heat release from body and others	(Qr)	54.46×10^3 kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Boilers

(1) Improvement of Combustion

The oxygen concentration in exhaust gas is as rather high as 7.7% at 40% of boiler load. The air ratio is m = 1.58. This value is higher than the appropriate air ratio of m = 1.3. It is desired, therefore, the air damper for burner be adjusted for the operation at an appropriate air ratio.

If the air ratio of m 1.58 is reduced to 1.3 by improving the combustion, the estimated reduction of fuel consumption will be as follows:

When m is equal to 1.3, the amount of exhaust gas G is a represented by the following equation:

$$G' = 10.96 + 10.39(1.3 - 1) = 14.08\ Nm^3/kg$$

Assuming that the estimated fuel consumption after improvement of the combustion is equal to x kg/h, the following equation will be established according to the boiler heat balance.

$$\frac{1{,}089.17 \times 10^3 x}{110} = (933.56 + 5.56 + 54.46) \times 10^3 + 14.08 \times 0.33 \times (190 - 35)x$$

$$x = 108.2\ l/h$$

Therefore, the estimated fuel reduction rate will be represented by the following equation:

$$\frac{F - x}{F} \times 100 = \frac{110 - 108.2}{110} \times 100 = 1.6\%$$

The estimated annual fuel conservation will be

800 kl/year × 0.016 ≒ 12.8 kl/year.

If this amount is converted to a monetary value, it will be 12.8 × 4,359 ≒ 55,800

Bt/year.

(2) Installation of Combustion Control Instruments

The existing boiler is a new one which was installed recently, and is kept in satisfactory insulation condition. Especially, a steam flowmeter which provides a definite amount of steam consumption is installed.

This is suggestive of the company's being highly conscious about energy control. We sincerely hope you will make the best use of the said instrument. We also hope you will study the feasibility of attaching an integrating meter to the instrument aiming more scrupulous combustion control of the boiler. At present, no oil flowmeter is installed. However, it is desired that this flowmetter be installed by all means for determining an evaporation multiple, an item which is controlled as an indicator of boiler efficiency on a daily base.

The evaporation ratio is represented by the following equation:

$$\text{Evaporation multiple} = \frac{\text{Amount of generated steam}}{\text{Amount of consumed oil}}$$

In addition to the above instruments, it is suggested that study be conducted to install any instruments which are helpful for combustion control such as feed water flowmeter and exhaust gas thermometer.

6.2 Recovery of Condensate and Utilization of Flash Steam

Steam-using facilities are scattered extensively throughout the factory. So it is only part of the oil refining process and the glycerine manufacturing process from which the condensate is recovered. However, the temperature of the feed water tank into which the condensate is recovered is approx. 40°C. For this reason, we estimate that the condensate is not recovered as scheduled, although the glycerine process is not in operation. Explained below are the possible causes and remedial procedures. The facilities are of such a design that the condensate discharged from the oil refining process is once collected into the recovery tank and then is fed into the feed water tank by means of a pump. Because of the failure of the ON-OFF floating-type level switch for actuating the condensate recovery pump, the condensate was not being recovered into the feed water tank, and was overflowing from the recovery tank to the pit. As a matter of fact, the temperature of the condensate recovering piping was as low as 40°C when we checked on it. It is suggested that the above system including the recovery pump be checked up on a daily base and at the same time, the level switch be repaired.

We also noticed an oily fouling on the condensate surface in the recovery tank. Therefore, we feel it is necessary to promptly check possible spots where foreign matter is mixed with condensate. It is also necessary to periodically check on the quality of condensate.

As a way of making the efficient use of steam, it is recommended that the condensate be once received into a closed pressure vessel and allowed to evaporate at a lower pressure than a steam service pressure, and that the steam thus obtained be used as a flash steam.

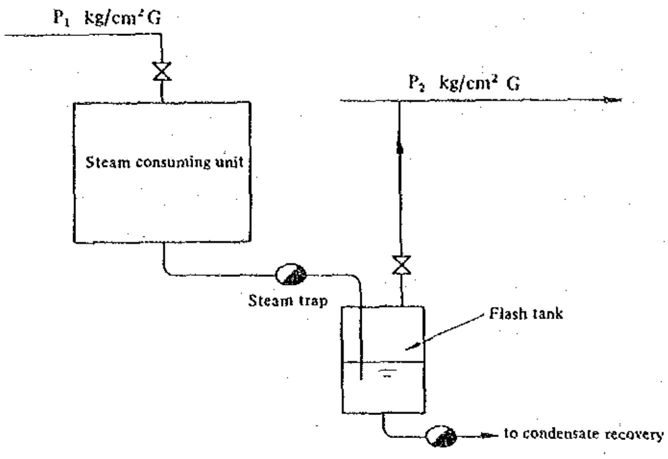


Fig. 5-3

For instance, as shown in Fig. 5-3, if a flash tank is provided, the steam flashed at a lower pressure P_2 than the primary side pressure P_1 can be used as a low-pressure steam. This amount is calculated by the following equation:

Flash steam evaporation amount Gkg of P_2kg/cm^{2}G per kg of condensate of P_1 kg/cm^{2}G is expressed as:

$$G = \frac{h_1 - h_2}{\gamma_2}$$

Here,

h_1 Enthalpy kcal/kg of saturated water at P_1 kg/cm^{2}G

h_2 Enthalpy kcal/kg of saturated water at P_2 kg/cm^{2}G

r_2 Evaporation heat kcal/kg at P_2 kg/cm^{2}G

For instance, if flash steam at 3 kg/cm^{2}G is evaporated using 1 t/h of condensate at 9 kg/cm^{2}G, approx. 7.4% of flash steam is obtained as shown in the following equation:

$$G' = \frac{(181.3 - 143.7)}{510} \times 1{,}000 = 74 \text{ kg/h}$$

This flash steam contains approx. 27% of the calorific value of condensate.

6.3 Steam Trap Control

The steam trap is a device requiring a periodical check, so it should be checked more than once a month for clogging or leakage. A check instrument called "trap tester" is available for checkup, or it is suggested that a test valve as shown in Fig. 5-4 be installed for confirmation.

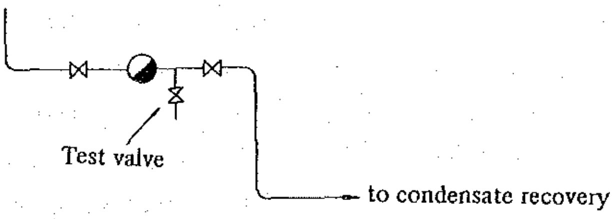


Fig. 5-4

In the neutralization and hot water washer of the oil refining process, it was found that some bypass valves around the steam traps were opened. This method is not effective and a heat loss is significant on account of wasteful steam release. The advantage of using steam as a heating medium, is the possibility to use a larger quantity of condensation heat and the exceedingly high heat transfer rate at the time of condensation. If the bypass valve is opened to let the steam pass through without utilization of the latent heat, it happens that the steam will be wasted.

6.4 Prevention of Air Trapping in Steam Heating Jacket

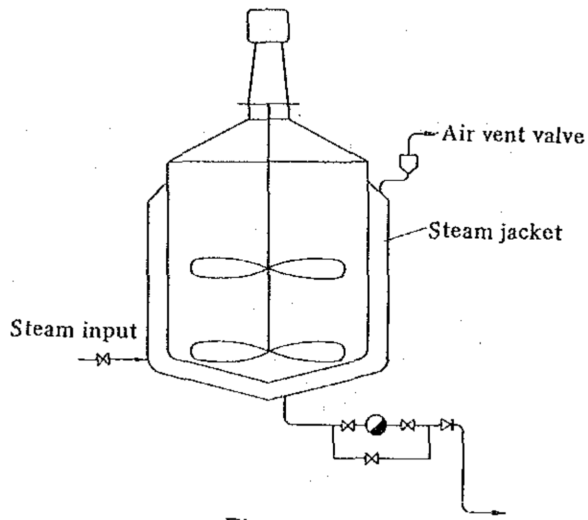


Fig. 5-5

Air often tends to be trapped in the upper part of the jacket as shown in Fig. 5-5. This would result in the temperature drop in the said part and a subsequent qualitative trouble.

In order to prevent this trouble, it is the best way to install an air release valve of temperature detection control type at a spot where an air is structurally apt to be trapped. Specially the said valve is required for a device to repeat the batch-type cycle of steam feed and discharge.

6.5 Prevention of Heat Loss with Improved Insulation

(1) If insulation is repaired and upgraded or newly installed for the following facilities, a large amount of energy will be conserved:

Each reactor using steam in the factory, steam piping, condensate recovery tank, condensate recovery piping in the oil refining process and feed water tank.

The effects of insulation improvement on the major items and cost involved are shown in Table 5-3. The cost will be recovered in a short period of time.

If 80% of the heat loss can be prevented by insulation, the estimated amount of conserved heat will be represented by the following equation:

$1{,}555 \times 10^6 \times 0.8 = 1{,}244 \times 10^6$ kcal/year

If this estimated amount is converted to a fuel equivalent, it will be represented by the following equation:

Table 5–3

Equipment or piping	Specification	Heat loss per unit length or area kcal/m² h	Heat loss per hour kcal/h	Estimated insulation cost Bt
Condensate recovery tank A	$1.3^L \times 1.3^W \times 2.0^H$ Surface area 13.8 m² Skin temperature 83°C	550	7,590	6,900
Condensate recovery tank B	$1.5\phi \times 1.4^H$ Surface area 10.2 m² Skin temperature 87°C	600	6,120	5,100
Boiler feed water tank	Surface area 22.5 m² Skin temperature 80°C (When condensate is recovered)	500	11,250	11,250
Condensate recovery piping	1½" x 150 m Skin temperature 80°C	80	12,000	45,000
Steam piping (including valves)	Equivalent length to 3" pipe 200 m	620	124,000	76,000
Tanks	20 m² x 2 units (temp. 80°C)	500	20,000	10,000
	35 m² x 2 units (temp. 80°C)	500	35,000	17,500
	Total		215,960	171,750

Annual heat loss $216.0 \times 10^3 \times 300^d \times 24^h = 1,555 \times 10^6$ kcal/year

$$\frac{1,244 \times 10^6}{9,870 \times 0.85 \times 0.952} = 155.8 \text{ kcal/year}$$

If this amount is converted to a monetary value, it will be as follows: 155.8 × 4,123 Bt ≒ 642,400 Bt/year. The estimated cost involved in insulation will be approx. 172,000 Bt.

Again we request you to carry out the above work.

(2) At the deodorizing unit of the oil refining process, the oil is heated at high temperature using "ESSO-Therm" heating medium. However, insulation for the heater, piping and deodorizing tank has fallen due to its becoming old, so it is necessary to repair and reinforce the insulation by all means. The expected improvement effect and cost of the insulation are shown in Table 5-4.

Table 5–4

Equipment or piping	Specification	Heat loss per unit length or area kcal/m² h	Heat loss per hour kcal/h	Estimated insulation cost Bt
Expansion pot of Essotherm	$0.6\phi \times 1.8^L$ Surface area 5.4 m² (Including piping) Skin temperature 220°C	3,460	18,680	2,700
Piping, valves	2" x 50 m Surface area 10 m² Skin temperature 95°C	730	7,300	5,000
Deodorizing tank neutralizing tank	$2.0\phi \times 3.5^H \times$ 6 units Surface area, 28 m² x6=168 m² Skin temperature 95°C	730	122,640	84,000
	Total		148,620	91,700

Annual heat loss $148,620 \times 300^d \times 24^h = 1,070 \times 10^6$ kcal/year

Assuming that 80% of the heat loss can be prevented, the following advantage is estimated:

$1{,}070 \times 10^6 \times 0.8 \fallingdotseq 856 \times 10^6$ kcal/year

If converted to fuel

$$\frac{856 \times 10^6}{9{,}888 \times 0.85} = 101.8 \text{ kl/year}$$

If converted to monetary value,

$101.8 \times 4{,}359$ Bt $= 443{,}700$ Bt/year

Against the above figures, cost involved in insulation is estimated at approx. 91,700 Bt. It is possible to recover this amount in a short period of time.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	380 V line 240 kW 220 V line 56 kW
Power Consumption	:	1,027,400 kWh/year
Load Factor	:	380 V line 46% 220 V line 56%
Penalty Fee	:	24,540 Bt/year
Power Factor	:	380 V line 63 to 69% 220 V line 45 to 68%
Transformer	:	1ϕ 167 kVA $\times$ 3(380 V), 1ϕ 75 kVA $\times$ 3 (220 V)
Power Consumption Rate	:	Not calculated per product 1.78 Bt/kWh including demand fee and penalty fee.

7.2 One Line Diagram

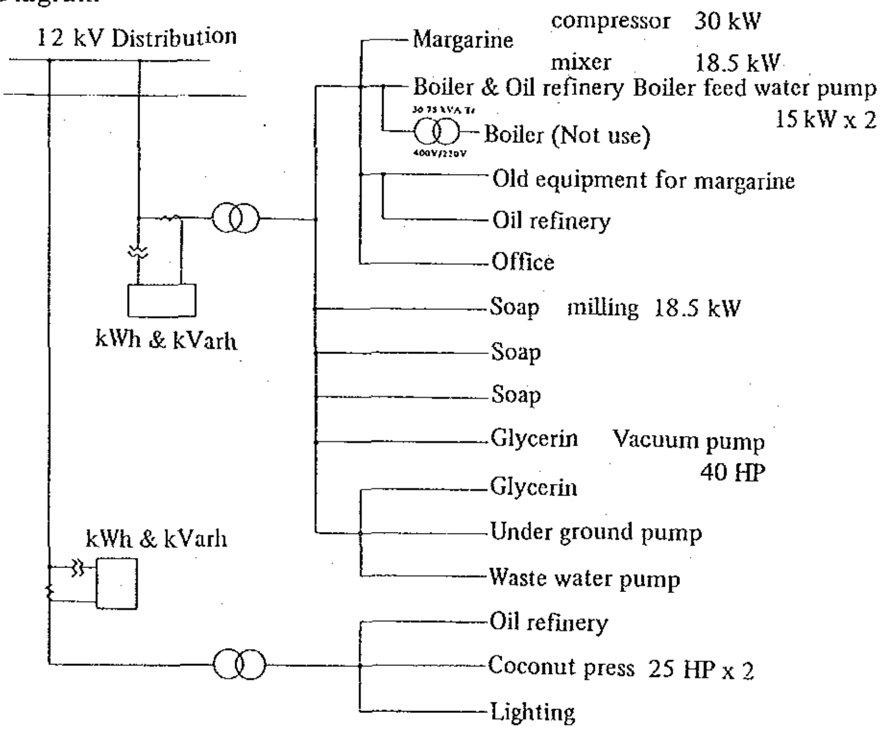


Fig. 5–6

8. Problems of Power Control and Potential Solutions

8.1 Integration of Incoming Wattmeters

The 380 V line and 220 V line are provided from same 12 kV distribution line with wattmeters and reactive meters and they are contracted respectively. (Refer to Table 5-5). If these systems are synthesized to the same incoming line and contracted by a single watt-hour meter as indicated in Fig. 5-7, a peak demand can be kept at low level, when the peak demand of both lines have time lag.

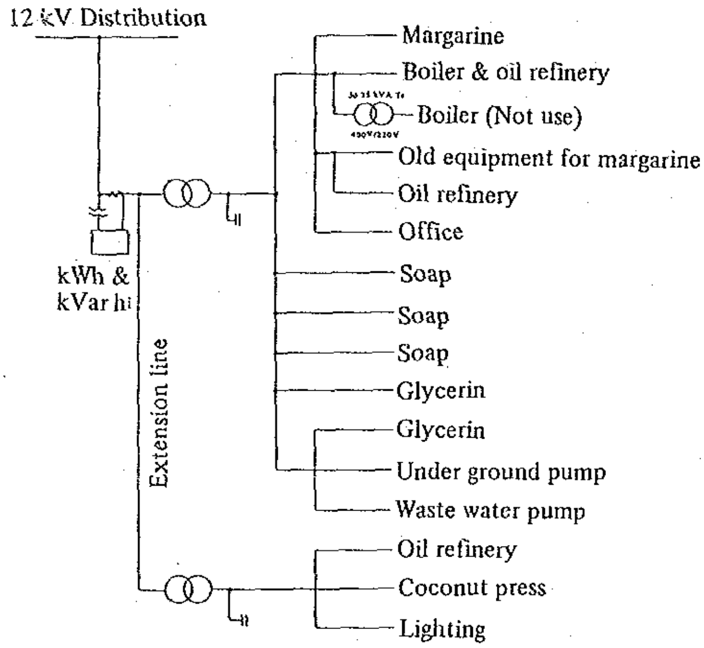


Fig. 5-7 Improved Distribution Diagram

Assuming that the peak demand is reduced by 20 kW, the advantage is estimated at

(20) × 95 × 12 = 22,800 Bt/year..(8.1)

The estimated cost involved in the changeover to this method will be as follows:

Bare copper wire 20 Bt/m × 3ϕ × 40 = 2,400 Bt

Pin insulator 300 Bt × 3 pcs × 3 spots = 2,700 Bt

One set of concrete pole, assembling metals and wooden crossarm 50,000 Bt

Installation work 10,000 Bt

Total: 65,100 Bt

This cost could be paid back in two years and 10 months. It is suggested that you should collect data for some time and study whether the peak demand could be reduced.

Table 5–5 Data by Power Chart by Every Month

Month	Voltage class V	kWh	Max. demand power kW	Penalty kVar	Max. demand power x 0.63 kVar	Max. kVar	Apparent power kVA	Cos ϕ	Remark
1982 6	220	11,400	36	25	23	48	60	0.600	
	380	77,000	240	114	151	265	358	0.670	
7	220	18,120	36	48	23	71	80	0.450	
	380	72,000	230	115	145	260	347	0.663	
8	220	18,588	46	30	29	59	75	0.613	
	380	62,500	230	105	145	250	340	0.676	
9	220	20,280	43	27	27	54	69	0.623	
	380	78,000	220	91	139	230	318	0.692	
10	220	23,880	47	31	30	61	77	0.610	Peak Demand
	380	75,500	240	99	151	250	347	0.692	max.
11	220	23,880	56	31	35	66	87	0.644	
	380	64,500	230	105	145	250	340	0.676	
12	220	19,800	56	25	35	60	82	0.683	
	380	61,500	230	120	145	265	351	0.655	
1983 1	220	18,720	48	31	30	61	78	0.615	
	380	52,500	200	84	126	210	290	0.690	
2	200	14,640	42	34	26	60	73	0.575	
	380	51,500	230	105	145	250	340	0.676	
3	220	24,120	54	27	34	61	81	0.667	
	230	79,500	220	106	139	245	329	0.669	
4	220	18,840	52	29	33	62	81	0.642	
	380	67,000	230	95	145	240	332	0.693	
5	220	14,640	50	26	32	58	77	0.649	
	380	59,000	225	133	142	275	355	0.634	
Total	220	226,908	ave	1,636 kW					
	380	800,500	274	24,540 Bt					

220 V Side

Average power $= \dfrac{226{,}908}{24 \times 300} = 31.5$ kW

Load factor $= \dfrac{31.5}{56} = 0.563$ 56.3%

380V Side

Average power $= \dfrac{800{,}500}{24 \times 300} = 111.2$ kW

Load factor $= \dfrac{111.2}{240} = 0.463$ 46.3%

8.2 Improvement of Power Factor

As shown in Table 5-6, we measured hourly electric active and reactive power under cooperation with the factory for 24 hours from July 14 through 15 and calculated the followings:

Combined active and reactive power, apparent power and power factor on the 12 kV side.

As apparent by Table 5-5 and Table 5-6, the power factor is extremely low and the penalty fee paid annually amounts to 24,540 Bt.

If the power factor is improved by connecting the condenser to the load sides of main switches for 380 V and 220 V respectively, the penalty fee will not have to be paid, and the loss on the transformer and wiring before main switches be reduced. If three 50 kVar condensers totaling 150 kVar are connected to the 380 V side and a 250 kVar condenser to the 220 V side, the power factor will be improved as mentioned below.

When the power factor was lowest as in May, 1983, the reactive power was 275 kVar according to Table 5-5. If a 150 kVar condenser is inserted, this reactive power will be reduced to 125 kVar. The apparent power will be $\sqrt{225^2 + 125^2} = 257$ kVA. Therefore, the power

Table 5–6 24 Hour's Record

Time	167 kVA x 3 3φ 380V			75 kVA x 3 3φ 220V			Total		
	kWh/h	kVarh/h	Cos φ	kWh/h	kVarh/h	Cos φ	kWh/h	kVarh/h	Cos φ
7–14 3 PM	200	200	0.707	36	48	0.600	236	248	0.689
4	150	200	0.600	36	36	0.707	186	236	0.619
5	150	150	0.707	36	36	0.707	186	186	0.707
6	50	50	0.707	24	36	0.555	74	86	0.652
7	100	100	0.707	36	36	0.707	136	136	0.707
8	50	50	0.707	24	36	0.555	74	86	0.652
9	50	50	0.707	24	24	0.707	74	74	0.707
10	50	100	0.447	36	36	0.707	86	136	0.534
11	100	50	0.894	36	48	0.600	136	98	0.811
12	50	50	0.707	24	36	0.555	74	86	0.652
7–15 1 AM	50	50	0.707	24	24	0.707	74	74	0.707
2	50	50	0.707	24	36	0.555	74	86	0.652
3	50	100	0.447	36	36	0.707	86	136	0.534
4	50	50	0.707	24	36	0.555	74	86	0.652
5	50	50	0.707	24	36	0.555	74	86	0.652
6	50	50	0.707	36	48	0.600	86	98	0.66
7	100	100	0.707	36	24	0.832	136	124	0.739
8	150	200	0.600	24	36	0.555	174	236	0.593
9	200	200	0.707	36	36	0.707	236	236	0.707
10	150	200	0.600	36	36	0.707	186	236	0.619
11	200	200	0.707	24	36	0.555	224	236	0.688
12	150	200	0.600	36	36	0.707	186	236	0.619
1 PM	200	200	0.707	24	36	0.555	224	236	0.688
2	150	150	0.707	36	36	0.707	186	186	0.707
Total	2,550	2,800	Average 0.673	732	864	Average 0.646	3,282	3,664	Average 0.667

max kW = 236

factor will be improved as $\cos\varphi = 225/257 = 0.875$, (87.5 %).

Similially, in case the peak demand was highest as in Octover, 1983, the factor will be improved to 92.3%. When the penalty was smallest as in January, 1983, the power factor will be 95.7%. When the power factor was lowest such as 60% according to Table 5-6, it will be improved to 94.9%. If the reactive power is low, part of the condenser shall be opened by using a relay.

Next, when it is lowest such as 0.555 on the 220 V side according to Table 5-6, the power factor will be improved as follows:

$$P_a = 24 + j(36\text{-}25) = 24 + j\,11 \quad \text{(8.2)}$$

$P_a = 26.4$ $\cos\varphi = 0.909$ 90.9%

The maximum total penalty for the 220 V side and 380 V side was 163 kVar in July 1982 according to Table 5-5. It will be compensated for by a condenser of a total of 175 kVar.

Next, the copper loss of the transformer will be improved as follows: If the annual average power is 111.2 kW on the 380 V side, 31.5 kW on the 220 V side according to Table 5-5, and the average power factor is 0.673 on the 380 V side and 0.646 on the 220 V side according to Table 5-6, the average apparent power on the 380 V side will be:

$$\dot{P}_{a1} = 111.2 + j\cdot 11.2 \times \frac{\sqrt{1-0.673^2}}{0.673} = 111.2 + j\cdot 122.2 \quad \text{(8.3)}$$

$P_{a1} = 165$ kVA

Assuming that an average 100 kVar condenser is switched on to the 380 V side by means of a relay, the power factor will be improved as follows:

$\dot{P}_{a11} = 111.2 + j(122.2\text{-}100) = 111.2 + j\,22.2$ .... (8.4)

$P_{a11} = 113$ kVA

On the other hand, the average apparent power on the 220 V side will be:

$$\dot{P}_{a2} = 31.5 + j31.5 \times \frac{\sqrt{1-0.646^2}}{0.646} = 31.5 + j37.2 \quad \ldots\ldots\ldots (8.5)$$

$P_{a2} = 49$ kVA

The power factor will be improved by a 25 kVar condenser as follows:

$\dot{P}_{a22} = 31.5 + j(37.2\text{-}25) = 31.5 + j\,12.2 \quad P_{a22} = 34$ kVA

If copper loss on the 1ϕ 167 kVA transformer is 2.5 kW and copper loss on the 1ϕ 75 kVA transformer 1.3 kW, a reduction of the loss due to the improvement of power factor will be:

For 1ϕ 167 kVA × 3,

$$2.5 \times 3 \times \{(\frac{165}{167 \times 3})^2 - (\frac{113}{167 \times 3})^2\} \times 7{,}200 = 3{,}110 \text{ kWh/year} \ldots\ldots (8.6)$$

For 1ϕ 75kVA × 3,

$$1.3 \times 3 \times \{(\frac{49}{75 \times 3})^2 - (\frac{34}{75 \times 3})^2\} \times 7{,}200 = 690 \text{ kWh/year} \ldots\ldots (8.7)$$

Next, the resistance of wiring to the main switch will be:

For 380 V, assuming that, the resistance of 1c 200 mm^2 × 2 wiring as

$0.0933/2 = 0.04665\Omega/\text{km}(20°\text{C})$

resistance temperature coefficient at 20°C as 0.00393, the length as 70 m.

Then the resistance of wire at 33°C will be

$0.04665 \times 70 \times 10^{-3} \times \{1 + 0.00393 \times (33\text{-}20)\} = 0.00342\Omega$

For 220 V, the resistance of 1 c 150 mm^2 × 2 wiring as

$0.124/2 = 0.062/\text{km}$ (20°C), the length as 50 m,

Then $0.062 \times 50 \times 10^{-3} \times \{1 + 0.00393 \times (33\text{-}20)\} = 0.00326\Omega$

The electric current under an average load for 380 V side is 250 A before improved power factor and 172 A after improved. In the same way, the current for 220 V side will be improved to 89 A from 129 A. Accordingly, the energy conservation will be:

$\{3 \times 0.00342 \times (250^2 - 172^2) \times 10^{-3} + 3 \times 0.00326 \times (129^2 - 89^2) \times 10^{-3}\} \times 7{,}200 =$

3,046 kWh/year.. (8.8)

Total: 6,846 kWh/year 9,927 Bt/year.

If combined with a penalty fee, the monetary merit will amount to 34,467 Bt/year. The estimated cost of equipment such as condenser, contactor and relay including their installation will be 100,000 Bt and recovered in approx. three years.

8.3 Maintenance of Meters

No voltmeter, ammeter and wattmeter are provided at the receiving point, so it is difficult to determine a state of load. It is desired that the above meters are installed and maintenanced well so as to determine a power consumption rate. It is impossible to conserve energy, unless a present state is grasped.

8.4 Improvement of Illumination

Daylight-color fluorescent lamps are now in use. However, because of their low luminous efficiency, they shall be replaced by energy conservation-type white-color fluorescent lamps. The expected energy conservation will be 5 W per lamp and $5 \times 300 \times 10^{-3} \times 10 \times 300 = 4{,}500$ kWh/year if the annual lighting hours are 10×300 h.

8.5 Supression of Peak Demand

At present, the electric power is recorded by means of a watt-hour meter of MEA everyday from 8 AM through 5PM. This is a commendable practice. However, it is suggested that as shown in Table 5-6 and Fig. 5-8, "kWh" and "kVarh" be recorded every one hour for 24 hours so as to prepare a load curve and using them the operating method be changed to improve load factor. If the peak demand is restricted, a load loss of the transformer and wiring will be diminished, beside the reduction of demand fee.

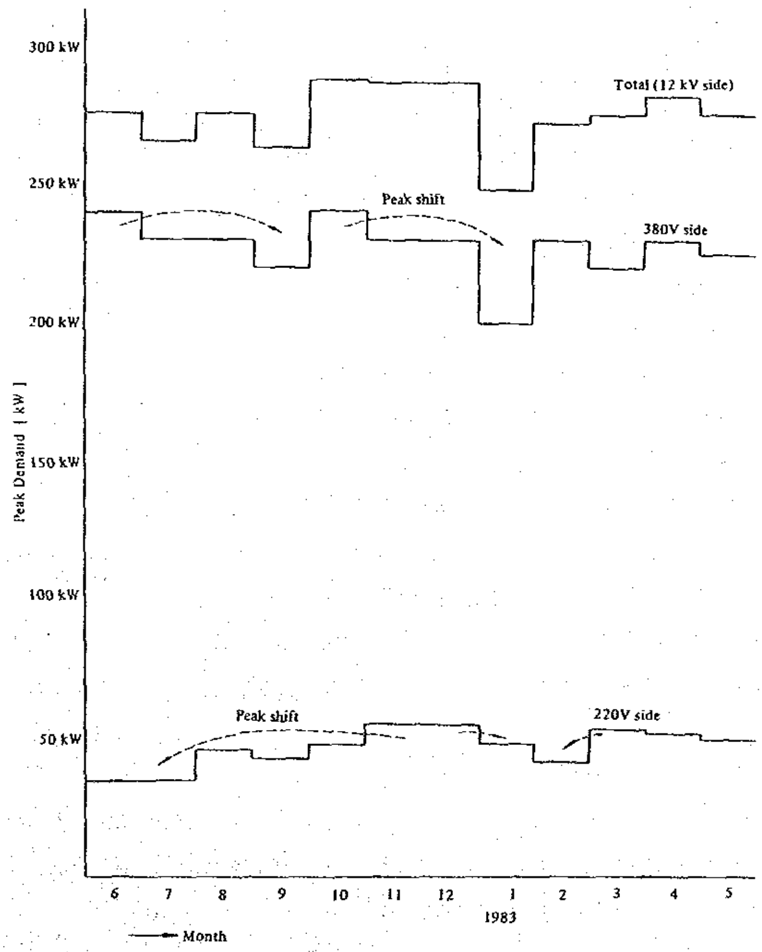


Fig. 5–8 Peak Demand for Every Month

Table 5-7 Actual Load for Each Motor

Using for	No. of pole	Rated out put	Measured in put kw	Rated voltage V	Measured voltage V	Rated current A	Measured current A	Measured power factor
Coconut oil refinery	6	25 HP (18.5 kW)	10.3	220/380	223	64/37	41.2	0.65
Coconut oil refinery	6	25 HP (18.5 kW)	11	220/380	222	64/37	39.8	0.72
Margarine compressor	4	30	16	380	390	60	33.4	0.71
Margarine mixer	4	18.5	4	380	390	38.3	9	0.67
Soap milling	6	18.5	6.9	380	386	39	10.1	0.75
Vacuum pump	U.K.	40 HP	17	U.K.	385	U.K.	32.7	0.78
Boiler feed water pump	2	15 kW	5	380	381	20.5	9.2	0.82
Boiler feed water pump	2	15	7	U.K.	381	U.K.	12.7	0.84

U.K. = Unknown

8.6 Drop of Service Voltage for Electric Motors

The electric motors of the factory have a load equivalent to 50% or less of the rated output as indicated in Table 5-7. In the case of such a light load, if the service voltage is low, the power factor and efficiency will be higher than when a voltage almost equivalent to a rated is applied. Generally, if a load is 50% or less on the induction motor, the rated voltage shall be reduced by 5%. Then the overall efficiency will be higher by approx. 2%.

For 24 hours operating motors, the energy conservation will be:

$(10.3 + 11 + 17 + 7) \times 0.02 \times 24 \times 300 = 6{,}523$ kWh/year

For 8 hours operating motors,

$(16 + 4 + 6.9 + 5) \times 0.02 \times 8 \times 300 = 1{,}531$ kWh/year

Total: 8,054 kWh/year 11,678 Bt/year

9. Summary

The above-mentioned improving measures, if actually taken, will bring about energy conservation effects as shown below:

	(Heavy oil equivalent) kl/year	%
Improvement of Boiler Combustion	12.8	1.3
Improvement of Insulation	257.6	25.8
Total	270.4	27.0

	10^3kWh/year	%
Improvement of Power Factor	6.8	0.7
Illumination	4.5	0.4
Drop of Service Voltage for Electric Motor	8.0	0.8
Total	19.3	1.9

Report No. 6: Plastic & Chemical

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Siam Chemical Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Siam Chemical Co., Ltd. —

1. Outline of the Factory

Address	196 Suksawad Rd. T. Bangprakod A. Maung Samutprakarn	
Capital	40 Million Bt	
Type of industry	Chemical	
Major products	Sulfuric acid, Sulfur roll/powder, Alum, Fetilizer, Nitrous oxide	
Annual product	Sulfuric acid 18,000 ton, Sulfur 3,400 ton, Alum 32,400 ton, Fertilizer 200,000 ton, Nitrous oxide 43 ton	
No. of employees	169	
Annual energy consumption	Electric power	2,082 x 10^3 kWh
	Fuel	Bunker A 190 kℓ
Interviewees	Process engineer Mr. Wichian Production engineer Mr. Schatchwal	
Date of diagnosis	July 18 ~ 19, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

The factory is an enterprise capitalized in Thailand and started the production of 10 t/day of sulfuric acid in 23 years ago. After that, the capacity was increased successively to 100 t/day five years ago and the factory ranks now in the top manufacturer in Thai. The factory produces also various chemicals originated from sulfuric acid as a raw material, such as alum, fertilizer, sulfur roll and so on. The production scale is the 1st or 2nd rank in sulfur roll and the 2nd rank in alum among the domestic manufacturers and can be ranked as a leading company in inorganic chemical industry.

Since the whole quantity of sulfur which is a raw material of sulfuric acid depends on the imported sulfur from Canada, the factory is in a disadvantageous position on the cost. The company was under the protection of the Promotion of Investment Act for a given period with the qualification of BOI. But now after the expiration of this period, the factory has been exposed to competition with the imported products of a lower cost which have been produced with a recovered sulfur. And so the operation rate of the existing sulfuric acid plant has been reduced to 50%. And then the plant stopped operation from the beginning of this year and is not scheduled to operate before the end of the year.

On the other hand, each plant of alum, nitrous oxide and fertilizer is under full operation, and this is a great difference from the inactive sulfuric acid plant.

The fact, that the up-to-date large scale plant is under a lower operation rate for a long time is a serious economical loss. The procurement of a low cost raw material or a development of the high profitable products which are derived from sulfuric acid as a raw material is desired earnestly.

2. Manufacturing Process

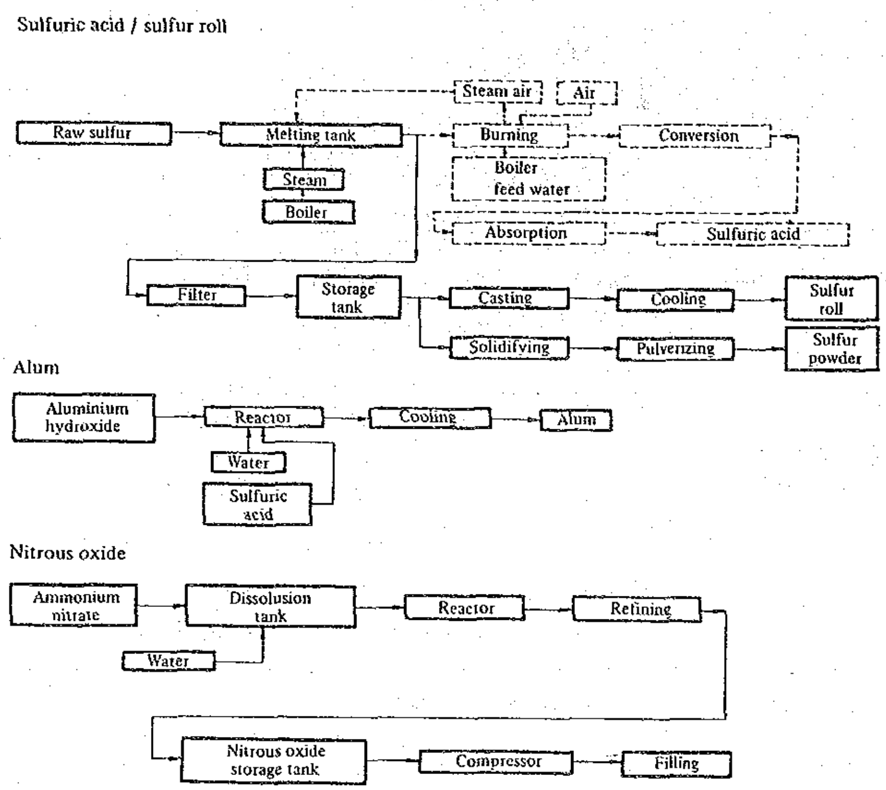


Fig. 6–1

3. Major Equipment

3.1 Major Equipment

Table 6–1

Name	No. of units installed	Type, etc.
Sulfuric acid plant	1	100 t/day, Sulfur burning, contact conversion, designed/constructed by Polimese Cekop, Poland
Sulfur roll plant	1	20 t/day
Alum plant	1	3 Reactors, 6 t/batch
Nitrous oxide	1	Electric heated reactor, refining unit, filling compressor
Fertilizer plant	2	N.P.K. fertilizer and super phosphate manufacturing units
Boiler	1	6 t/h, fire tube

3.2 Layout

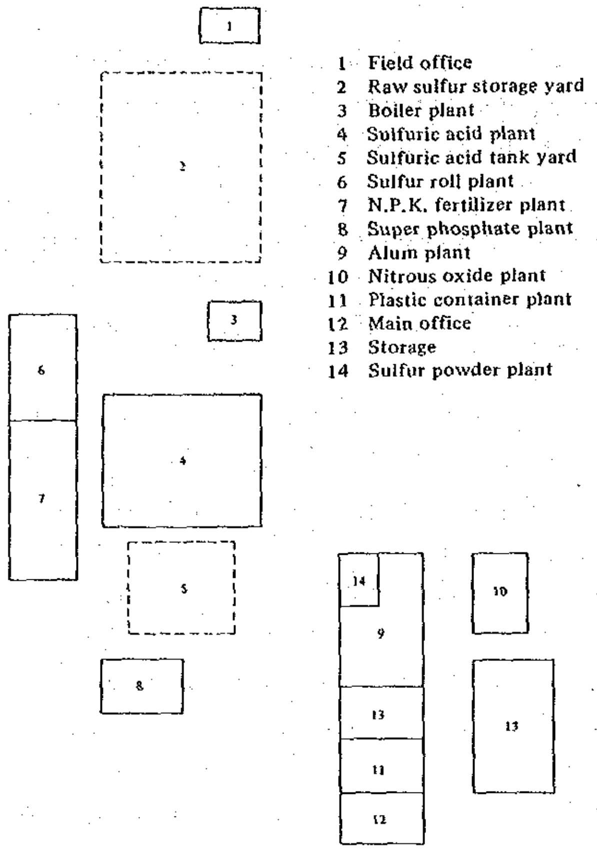


Fig. 6–2

4. State of Energy Management

4.1 Policy for Energy Conservation

The company's technique represented by the sulfuric plant is on an international level and the company engages some excellent technical staffs.

Now, since the main sulfuric acid plant is compelled to operate in a lower rate, a financially difficult circumstance is conjectured. The company has not invested for energy conservation in several years and the investment is not concretely scheduled in future. However the maintenance of the plant and replacement or modification of equipment is taken in the dead time to provide for a start-up operation.

The technical subjects on energy conservation are studied among the staffs to provide for execution. But, the operation rate of 50% presents an extreme severe condition to the energy conservation measures. The person concerned gets anxious about this.

The problems to be investigated, such as utilization of the surplus steam in the operation of sulfuric acid plant, remain there.

4.2 Participation by All Employees

There is no self-control activity such as QC circle. And also there is no suggestion system or commendation system. The investigation on an improvement of the operation and energy conservation measures are put to the duty of the staff engineers and the operators are not engaged. The energy conservation is appealed from the chiefs of each section to the employees of respective section.

4.3 Control through Data

The fuel oil consumption is calculated every day by measuring the stock in the tank. The electric power consumption in the whole factory is grasped every day by the reading of the private integrator and the consumption by each process is recorded every day by the watt-hour meter provided to each facility.

The sulfuric acid plant and the nitrous oxide plant are operated by an automatic controller and the required operating data are collected intensively in the control room. Also in the other plants, the instruments and meters required for the operation are provided. The whole plants are operated rationally.

The raw material and utility consumption rates are grasped for certain by each process and the fluctuating factors are analyzed. The heat balance is calculated in the sulfuric acid plant. The energy cost is calculated once a month by each process.

4.4 Education and Training for Leveling-Up of Employees

Any energy conservation committee is not organized but the production manager takes up the duties of planning and promotion of the energy conservation.

Each one person of the heat and electrical engineers participates in the seminar of TPA once a year.

Any visit for study is not carried out. On the contrary, the factory is open to visitors (mainly students) from outside and is used as an occasion to introduce the model technique.

5. State of Fuel Consumption

5.1 Fuel Consumption

The fuel consumption differs depending on whether sulfuric acid plant is operated or not.

Fuel oil A	190 kl/year
Breakdown	For the start-up operation of the sulfuric acid plant. 8 kl/year
	For the sulfur melting during suspension of the sulfuric acid plant. 182 kl/year

Credit steam generation rate (Pressure: 20 kg/cm^{2}G) 1.08 t/t H_2SO_4

5.2 Heat Balance of Boiler

Table 6–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	387.8	99.7	Heat of steam	335.97	86.3
Sensible heat of fuel	1.3	0.3	Heat loss in exhaust gas	22.01	5.7
			Heat loss in blow water	11.67	3.0
			Heat release from boiler body, others	19.45	5.0
Total	389.1	100.0	Total	389.1	100.0

Data Given for Calculation of the Heat Balance

Fuel type		Fuel oil A
Fuel consumption	(F)	41.7 kg/h
Heat content of fuel (low value)	(Hl)	9,300 kcal/kg
Specific gravity of fuel	(SG)	0.959
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	105°C
Reference temperature	(To)	35°C
Oxygen content in exhaust gas	(O_2)	3.7%
Temperature of exhaust gas	(Tg)	164°C
Quantity of blow down water	(B)	164 kg/h
Temperature of blow down water	(Tb)	156°C
Quantity of feed water	(W)	749 kg/h
Temperature of feed water	(Tw)	85°C
Steam pressure	(P)	5.7 kg/cm^{2}G
Quantity of steam (S = W − B)	(S)	585 kg/h
Enthalpy of steam	(Es)	659.0 kcal/kg
Enthalpy of feed water	(Ef)	85 kcal/kg

Equation for Calculation of the Heat Balance

Input

Heat of fuel combustion (Qc) 387.8×10^3 kcal/h

$$Qc = F \times Hl$$

Sensible heat of fuel (Qs) 1.3×10^3 kcal/h

$$Qs = F \times Cp\,(Tf - To)$$

Output

Heat of steam (Qv) 335.97×10^3 kcal/h

$$Qv = S \times (Es - Ef)$$

Heat loss in exhaust gas (Qe) 22.01×10^3 kcal/h

$Qe = F \times G \times 0.33\,(Tg - To)$

Theoretical amount of air (Ao)

$Ao = 0.85\ Hl/1{,}000 + 2.0 = 9.9\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11\ Hl/1{,}000 = 10.3\ Nm^3/kg$

Air ratio (m)

$$m = 21/(21 - O_2) = \frac{21}{21 - 3.7} = 1.21$$

Actual amount of exhaust gas (G)

$G = Go + Ao\,(m - 1) = 12.4\ Nm^3/kg$

Heat loss in blow down water (Qb) 11.67×10^3 kcal/h

(Take as 3% of input)

Heat release from body and others (Qr) 19.45×10^3kcal/h

(Take as 5% of input)

6. Problems in Heat Control and Potential Solutions

6.1 Intensification of Insulation

(1) Intensification of insulation for steam piping to sulfuric acid plant

The steam piping to the sulfuric acid plant is insulated sufficiently and finished with proper cover, but down stream piping from the sulfur melter including the valve, part in touch with supporters and flanges is necessary to repair and intensify the insulation. The side surfaces of the molten sulfur service tank are insulated enough but the bottom and upper surface are not insulated.

The heat loss from the uninsulated parts of the service tank is as follows:

Heat loss from the tank upper surface:

$3.22m^2 \times 680\ kcal/m^2h = 2{,}190\ kcal/h$

Heat loss from the bottom of tank:

$3.22m^2 \times 1{,}040\ kcal/m^2h = 3{,}350\ kcal/h$

Annual radiation heat

$(2{,}190 + 3{,}350)kcal/h \times 24h \times 365 = 48{,}530{,}400\ kcal/year$

The reduction of heat loss when the insulation efficiency is taken as 80%, is 38,824,320 kcal/h. When the value is converted to the equivalent fuel oil, it is as in the following.

$$\frac{38{,}824{,}320}{9{,}300 \times 0.959 \times 0.863} \fallingdotseq 5.04\ kl/year$$

The annual reduced cost is as follows:

$5.04\ kl \times 4.5\ Bt \times 10^3 = 22{,}680\ Bt/year$

The insulation cost required to this measures is approximately 1,600 Bt. The cost can be paid back within one month, so it had better to insulate regardless of operation time of sulfuric acid plant.

6.2 Boiler

(1) Instrument for Control Energy

Although the flow meters for feed water and fuel oil are installed, these are out of order for a year. The boiler is operated in a groping condition depending on the past data and experience. The flow meters should be immediately repaired and the daily evaporation multiple should be calculated to check as the mark of the boiler operation.

$$\text{Evaporation multiple} = \frac{\text{Quantity of feed water} - \text{Quantity of fuel oil}}{\text{Fuel oil consumption}}$$

(2) Proper Control of Air Ratio

Since the measured result of the oxygen concentration in exhaust gas shows a lower value of 3.4 to 3.7% in spite of a low load of 30 to 40% and a emission of black smoke is not found, the link in the combustion equipment is judged to be a proper setting. The air ratio (m) of 1.3 or less is regarded as a proper value to this scale of the boiler. When the air ratio (m) is calculated with the oxygen content of 3.7%, it is as follows:

$$m = \frac{21}{21 - O_2} = \frac{21}{21 - 3.7} = 1.21$$

That is, the air ratio (m) has been controlled in a low value.

The measured exhaust gas temperature of 164°C is low due to a low load and has no problem as the fuel is used with fuel oil A. If fuel oil C of a higher sulfur content is used, the outlet of boiler and the flue may be corroded. Accordingly, the exhaust gas temperature is required to control not to go to lower than this temperature.

6.3 Recovery of Condensate

The condensate is recovered mainly from the sulfur melter and its recovery is around 40%. The condensate to be further recovered is as follows:

(1) Condensate in the steam header located outside the boiler room.

(2) Condensate of the sulfuric acid plant.

The recovery can be improved to about 70% if these condensates are recovered. At present the temperature of the feed water tank for boiler is more than 80°C resulting from leakage of live steam due to a poor operation of the steam trap located in the sulfur melter. It is to be noted to the higher temperature than the estimated temperature. Before everything, the steam trap should be checked and repaired. It is recommendable to check the steam trap periodically at least once a month.

6.4 Power Saving of the Reactor in the Nitrous Oxide (N_2O) Manufacturing Process

In the reactor, NH_4NO_3 is treated in the temperature of 200 to 220°C by a resistance type electric heating. The heat loss from this surface can be reduced substantially by the intensification of insulation and the power consumption of the electric heater can be reduced as in the following.

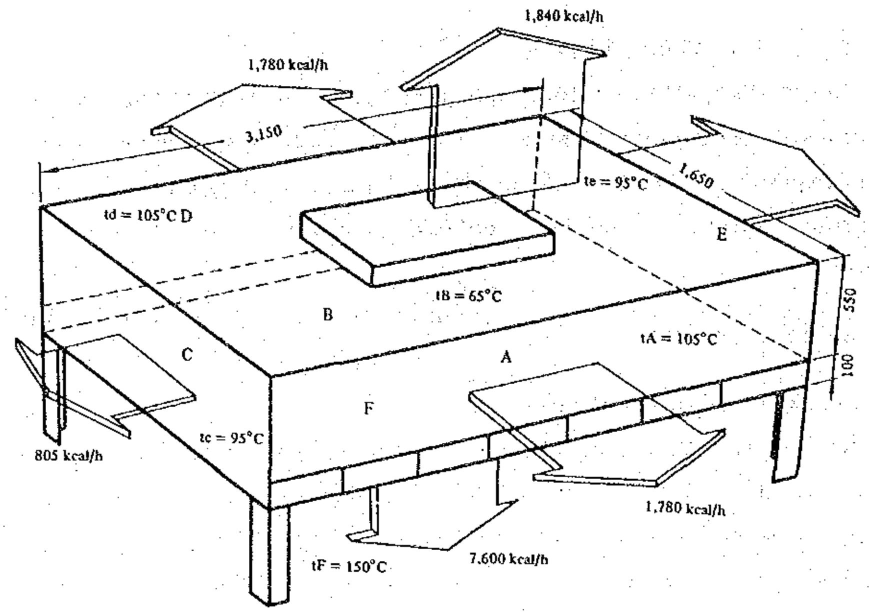


Fig. 6–3

When the heat loss is prevented by a glass wool blanket of 50 mm thickness as shown in Figure 6-3 and the heat loss after the insulation is taken as 60 kcal/m^2h, the improving effect by a prevention of the heat loss is as follows:

Heat loss of each section:

(A) and (D) surfaces,	2.0 m^2 × 890 kcal/m^2h = 1,780 kcal/h
	1,780 × 2 = 3,560 kcal/h
(C) and (E) surfaces,	1.1 m^2 × 731 kcal/m^2h = 805 kcal/h
	805 × 2 = 1,610 kcal/h
(B) surface,	5.2 m^2 × 354 = 1,840 kcal/h
(F) surface,	5.2 m^2 × 1,462 = 7,600 kcal/h
Total	14,610 kcal/h

Annual heat loss,

14,610 kcal/h × 24h × 365 = 127,983,600 kcal/year

Let the insulation efficiency be 80%, the reduced heat loss is,

127,983,600 × 0.8 = 102,386,900 kcal/year

Converted this to power,

$$\frac{102,386,900}{860} = 119,050 \text{ kWh/year}$$

The reducing cost of the electric power,

119,050 kWh × 1.45 Bt = 172,622 Bt/year

The insulation cost is 1,000 Bt/m^2. Accordingly, the investment cost is about 16,600 Bt. This investment can be paid back in 1.2 months.

6.5 Change of Steam Piping Routing

The sulfuric acid plant is operated in only six months a year. And so during the suspension of the plant, steam for the whole factory is covered by operation of the auxiliary boiler. The steam piping coming from the auxiliary boiler is arranged through the sulfuric acid plant as shown Figure 6-4. This piping system has too much heat losing area due to a roundabout piping beyond the necessity.

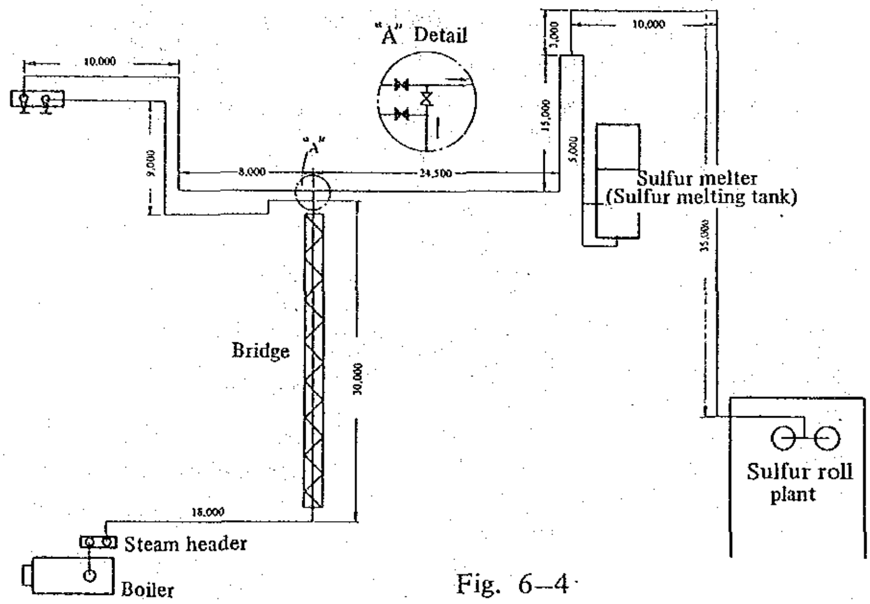


Fig. 6–4

Installation of valves at the A point in Figure 6-4 prevents the heat loss in the roundabout piping during the suspension of the sulfuric acid plant.

The reduction of heat loss in only piping,

$(10+9+8)\text{m} \times 2 \times 1.5 \times 46$ kcal/h = 3,726 kcal/h

The annual reduction of heat,

3,726 kcal/h $\times$ 24h $\times$ 365 $\times$ 7/12 = 19,039,860 kcal/year

Converted this heat to equivalent fuel oil,

$$\frac{19{,}039{,}860}{9{,}300 \times 0.959 \times 0.863} \fallingdotseq 2.47 \text{ kl/year}$$

The annual cost reduction,

2.47 kl $\times$ 10^3 $\times$ 4.5 Bt = 11,115 Bt/year

The cost is about 20,000 Bt. The cost can be paid back within two years.

6.6 Power Recovery by Installation of Back Pressure Turbine

The waste heat recovery boiler in the sulfuric acid plant has the capacity of steam generation of 100 t/d with 20 kg/cm^{2}G of pressure, but the steam of 60% is released into the atmosphere as a surplus steam. As a recovery method of the surplus steam, there is a method to convert the steam to electric power by power generation of a steam turbine installation to utilized effectively as power for the factory.

As an example, the power generation capacity with a back pressure turbine when the back pressure is set to 4 kg/cm^2G of steam pressure used in the factory can be calculated as the following.

The turbine output Ne(kW) is according to the following equation.

$$Ne = \frac{Gs \cdot \eta \cdot h_{ad}}{102 \cdot A}$$

Hereupon; Gs : Quantity of steam kg/s

η : Turbine efficiency. Taken as 50%

h_{ad} : Adiabatic enthalpy drop (kcal/kg)

A : 1/427 (kcal/kgm)

From the Mollier diagram h-s (See Figure 6-5), $h_{ad} = 63$ kcal/kg

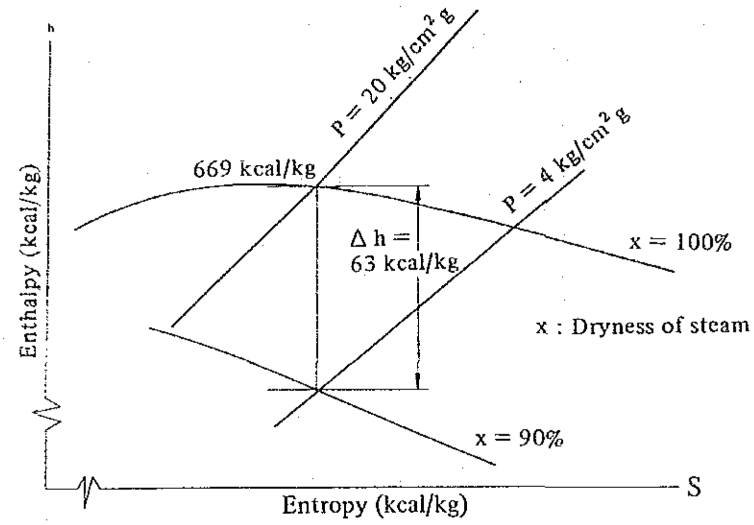


Fig. 6-5

If the evaporation is taken as 100 t/day,

$$Gs = \frac{100 \times 10^3}{24 \times 60 \times 60} \doteqdot 1.16 \text{ kg/sec}$$

Accordingly, the output of turbine is,

$$Ne = \frac{1.16 \times 0.5 \times 63}{102 \times (1/427)} \doteqdot 153 \text{ kW}$$

Let the annual operating day be 180 days,

$153 \times 24 \times 180 = 661.0 \times 10^3$ kWh/year

Converted it to the cost,

661×10^3kWh $\times$ 1.45 Bt/kWh = 958,400 Bt/year

The power cost can be reduced by 958,400 Bt/year.

The investment cost is estimated as $1,000 \times 10^3$Bt.

Accordingly, the cost can be paid back within one year.

6.7 Others

(1) Improvement of steam heater in the sulfur melter.

In the present heater structure, a steam condensate stays in the heater as shown in Figure 6-6. The type shown in the improving plan enables an effective heat exchange.

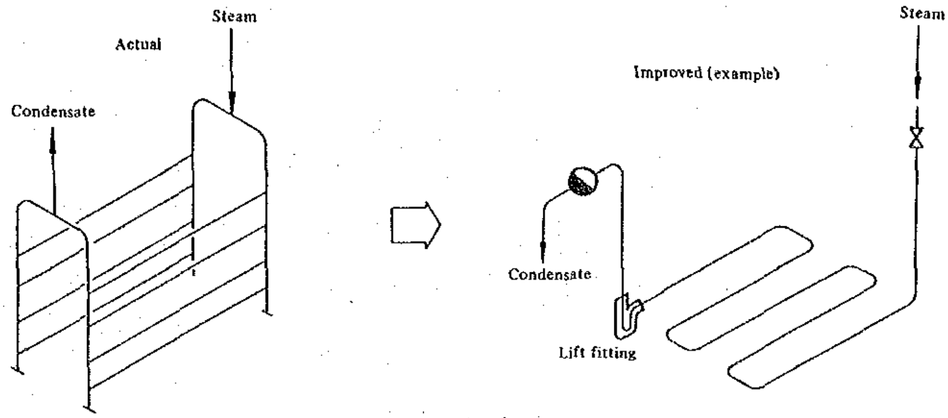


Fig. 6–6

(2) In the sulfur roll manufacturing process, there is over flow at the mold injection. This overflow decreases the yield. If the injection method is improved to reduce the overflow as much as possible, the energy conservation effect of about 10% is estimated to be possible enough. Therefore, an improvement of the operation procedure is recommendable.

(3) The boiler capacity is excessive to the factory load (less than 10%). The examination to a low capacity of the burner is recommendable.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	640 kW
Power Consumption	:	2,082,000 kWh/year
Load Factor	:	37% by the reason of the suspension of the sulfuric acid plant. (Half years)
Penalty Fee	:	14,310 Bt/year
Power Factor	:	61.8% ~ 81.2%
Transformer	:	3ϕ 315 kVA, 1ϕ 333 kVA × 3, 3ϕ 500 kVA
Power Consumption Rate	:	Alum 0.759 kWh/t, N_2O 4,813kWh/t Sulfur Powder 10 kWh/t.
Power cost	:	1.68 Bt/kWh

7.2 One Line Diagram

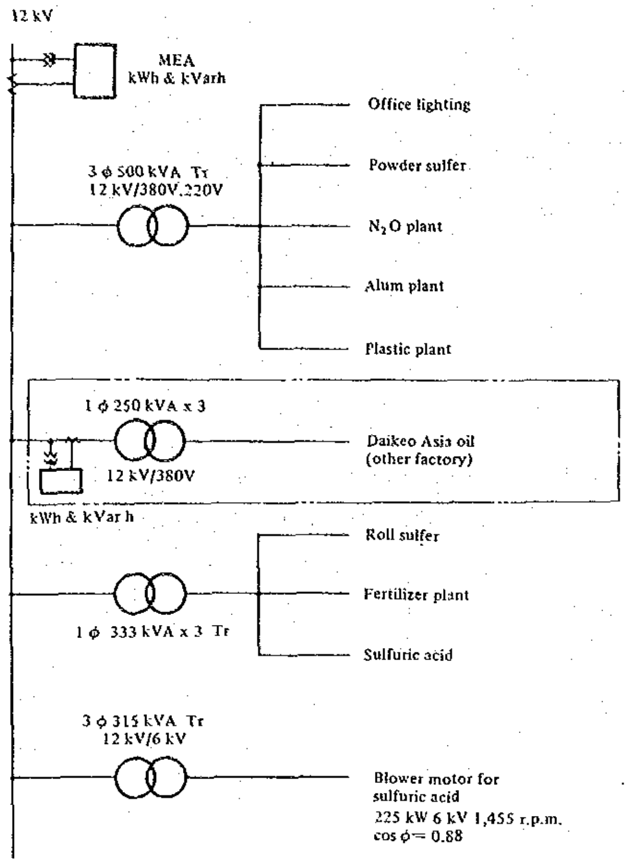


Fig. 6–7

8. Problems in Electric Power Control and Potential Solutions

The lead-in wire is provided from the 12 kV distribution line on the road and the power is distributed with a low voltage being stepped down by the transformer provided near the each plant. Since Asia Oil, an other company in the neighbor, receives power from the same 12 kV service line, the power consumption of the both companies is integrated with the total in the MEA's watt-hour meter and integrating reactive power meter. The company's power consumption is calculated by deduction of the value in the Asia Oil's watt-hour meter from the total power consumption.

8.1 Separation of Transformer During the Suspension of Sulfuric Acid Plant

Since the suspension of sulfuric acid plant is for about half year, the transformer of 1ϕ 333 kVA$\times$3 is in a very low load for the period. During the period, if the power for the load of the sulfur roll and fertilizer plant is supplied from the 3ϕ 500 kVA transformer and the transformer for the sulfuric acid plant is stopped, the loss in the transformers will be reduced.

According to the data (Table 6-3) measured by the factory side in June 1983, the maximum power consumptions in each plant are as follows:

Table 6–3 Monthly Record

Date 1983 June	MEA	3φ 500 kVA Tr					1φ 333 kVA x 3		
	kWh	N_2O kWh	Powder Sulfur kWh	Alum kWh	Plastic kWh	Total	Roll Sulfur kWh	Fertilizer mill kWh	Total
1	3,400	646	84	88	904	1,722	136	240	376
2	3,600	694	100	68	860	1,722	148	200	348
3	3,800	728	100	44	972	1,844	156	190	346
4	3,700	740	210	112	1,036	2,098	134	100	234
5	3,700	688	122	44	860	1,714	94	190	284
6	3,000	718	84	68	840	1,710	112	220	332
7	2,900	662	84	48	256	1,050	110	220	330
8	2,300	644	68	72	288	1,072	108	220	328
9	3,000	636	116	68	448	1,268	58	210	268
10	3,000	564	196	76	208	1,044	84	110	194
11	3,700	764	164	92	200	1,220	112	375	487
12	2,200	640	8	14	152	814	190	165	355
13	2,900	654	76	56	280	1,066	156	210	366
14	2,900	712	112	70	336	1,230	138	240	378
15	3,100	776	96	72	272	1,216	170	225	395
16	3,000	770	76	44	336	1,226	162	205	367
17	3,000	762	74	76	312	1,224	138	245	383
18	3,000	642	82	48	256	1,028	94	225	319
19	2,100	676	48	48	200	972	72	195	267
20	3,100	654	144	124	236	1,158	206	305	511
21	2,900	628	144	100	256	1,128	114	255	369
22	3,600	636	142	62	868	1,708	124	305	429
23	3,700	620	150	54	1,008	1,832	138	235	373
24	3,600	608	56	62	1,004	1,730	148	290	438
25	3,400	638	0	46	852	1,536	108	255	363
26	1,800	240	2	30	144	416	120	90	210
27	2,000	0	0	70	216	286	132	150	282
28	2,300	4	0	138	324	466	98	220	318
29	2,900	52	154	78	468	752	120	160	280
30	1,800	52	154	76	300	582	164	225	389
Total	89,400	17,248	2,846	2,048	14,692	36,834	3,844	6,475	10,319

N_2O 776/24 = 32 kW Sulfur powder 210/24 = 9 kW

Alum 138/16 = 9 kW Sulfur roll 206/24 = 9 kW

Fertilizer 375/16 = 23 kW

The maximum values measured in the 19th of July in each plant are as follows (Measured for just 60 minutes):

N_2O 28 kW Sulfur powder 20 kW

Alum 10 kW Sulfur roll 20 kW

Table 6–4

(1) From peak demand to power factor

Time	kWh	Average power kW	Peak demand kW	Peak kVar kVar	P.D x 0.63 kVar	Penalty kVar	kVA	cos ϕ
1	46,000	64	280	220	176	44	356	0.787
2	70,000	104	160	130	101	29	206	0.777
3	264,000	355	580	480	365	115	663	0.766
4	344,000	478	600	460	378	82	756	0.794
5	388,000	522	640	520	403	117	825	0.776
6	334,000	464	640	460	403	57	788	0.812
7	264,000	355	640	520	403	117	825	0.776
8	82,000	110	580	480	365	115	753	0.77
9	70,000	97	200	160	126	34	256	0.781
10	66,000	89	220	280	139	141	356	0.618
11	84,000	117	180	180	113	67	255	0.707
12	70,000	94	260	200	164	36	328	0.793
Total	2,082,000							

(2) Measuring data

Time	MEA kWh	MEA kVarh	kVA	cos ϕ	500 kVA Tr kWh	3 x 333 kVA Tr kWh	500 kVA Tr V	500 kVA Tr A	500 kVA Tr kVA	Remark
7–19 11 AM	100	100	141.4	0.707	81	10	370	100	64	500 kVA Tr V, A is instantaneous value.
12 AM	100	100	141.4	0.707	64	10				
1 PM	100	100	141.4	0.707	64	9	375	150	97.4	

The maximum values of the sulfur roll and fertilizer plants especially related to this paragraph are estimated as 20 kW and 25 kW respectively. In the data in 1982 (Table 6-4), the maximum apparent power for six months of September to December, January and February during the stop of the sulfuric acid plant was 356 kVA. So one bank of 500 kVA is enough to these whole plants. Accordingly, when the sulfuric acid plant is stopped, it would be better that the transformer of 1ϕ 333 kVA $\times$ 3 is opend from the bus and the sulfur roll and fertilizer plants is supplied power from the 500 kVA transformer, though the distance is long. It is recommended to set up 3 cables of single core 150 mm^2 and 1 single core 14 mm^2 (for the neutral line) and to install a changeover switch on the panel as shown in Figure 6-9.

The above brings the following merit.

Let the iron loss of the 1ϕ 333 kVA transformer be 1.2 kW, the reduction of the iron loss is as follows;

1.2 kW $\times$ 3 $\times$ 8,760 $\times$ 7/12 = 18,396 kWh/year .... (8.1)

From Table 6-3 and Table 6-4, the copper loss is the followings (assuming the average power factor as 0.7).

	1ϕ 333 kA $\times$ 3	3ϕ 500 kVA
Present state	14 kW (20 kVA)	82 kW (117 kVA)
After translating the load to 500 kVA	0 (OFF)	96 kW(137 kVA)

If the rated copper loss is taken as 5 kW, the copper loss of the 1ϕ 333 kVA $\times$ 3 transformer is reduced as in the following.

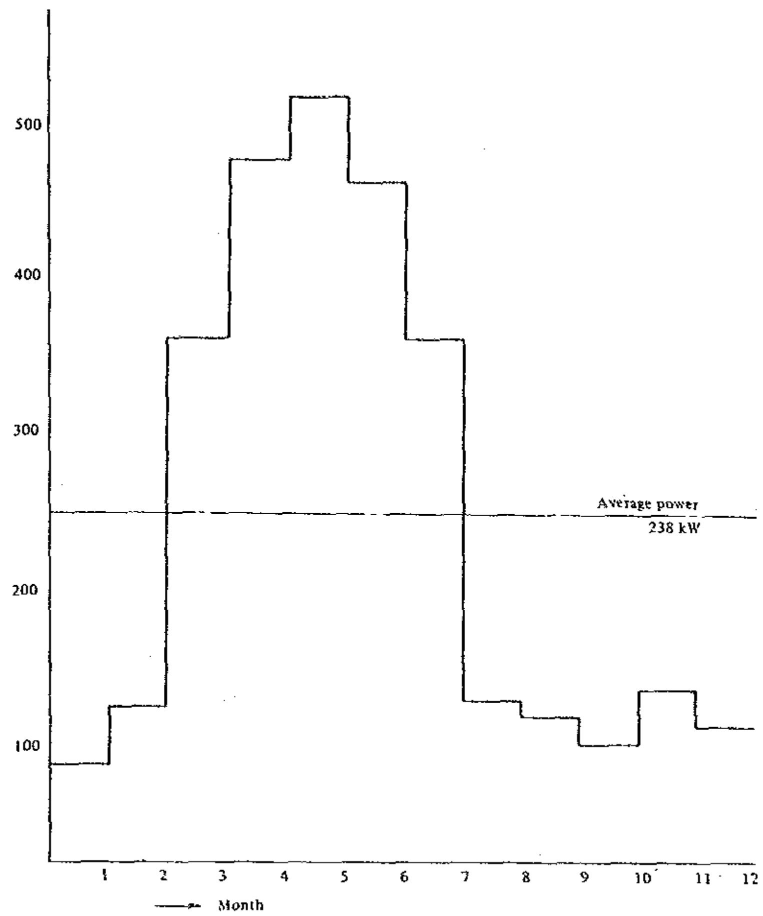


Fig. 6–8 Monthly Average Power & Annual Average Power

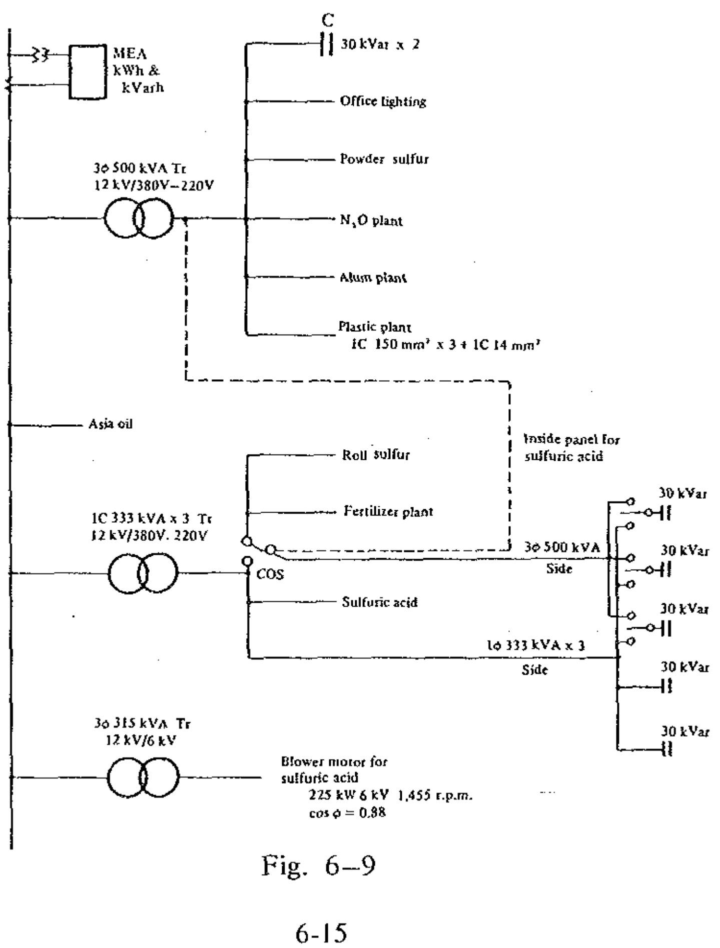


Fig. 6–9

$$5 \times 3 \times \left(\frac{20}{3 \times 333}\right)^2 \times 8{,}760 \times \frac{7}{12} = 31 \text{ kWh/year} \quad \text{......(8.2)}$$

If the rated copper loss of 3ϕ 500 kVA is taken as 7 kW, the copper loss is increased as in the following.

$$7 \times \left\{ \left(\frac{137}{500}\right)^2 - \left(\frac{117}{500}\right)^2 \right\} \times 8{,}760 \times \frac{7}{17} = 727 \text{ kWh/year} \quad \text{......(8.3)}$$

Assuming the average temperature of conductor as 33° C, the resistance of conductor of single core 150 mm^2 cable as 0.12Ω/km (20° C) and the resistance temperature coefficient as 0.00393, the loss of single core 150 $mm^2 \times$ 130 m cable is as follows;

$$3 \times \left(\frac{20}{\sqrt{3} \times 0.38}\right)^2 \times 0.12 \times \frac{130}{1{,}000} \times \{1 + 0.00393 \times (33 - 20)\} \times 8{,}760 \times \frac{7}{12} \times 10^{-3}$$

$= 232$ kWh/year ......(8.4)

Total reduction of loss is,

$(18{,}396 + 31) - 727 - 232 = 17{,}468$ kWh/year ......(8.5)

The merit during the suspension of the sulfuric acid plant is 21,106 Bt/year. Let the expense of the cable per m for 600 V CV 1C 150 mm^2 be 100 Bt and for 600 V CV 1C 14 mm^2 be 13 Bt, the total comes to as follows.

$100 \times 3 \times 130 + 13 \times 130 = 40{,}690$ Bt ......(8.6)

Except the aboves, it costs 250 Bt for 3P change-over safety switch (60A), 650 Bt for the messenger wire including accessories and 6,200 Bt for working. Then the total expence is about 47,800 Bt.

This expense can be paid back in about 32 months.

8.2 Improvement of Power Factor

As large penalty has been paid due to low power factor, an improving plan is examined below.

A condenser of 150 kVar is inserted to the secondary side of the 1ϕ 333kVA $\times$ 3 transformers and the 90 kVar out of them takes position to be possible to connect to the secondary side of the 500 kVA transformer too by the changeover switch. And the condenser of 60 kVar of them is inserted to the secondary side of the 3ϕ 500kVA transformer. (See Fig.6-9). Taking up the case of the largest peak demand in May, the condenser is connected to $60 + 150 = 210$ kVar and the reactive power reduces to $520 - 210 = 310$ kVar. The power factor in the case is improved to

$$\cos \varphi = \frac{640}{\sqrt{640^2 + 310^2}} = 0.90 \quad \text{......(8.7)}$$

Taking up the case of the largest penalty in October during the suspension of the sulfuric acid plant, the condenser is connected to 150 kVar and the reactive power reduces to $280 - 150 = 130$ kVar. The power factor is,

$$\cos \varphi = \frac{220}{\sqrt{220^2 + 130^2}} = 0.861$$

That is, the power factor is improved from 61.8% to 86.1%. The reduction of the loss in the transformer and the cable by the improvement of power factor is shown in Table 6-5 and Table 6-6.

Table 6–5 Decrease of Transformers Loss by Improving Power Factor

	Present state	Improved state	Difference
Sulfuric acid plant being operated			
3ϕ 500 kVA transformer			
Active power	82 kW	82 kW	
Reactive power	84 kVar	84–60 = 24 kVar	
Apparent power	$\sqrt{82^2+84^2}$ = 117 kVA	85 kVA	
Power factor	0.7 (Assumption)	0.965	
Loss	$7 \times (\frac{117}{500})^2 \times 8{,}760 \times 5/12$	$7 \times (\frac{85}{500})^2 \times 8{,}760 \times 5/12$	
	= 1,402 kWh/year	= 738 kWh/year	664 kWh /year
1ϕ 333 kVA x 3 transformer			
Active power	218 kW	218 kW	
Reactive power	222 kVar	222–150 = 72 kVar	
Apparent power	311 kVA	230 kVA	
Power factor	0.7 (Assumption)	0.950	
Loss	$5 \times 3 \times (\frac{311}{333x3})^2 \times 8{,}760 \times 5/12$	$5 \times 3 \times (\frac{230}{333x3})^2 \times 8{,}760 \times 5/12$	
	= 5,306 kWh/year	= 2,902 kWh/year	2,404 kWh/year
Sulfuric acid plant not being operated			
3ϕ 500 kVA transformer			
Active power	96 kW	96 kW	
Reactive power	98 kVar	98–60 = 38	
Apparent power	137 kVA	103 kVA	
Power factor	0.7 (Assumption)	0.930	
Loss	$7 \times (\frac{137}{500})^2 \times 8{,}760 \times 7/12$	$7 \times (\frac{103}{500})^2 \times 8{,}760 \times 7/12$	
	= 2,685 kWh/year	= 1,518 kWh/year	1,167 kWh/year
Sum			4,235 kWh/year

Here the distribution of power to each transformers is assumed as in the followings.

(1) While the sulfuric acid plant is operated from March ot July, the average power is 435 kW.

(2) 82 kW out of this 435 kW is delivered to the 500 kVA transformer, 135 kW to the blower in the sulfuric acid plant and the rest power 218 kW (435 − 82 − 135 = 218 kW) to the 1ϕ 3 × 333 kVA transformers.

The energy conservation due to the improvement of power factor is,

4,235 + 2,046 = 6,281 kWh/year, 9,107 Bt/year

The total merit including the penalty is 23,400 Bt/year. On the other hand, the expenses of the condenser and the switchgear is 105,000 Bt. This expense can be paid back in about 4.5 years. This pay back time will be shorten if the sulfuric acid plant is in a full operation.

Table 6–6 Decrease of Cable Loss by Improving Power Factor

	Present state	Improved state	Difference
Sulfuric acid plant being operated			
3ϕ 500 kVA distribution line Cable Temperature of wire Resistance of wire	$200\ mm^2 \times 2 \times 50\ m$ $33°C$ $0.0922\ \Omega/km \times [\ 1 + 0.00393\ (33-20)\ ]$ $\times \frac{1}{2} \times \frac{50}{1,000} = 2.42 \times 10^{-3}\ \Omega$		
Current Loss	$\frac{117}{\sqrt{3} \times 0.37} = 183A$ $3 \times 183^2 \times 2.42 \times 10^{-3}$ $\times 8,760 \times \frac{5}{12} \times 10^{-3}$ $= 887$ kWh/year	$\frac{85}{\sqrt{3} \times 0.37} = 133A$ $3 \times 133^2 \times 2.42 \times 10^{-3}$ $\times 8,760 \times \frac{5}{12} \times 10^{-3}$ $= 469$ kWh/year	418 kWh/year
1ϕ 333 kVA x 3 distribution line Cable Temperature of wire Resistance of wire	$200\ mm^2 \times 3 \times 25\ m$ $33°C$ $0.0922\ \Omega/km \times [\ 1 + 0.00393\ (33-20)\ ]$ $\times \frac{1}{3} \times \frac{25}{1,000} = 0.81 \times 10^{-3}\ \Omega$		
Current Loss	$\frac{311}{\sqrt{3} \times 0.37} = 485A$ $3 \times 485^2 \times 0.81 \times 10^{-3}$ $\times 8,760 \times \frac{5}{12} \times 10^{-3}$ $= 2,086$ kWh/year	$\frac{230}{\sqrt{3} \times 0.37} = 359A$ $3 \times 359^2 \times 0.81 \times 10^{-3}$ $\times 8,760 \times \frac{5}{12} \times 10^{-3}$ $= 1,143$ kWh/year	943 kWh/year
Subtotal			1,361 kWh/year
Sulfuric acid plant not being operated			
3ϕ 500 kVA distribution line Loss	$3 \times 183^2 \times 2.42 \times 10^{-3}$ $\times 8,760 \times \frac{7}{12} \times 10^{-3}$ $= 1,242$ kWh/year	$3 \times 133^2 \times 2.42 \times 10^{-3}$ $\times 8,760 \times \frac{7}{12} \times 10^{-3}$ $= 656$ kWh/year	586 kWh/year
1ϕ 333 kVA distribution line Cable Temperature of wire Resistance of wire	$150\ mm^2 \times 1 \times 130\ m$ $33°C$ $0.12\ \Omega/km \times [\ 1 + 0.00393\ (33-20)\ ]$ $\times \frac{130}{1,000} = 16.4 \times 10^{-3}\ \Omega$		
Current	$\frac{14}{\sqrt{3} \times 0.38 \times 0.7} = 30A$ $3 \times 30^2 \times 16.4 \times 10^{-3} \times 8,760$ $\times \frac{7}{12} \times 10^{-3}$ $= 232$ kWh/year	$\frac{14}{\sqrt{3} \times 0.38 \times 0.93} = 23A$ $3 \times 23^2 \times 16.4 \times 10^{-3}$ $\times 8,760 \times \frac{7}{12} \times 10^{-3}$ $= 133$ kWh/year	99 kWh/year
Subtotal			685 kWh/year
Total			2,046 kWh/year

8.3 Arrangement of Instrument

The power factor meter in the secondary panel of the 500 kVA transformer indicates 90% or more, but the actual power factor is about 70%. If the load condition is not grasped exactly, any proper countermeasures cannot be taken.

It is the first step toward the energy conservation that the instrument and meter are always arranged to show a proper indication.

8.4 Control of Peak Demand

The watt-hour meters are provided in each plant and the power consumption rate can be calculated by each product. This is all right to take up an energy conservation countermeasures. After now, if the above watt-hour meters and the main watt-hour meter are measured by each hour, it is possible to draw a load curve, and by using it to improve the load factor and to control the peak demand will be possible.

8.5 Rationalization of Lighting

The daylight fluorescent lamps of a low luminous efficacy are used. With replacement to white fluorescent lamps of an energy conservation type, the following advantage of energy conservation is obtainable.

$5\ W \times 160\ \text{Lamps} \times 10\ h \times 365\ \text{days} \times 10^{-3} = 2{,}920\ kWh/year$ . . . . (8.8)

9. Summary

When the above countermeasures are taken, the effect is as follows:

	(Converted to fuel oil) kl/year	%
Insulation of melting sulfur service tank	5.0	2.6
Change of steam piping route	2.5	1.3
Subtotal	7.5	3.9

	10^3kWh/year	%
Separation of transformer during the stop of the sulfuric acid plant.	17.5	0.8
Improvement of power factor	6.3	0.3
Replacement to white fluorescent lamp of an energy conservation type	2.9	0.1
Insulation of nitrous oxide reactor	119.0	5.7
Power recovery by back pressure turbine	661.0	31.7
Subtotal	806.7	38.7

Report No. 7: Plastic & Chemical

REPORT ON THE DIAGNOSIS FOR ENERGY CONSERVATION

— Thai Chemical Corporation Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Thai Chemical Corporation Ltd. —

1. Outline of the Factory

Address	116 Moo 1, Suksawasdi Rd. Amphur Muang Samutprakarn	
Capital	12 Million Bt	
Type of industry	Chemical	
Major products	Formalin, Plasticizer, Urea resin	
Annual product	Formalin 13,000 ton, Plasticizer 7,200 ton, Urea resin 15,000 ton	
No. of employees	100	
Annual energy consumption	Electric power	4,210.5 x 10^3 kWh
	Fuel	Bunker C 1,600 kl Diesel oil 310 kl
Interviewees	Factory manager Mr. Monoe Process engineer Mr. Nuth, Mr. Vichien Electric engineer Mr. Veerasak	
Date of diagnosis	July 21 ~ 22, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

The corporation is a joint concern organized in 1973, with the Thai capital of 60% and the Japanese capital of 40% under the permission of Board of Investment and the production started in 1974.

The manufacturing know-hows were introduced from Mitsubishi Monsant for plasticizer, and from Nihon Kasei for formalin and urea resin and phenol resin. The design and fabrication of the plant were worked by the Japanese side. The plant manager and one staff have been dispatched from Japan. A part of staffs and foremen had received the education and training in Japan prior to the operation.

The production of plasticizer meets 60% of the domestic demand and the corporation is in the first rank. The production of urea resin meets 90% of the domestic demand. Phenol resin is monopolized by the corporation. Formalin, excepting the import of a small quantity of paraform, is monopolize in the market by the corporation, provided that the 90% of product is used for own-consumption.

As mentioned above, the corporation monopolizes the domestic market of all the products or occupies the first rank. Therefore, we regard the corporation as a leading enterprise in an organic chemistry and polymer chemistry fields in Thailand.

2. Manufacturing Process

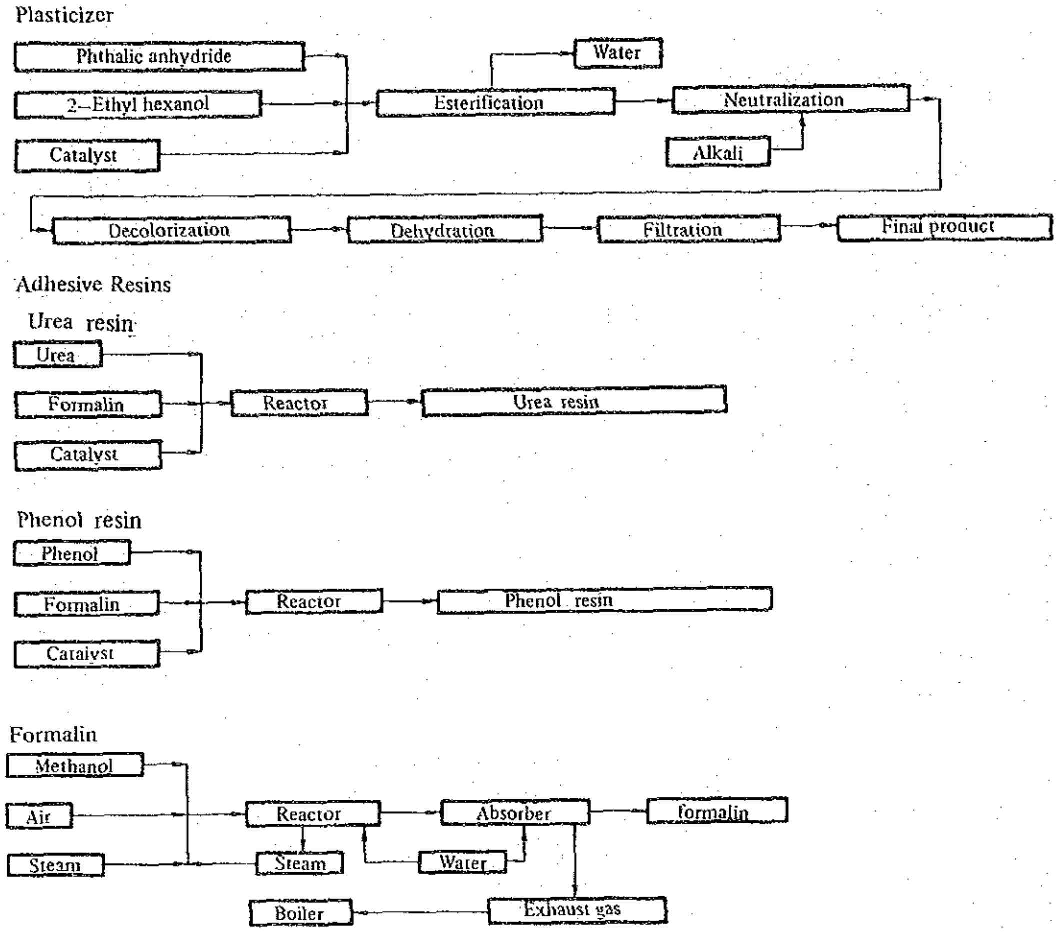


Fig 7–1

3. Major Equipment

3.1 Major Equipment

Table 7–1

Name	No. of units installed	Type, etc.
Plasticizer plant	1	1,000 t/month, Batch system, Mitsubishi-Monsant process
Adhesive resin plant	1	2,500 t/month, Batch system, Nippon Kasei process, Urea-resin: 2 reactors, Phenol-resin: 1 reactor
Formalin plant	1	50 t/day, Nippon Kasei Process
Boiler	2	10 t/h x 8.5 kg/cm^2, water tube, 12 t/h x 8.5 kg/cm^2, fire tube
Water purification unit	1	Reverse osmosis, 80 m^3/h
Cooling tower	1	
Diesel engine generator	2	240 kVA/unit
Waste water incinerator	1	350 kg/h

3.2 Layout

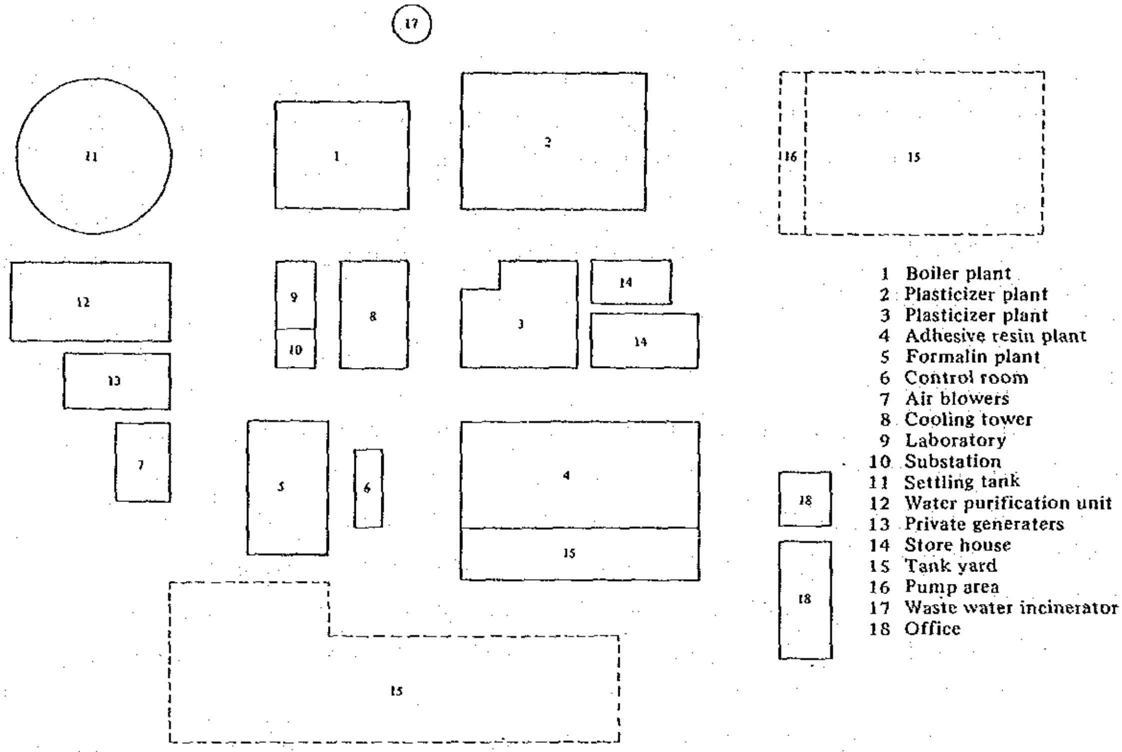


Fig. 7–2

4. State of Energy Management

4.1 Policy for Energy Consumption

Formalin as the main product in the factory is a toxic substance and its manufacturing process is an air oxidation of combustible material. Accordingly, safety of the operation and prevention of any accident must be taken with priority above all. This is also important for energy conservation. The monitoring and maintenance of the facility have been exerted with a constant attentions and the spare parts for major equipment have been usually provided for. To prevent a stress corrosion cracking of the stainless steel equipment, the cooling water is dechlorinated by a reverse osmosis method. Providing against an emergency, the private generator is operated at all times.

As the measures for energy conservation, a condenser for improvement of the power factor and a waste heat boiler of the formalin plant is installed and the condensate in the plasticizer plant is recovered. Taking note of the fact that hydrogen of 20% is contained in the exhaust gas of the formalin plant, this hydrogen has been utilized as a boiler fuel with a renewal of the boiler and a pipe arrangement with the investment of 7,900,000 Bt in last year. The pay back time is estimated as three years.

Furthermore, from the fact that there is a room of capacity in the boiler and in order to take a stability of the steam generation, it attracts attention to conduct the energy conservation between the enterprises with the supply of steam of 2t/h to the adjacent factory and with the stoppage of the other party's small boiler.

Although a target value of energy conservation is not set up especially, the attitude to pursue the energy conservation with seizing an individual subject is observed.

4.2 Participation by All Employees

There is no voluntary activity like a QC activity. However, an education to the general employees is exhaustive with definiteness of the operation standard and, under a strong leadership of the plant manager, a system that the staffs and foremen perform the management of both the operation and the equipment is established.

The plant manager appeals the energy conservation to the staffs and also to the general employees by posters. The regular meeting is held by the staffs and the foremen every two months to exchange views.

4.3 Control through Data

The fuel consumption is grasped every day by the measuring of an inventory and the flow meter. The power consumption is grasped every day by the private watt-hour meter provided in the terminal of receiving panel. The purchased quantities of fuel and raw materials and the shipped quantities of products are measured and confirmed by the private truck scale. The power factor is read out every day by the private instrument.

The steam flow meters and the watt-hour meters are provided to every process and the consumption per hour is read out, recorded manually or automatically.

The energy consumptions are grasped every day to the whole factory, every major process. These data are utilized to the computation of consumption rates and the analysis of fluctuating factors. The control through data is perfect.

But, a control chart is not prepared and a heat balance is not prepared in any process. The energy cost is computed every month by each process.

The required measuring instruments, controllers and automatic controllers are built in each equipment and a high efficiency-production is maintained under the instrumental operation. The maintenance of each instrument and meter is satisfactory and all of these are operated correctly.

4.4 Education and Training for Leveling-Up of Employees

There is no systematized committee for energy conservation but some subjects are given as a special command from the plant manager to the staffs to examine the process. The staffs' interest in the energy conservation is in a high level.

The preservation of the engineering data is performed systematically and the engineering data has been utilized for a technical examination. The staffs take part in seminars or a study visit held by outsiders at any time upon occasion.

5. State of Fuel Consumption

5.1 Fuel Consumption

Fuel oil C 1,600 kl/year ─┐

├→Boiler (Steam quantity 4-9t/h)

Formalin absorber exhaust gas (EG) ca. 1,200 Nm^3/h ─┘

(H_2: ca. 20%, balance: CO_2, Co, N_2)

Diesel oil 310 kl/year → Engines for private generators (Normal:One engine in operation. Power failure: Two engines in operation)

Steam consumption 4~9t/h → 4 t/h Plasticizer plant
→ 2~3t/h → Formalin plant
↑↓ Credit steam 0.4t/h (200 kg/t-Formalin)
→ Other plants
→ 2 t/h Dia Glass(Adjacent enterprise)

5.2 Heat Balance of Boiler

At the day of diagnosis, a steady data could not be collected because of many flameout of the boiler. Accordingly, the heat balance could not be prepared. Only the loss of the exhaust gas is shown in Table 7-2.

Table 7–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	2,359.7	100.0	Heat of steam		
Sensible heat of fuel			Heat loss in exhaust gas	372.2	15.8
			Heat loss in blow water		
			Heat release from boiler body, others		
Total			Total		

Data Given for Calculation of the Heat Balance

Fuel type		Fuel oil C & EG
Fuel consumption	(F)	Fuel oil C 179 kg/h
		EG 1,200 Nm^3/h
Heating value of fuel (Low value)	(Hl)	Fuel oil C 9,415 kcal/kg
		EG 562 $kcal/Nm^3$
Reference temperature	(To)	35°C
Temperature of exhaust gas	(Tg)	280°C

Equation for Calculation of the Heat Balance

Input

Heat of fuel combustion (Qc) Fuel oil C 1,685.3 × 10^3kcal/h

$Qc = F \times Hl$ EG 674.4 × 10^3kcal/h

Total 2,359.7 × 10^3kcal/h

Output

Heat loss in exhaust gas (Qe) 372.2 × 10^3kcal/h

$Qe = F \times G \times 0.33(Tg - To)$

Air ratio (m)

$m = 21/(21 - O_2) = 1.23$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 4{,}603\ Nm^3/h$

5.2.1 Calculation of Heat Loss in Exhaust Gas

(1) Calculation of exhaust gas volume

In this boiler multifuel of fuel oil and Eg. are used. At the day of diagnosis, a serial data could not be collected due to flameout. Accordingly, the exhaust gas quantity was calculated from the past fuel consumption data.

(a) Theoretical volume of exhaust gas in fuel oil combustion Gb.

From the annual actual fuel oil consumption,

$$\frac{1{,}600 \times 10^3}{24 \times 363} \doteqdot 184\ l/h$$

The fuel consumption per hour is 184 × 0.975 = 179 kg/h. The contents of C, H and S in the fuel oil C are 85.7, 11.3 and 3.0 in wt%, respectively. Therefore, the volume of exhaust gas is as follows:

$$Gb = 179 \times 0.857 \times 8.89 + 179 \times 0.113 \times 32.27 + 179 \times 0.03 \times 3.33$$
$$= 2{,}025\ Nm^3/h$$

(b) Theoretical volume of exhaust gas in EG combustion Gg.

The consumption per hour is 1,200 m^3h. The contents of CO, H_2, CH_4, CO_2, N_2 in the Eg gas are 0.17, 20.64, 0.31, 3.85 and 75.07 in vol% respectively.

$$Gg = 2 \times 2.88 + 245 \times 2.88 + 4 \times 10.52 + 46 + 901 \doteqdot 1{,}701\ Nm^3/h$$

Table 7–3

Material	Component	Content	Flow rate of component	Flow rate of exhaust gas Nm^3/h	
Fuel oil	C	85.7 %	153 kg/h	1,360	2,025
	H	11.3	20	645	
	S	3.0	6	20	
EG	CO	0.17 %	2 Nm^3/h	6	170
	H_2	20.64	245	706	
	CH_4	0.31	4	42	
	CO_2	3.85	46	46	
	N_2	75.07	901	901	
Excess air				* Gx = 877	
			Total	4,603	

* Calculation of excess air $\frac{0.21 \times Gx}{3{,}726 + Gx} = 0.04$

$Gx = 877\ Nm^3/h$

(c) Total volume of exhaust gas

The quantity of exhaust gas is as shown in Table 7-3. Since the measured oxygen concentration in exhaust gas is 4.0%, the gross volume of exhaust gas is as follows:

$G = Gb + Gg + G X \doteqdot 4,603 \ Nm^3/h$

(d) Heat loss in exhaust gas

$Qe = 4,603 \times 0.33 \times (280 - 35) = 372.2 \times 10^3 kcal/h$

6. Problems in Heat Control and Potential Solutions

6.1 Boiler Operation Control

6.1.1 Improvement of Combustion Equipment

The structure of boiler is provided to recover effectively the heat of exhaust gas. The boiler is a high efficiency boiler of the most up-to-date model out of the flue smoke tube boilers. However from the measured result of an exhaust gas temperature, the boiler is operated in a low efficiency with the higher gas temperature of 280° C even in a low load (1/4). During the examination, black smoke emitted frequently and flameout was repeated. These are in a question on safety too. Its causes are judged to be an incomplete combustion or an excessive sooting of the smoke tube due to improper setting of the link in the damper for air adjustment.

In this measured results, the oxygen concentration in exhaust gas is almost a proper value of 4.0%. The controller of air volume to the boiler is set to the condition of a multifuel combustion of fuel oil and exhaust gas (EG) of 1,200 Nm^3/h. Therefore at the time of oil combustion only, air ratio goes to excess to a large extent and bring upon an increasing heat loss by exhaust gas. In the current condition, the set position of the damper link differs from that for the trial run. Re-adjustment of the link of the damper for air should be immediately carried out in each load step through request to the boiler supplier.

If the boiler is frequently operated in an extreme low load, a low capacity auxiliary burner should be installed.

6.1.2 Control of Boiler Feed Water Quality and Setting of Blow-off Quantity

The boiler feed water is treated by an ion exchange resin to high purity and a daily feed water quality control is sufficiently carried out. The boiler feed water is maintained in a good quality as shown in Table 7-4.

Table 7-4

	Raw water	Deionized water	Boiler water
pH	6.7	6.2	10.2
Electric conductivity (μS/m)	3,100	18	1,510
Cl^- ion (ppm)	670	0.5	42

The blow-off quantity of boiler water is standardized to keep in less than 2,000 μS/cm in electrical conductivity. This value is too much severe and results in an increase of blow-off loss. In general, a proper value is 6,000 μS/cm or less. The reference value should be looked at again.

6.2 Recovery of Condensate and Raising of Temperature of Boiler Feed Water

In the current state, the condensate in the steam consuming equipments is discarded in various places (found out in the places of 16) in the factory. These condensate should be recovered as far as possible by turn from the larger merit place in consideration of the quantity of condensate and the distance to the tank.

Especially, in the methanol evaporator in the formalin plant, the condensate is generated in much quantity. This condensate should be recovered. The merit when the condensate is recovered is as follows:

(1) Assuming that the production of formalin is 2.08 t/h (as 50t/24h), the methanol consumption per formalin of 1 t is 520 kg/t and the heat of vaporization of methanol is 250 kcal/kg, the required heat is $2.08 \times 520 \times 250 \fallingdotseq 271 \times 10^3$ kcal/h. When this value is converted to the steam quantity of 3 kg/cm^2:

$$\frac{271 \times 10^3}{510} \times 1.1 = 585 \text{ kg/h}$$

On other words, the steam consumption in this equipment is 585 kg/h. All of the condensate is possible to recover.

(2) Assuming that the 50% of the condensate quantity, after flashing steam by 8%, is recovered to the feed water tank, the recovered heat converted to the equivalent of fuel oil is as follows: Provided that the boiler efficiency is taken as 80%.

$$\frac{585 \times 0.92 \times (100 - 32) \times 0.5 \times 24 \times 363}{9{,}415 \times 0.80 \times 0.98} \fallingdotseq 21.6 \text{ kl/year}$$

Converted to the cost:

$21.6 \times 10^3 \times 4.5 = 97{,}200$ Bt/year

In the current state, the boiler feed water is at a room temperature. The temperature of boiler feed water should raise as much as possible with recovery of the condensate. In a rough estimation, it is expected that raising of the temperature of the feed water by 10° C brings the effect raising the efficiency by 1.5% in the boiler. In this case, the feed water tank is required to insulate.

6.3 Other Heat Recovery

6.3.1 Hot Drainage in Formalin Plant

The hot drainage of 73 to 76° C is disharged with 13 t/h from the heat exchanger in this plant. This hot drainage is possible to utilize to raise the temperature of the boiler feed water.

Calculated the heat recovered from the hot drainage, it is as follows:

Assuming that the quantity of boiler feed water is 4 t/h, the recovered quantity of condensate is 0.3 t/h, Δt at the heat exchanger (a plate type) is 5° C, the heat transfer coefficient is 1,000 kcal/m^{2}h° C and the temperature of feed water after the heat exchange is 70° C, the possible recovery heat and the heat transfer area of the heat exchanger are;

$(4.0 - 0.3) \times 10^3 \times (70 - 32) = 140{,}600$ kcal/h. As Q = U.A. Δt 140,600

5. $= 1{,}000 \times A \times A = 28$ m^2.

The equivalent fuel of the recovered heat is;

$$\frac{140.6 \times 10^3 \times 24 \times 363}{9{,}415 \times 0.80 \times 0.98} \fallingdotseq 165.9 \text{ kl/year}$$

Converted to the cost;

$165.9 \times 10^3 \times 4.5 = 746{,}600$ Bt/year

Assuming that the cost of heat exchanger and the piping cost are 100,000 Bt, the pay back time is 0.13 years. This is the improvement of an extremely good investment efficiency. As a hot drainage occurs an large amount of 13 t/h, a more higher temperature of feed water is obtainable by installation of heat pump. On the other hand, the hot drainage is possible to reuse by cooling and a large merit is expected. For an introduction of the heat pump, its investment effect should be confirmed through consultation with the supplier.

6.4 Cost down by Decreasing the Treatment Quantity of the Water by Reverse Osmosis Unit

The water used in the factory is supplied with well water. Chlorine ion concentration in this well water is 700 ppm. Therefore, all the water for processes and boiler are treated by the reverse osmosis and so the cost of water becomes higher. For the cost-down measures of this water treatment, it is important to classify the water by use and to reduce a required quantity of the reverse osmosis treatment.

According to the literature[1], Cl ions of 1,000 ppm does not occur a stress corrosion cracking in a temperature of 73° C or less as shown Fig. 7-3. The water used in a temperature of 73° C or less seems to be not necessary of the reverse osmosis treatment.

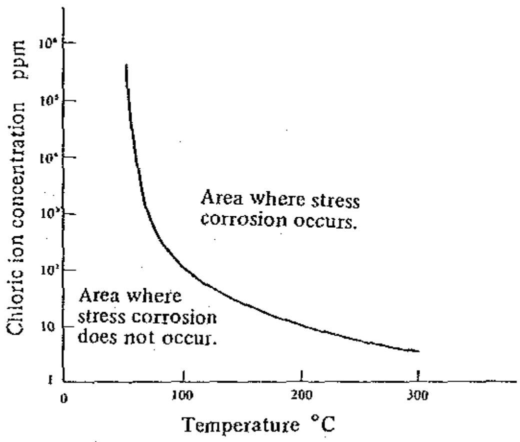


Fig. 7—3

Since the temperatures of the drainages from the several indirect coolers are less than 70° C, a reduction of the water treatment cost seems to may be expected by a large margin.

6.5 Other

The insulation of steam piping and valves is controlled well in a good condition without steam leakage. But some steam flows up to the inlet of a unused boiler facility. This is required to stop the steam flow at the main valve.

A load fluctuation of the boiler is larger. Installation of a steam accumulator enables the boiler to operate in a stable load combustion. When the accumulator capacity is calculated from the operation data, it is required to be the capacity of about 70 m^3 and the investment cost is approximately 4,000,000 Bt. Without a more detail research of the operating condition, a reliable merit can not be calculated.

Literature, KURITA KOGYO: Handbook of Water Treatment Chemicals, 1982, p.117

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	600 kW
Power Consumption	:	4,210,500 kWh/year
Load Factor	:	64.6%
Penalty Fee	:	2,700 Bt/year
Power Factor	:	81%-85%
Transformer	:	1,300 kVA
Power Consumption Rate	:	DOP 8.8 kWh/t, Formalin 70.3 kWh/t, Urea resin 9.1 kWh/t
Power cost	:	1.48 Bt/kWh
Power Generation Rate	:	2.65 kWh/l

7.2 One Line Diagram

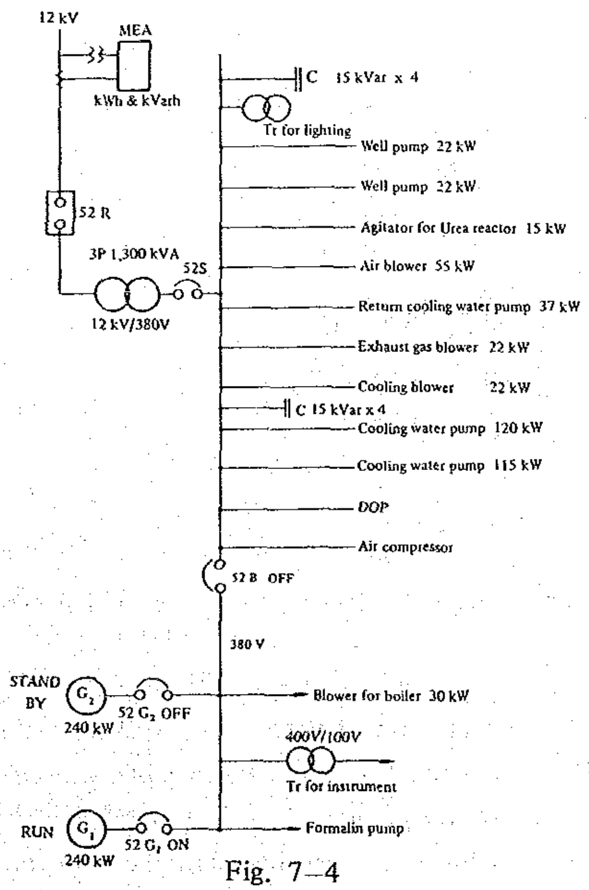


Fig. 7-4

8. Problems of Power Control and Potential Solutions

Although, there are some motors which must not be stopped for safety of formalin plant, electric power failure occured 80 times in last year including instant interruption. So, two 240 kW diesel generators have been installed, one generator is always in operating and another is prepared for back-up of power failure. If switching to a stable power source system is possible, the former generator also can be used for back-up.

8.1 Power Factor

Table 7-5 shows the power factor calculated from the monthly electric bill. The penalty was paid every month except May and June in 1982 and January in 1983.

The condensers are shown 15 kVar × 8 = 120 kVar in Figure 7-4, but the condensers in actual service are only 15 kVar × 4 = 60 kVar. If all the condensers are able to be connected to the circuit after arrangement, no penalty is required and the loss in the transformer is also reduced as follows: Assuming that average power factor as 0.835 and the average power as 388 kW from Table 7-5, the average apparent power is 388 ÷ 0.835 = 465 kVA and the average reactive power is $\sqrt{465^2 - 388^2} = 256$ kVar.

Now, the condenser of 60 kVar is connected to the circuit. If the rest condensers of 60 kVar are connected, the apparent power becomes $\sqrt{388^2 + (256-60)^2} = 435$ kVA. If the total load loss in the 1,300 kVA transformer is 18.2 kW, the energy conservation due to the improvement of power factor is

$$18.2 \times \{(\frac{465}{1,300})^2\} - (\frac{435}{1,300})^2 \times 8,712 = 2,533 \text{ kWh/year}$$

In other words, the merit comes out 6,373 Bt/year of 3,673 Bt plus 2,700 Bt/year of penalty.

Table 7–5 Peak Demand and Power Factor for Receiving Power

Month	kWh	Average power kW	Peak demand kW	P.D x 0.63 kVar	Penalty kVar	Peak reactive power kVar	Apparent power kVA	cos φ	Generator kWh
1982									
5	278,000	374	520	328	–	<328		0.846 <	60,410
6	298,000	414	540	340	–	<340		0.846 <	71,020
7	280,000	376	520	328	12	340	621	0.837	70,710
8	278,000	374	440	277	3	280	522	0.844	79,590
9	276,000	383	500	315	25	340	605	0.826	56,110
10	280,000	376	500	315	25	340	605	0.826	68,890
11	286,000	397	480	302	18	320	577	0.832	56,580
12	274,000	381	480	302	18	320	577	0.832	71,590
1983									
1	246,000	342	440	277	–	<277		0.846 <	74,460
2	262,000	390	500	315	45	360	616	0.812	64,490
3	320,000	430	520	328	12	340	621	0.837	86,970
4	298,000	414	600	378	22	400	721	0.832	73,680
Total	3,376,000				180				834,500

Penalty 15 Bt/kVar x 180 = 2,700 Bt/year

Max peak demand 600 kW

Annual average power 387.5 kW

Electric energy consumption 3, 376,000 + 834,500 = 4,210,500 kWh/year

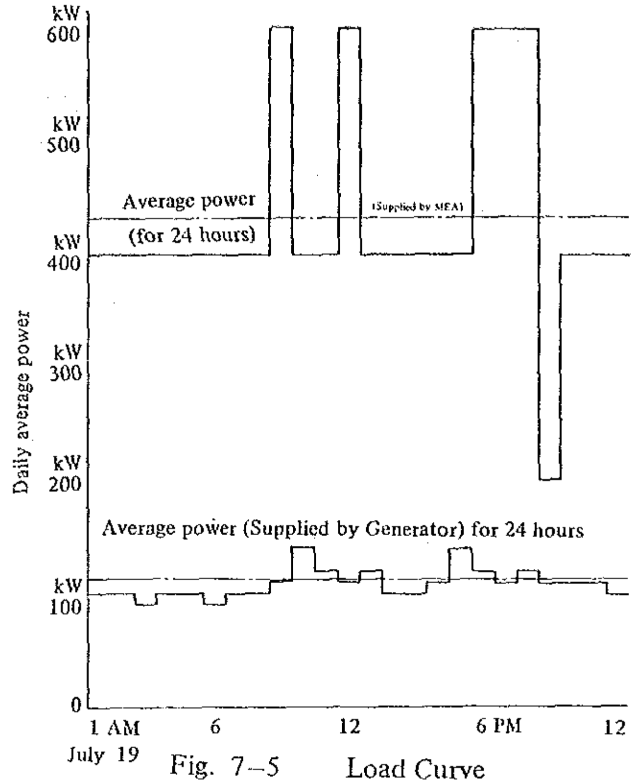


Fig. 7–5 Load Curve

Table 7–6 Daily Report of Electric Power

July 19	Receiving board (Primary)						(Secondary)		Generator					
Time	kV	A	Hz	$\cos\phi$	kW	kWh	V	A	V	A	$\cos\phi$	kW	Hz	kWh
1	11.2	22	50	0.9	370	400	400	620	400	195	0.82	110	50	100
2	11.2	22	50	0.9	370	400	400	620	400	200	0.82	120	50	100
3	11.2	23	50	0.9	370	400	400	620	400	195	0.81	120	50	90
4	11.2	22	50	0.9	360	400	400	600	400	195	0.81	110	50	100
5	11.1	22	50	0.9	370	400	400	620	400	200	0.82	120	50	100
6	11.2	23	50	0.9	370	400	400	620	400	200	0.81	110	50	90
7	11.5	22	50	0.9	380	400	400	600	400	195	0.8	110	50	100
8	11.1	23	50	0.9	380	400	385	680	400	195	0.8	108	50	100
9	11.0	24	50	0.89	410	600	385	680	400	205	0.8	118	50	110
10	11.2	23	50	0.89	390	400	390	650	400	190	0.8	98	50	140
11	11.1	23	50	0.89	390	400	385	650	400	200	0.8	110	50	120
12	11.1	24	50	0.9	420	600	385	650	400	200	0.8	110	50	110
13	10.9	24	50	0.9	430	400	380	680	400	205	0.8	115	50	120
14	11.0	23	50	0.89	390	400	390	700	400	200	0.8	110	50	100
15	11.1	24	50	0.88	400	400	390	700	400	205	0.8	115	50	100
16	11.0	25	50	0.89	430	400	385	720	400	200	0.8	115	50	110
17	11.1	25	50	0.89	430	400	390	720	400	198	0.81	110	50	140
18	11.1	26	50	0.9	450	600	390	710	400	195	0.81	110	50	120
19	11.0	26	50	0.9	450	600	380	740	400	200	0.8	110	50	110
20	11.0	26	50	0.9	450	600	380	720	400	190	0.8	105	50	120
21	11.0	26	50	0.9	420	200	380	720	400	200	0.8	110	50	110
22	11.0	26	50	0.9	420	400	385	700	400	200	0.8	110	50	110
23	11.1	23	50	0.9	400	400	385	650	400	200	0.8	110	50	110
24	11.1	23	50	0.9	400	400	385	620	400	200	0.8	110	50	100
Total						10,400								2,710

When the repairing expense of the dropped off 60 kVar capacitors is 6,000 Bt, the expenses can be paid back in a little less than a year.

8.2 Motor Voltage

The service voltage of motor is higher by 10 - 25 V to the rated voltage. When the motor load is larger than 75%, the service voltage drop does not affect so much change to the motor efficiency. But when the load is 50% or less, to reduce voltage improves the efficiency by approximately 2%. So being the service voltage reduced to about 370 V, the following energy conservation may be expected. In the case, the loss rate of a low load motor is reduced by 2%.

$(12.3 + 12.1 + 8 + 8.5) \times 0.02 \times 8,712 = 7,126$ kWh/year

The tap in 12 kV side of the transformer consists of 5 taps of 12, 11.7, 11.4, 11.1 and 10.8 kV. So it is expected to increase the tap.

8.3 Control of Peak Demand

In this factory, the data of a momentary value to the voltage, current, power and power factor and the data of the watt-hour meter (kWh) are recorded by every hour (See Table 7-6). The power management is done well. Furthermore, however, it is much better if the data of power consumption and reactive power in the whole factory are recorded by every hour. This enables to draw the load curve as shown in Figure 7-5. Then it is possible to control the peak demand and to improve the load factor by trying a peak shift through an adjusting of the operation procedure. These are connected to a reduction of the power loss and the demand fee.

8.4 Preparation of Motor List

A list of motors including spares should be prepared because of being useful when the motor is trouble or is examined to replace for its low load etc. And it is desirable to insert the following items into the above list. (1) Three or single phases. (2) Rated output, (3) Rated voltage, (4) Rated current, (5) Number of poles, (6) Rated r.p.m., (7) Type of insulation, (8) Protection type (for example: Totally-enclosed forced cooling type, Drip-proof type, Increased safety explosion-proof type, Explosion-proof type, etc.,) (9) Vertical or Horizontal types.

8.5 Pressure Drop of Compressed Air

The air compressor is driven by a motor of 37kW and its air is used for instrumentation. If the discharge pressure of compressor can be reduced from 7 kg/cm^2G to 3.5 kg/cm^2G because the required pressure for instrumentation is low, a saving power is possible.

A required power of the compressor can be obtained from the following equation.

$$L = \frac{(a+1)K}{K-1} \frac{PsQs}{6,120} \left\{ \left(\frac{Pd}{Ps}\right)^{\frac{K-1}{K(a+1)}} - 1 \right\} \frac{\phi}{\eta c \eta t}$$

L : Power requirement (kW)

Ps : Absolute of suction air pressure (kg/m^2)

Pd : Absolute pressure of delivery air (kg/m^2)

Qs	:	Air flow rate at the suction conditions (m^3 min)
a	:	Number of intercoolers
K	:	Adiabatic coefficient of the air K = 1.4
ηc	:	Total adiabatic efficiency of the compressor (0.70 - 0.85)
ηt	:	Transmission efficiency
ϕ	:	Safety factor

Therefore, if the discharge pressure is reduced from Pd to Pd', the required power is reduced as the following equation.

(as a = 0)

$$X = \frac{\left(\frac{Pd'}{Ps}\right)^{\frac{0.4}{1.4}} - 1}{\left(\frac{Pd}{Ps}\right)^{\frac{0.4}{1.4}} - 1}$$

Assuming that Ps = 10,330 kg/m^2, Pd = 80,000 kg/m^2 and Pd' = 45,000 kg/m^2, X comes to 0.66. So, the power saving of 34% is possible.

This compressor in on-load requires the input of 30 kW at the pressure of 7 kg/cm^2G. If the pressure is reduced to 3.5 kg/cm^2G, the required input comes to 20 kW. As the power consumption in off-load is almost same, and the compressor has a cycle of 20 seconds on-load and 100 seconds off-load in an operation of the circle, the power saving by reducing the pressure setting is expected as follows:

$$\{(30 - 20) \times \frac{20}{(100 + 20)}\} \times 8{,}712 = 14{,}520 \text{ kWh/year}$$

The cost reduction will be 21,054 Bt/year.

8.6 Power Recovery by RO Method

Recently, the performance of reverse osmosis membrane is improved extremely, and the water treatment method by the RO method (reverse osmosis method) applying this material has been adopted in many cases (for example, desalting of sea water). However, since there is necessity feeding the saline water in a high pressure upon the process of the RO unit, the brine which leaves the unit has an energy of a high pressure. And so this energy is recovered as power by a hydraulic turbine.

The schematic flow diagram of power recovery in the water treatment unit by the RO method is shown in Figure 7-6. The water is fed to the reverse osmosis module by the high pressure pump, and a part of the feed water is output as a desalted water and the rest is discharged as a brine.

The pressure drop in this process is approximately several kg/cm^2 and the brine keeps still a sufficient high pressure. When this brine is fed to the hydraulic turbine connected through the clutch to one end of the double end shaft motor installed for the high pressure pump driving, this pressure energy is recovered as an auxiliary power of the motor.

The recovery of power by the hydraulic turbine from a surplus pressure of water has been put to practical use in the plant of a certain scale or more and it is not a modern technique.

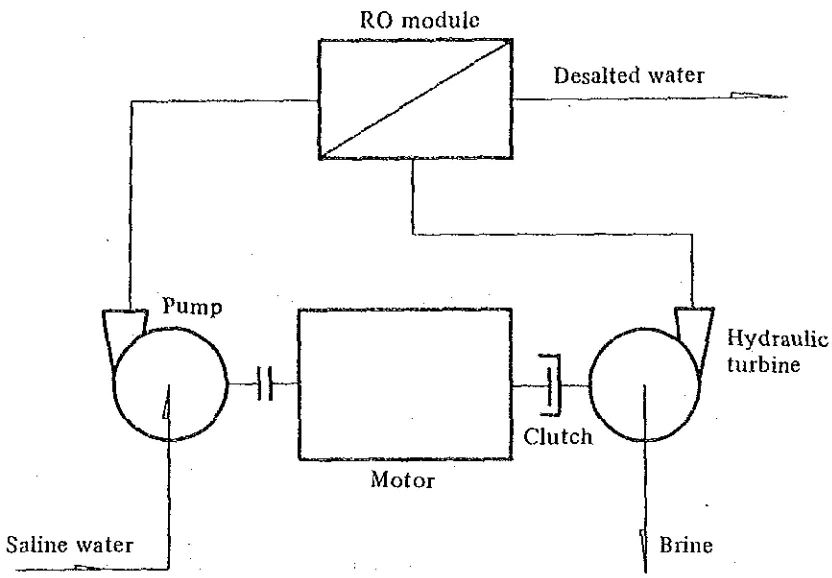


Fig. 7–6 Flow Diagram of Water-treatment Plant by Reverse Osmosis

Recently, however, the water pumps are standardized and various size pumps are put on the market, and an efficient pump is available to get with a lower price. Consequently, the power recovery through pumps as hydraulic turbine is paying to the investment, and the practical use cases are increasing in recent years. After the reduction of the quantity of RO treated water, the power recovery should be examined. The calculation of the power recovery effect is shown below.

Since the flow rate of the pump differes from the flow rate of the hydraulic turbine in the RO method, the recovery rate of power - the ratio of the recovered power to the pump shaft power - is as follows:

$$W_P \propto Q_P \cdot H_P / \eta_P \propto Q_P \cdot P_P / \eta_P$$

$$W_T \propto Q_T \cdot H_T \cdot \eta_T \propto Q_T \cdot P_T \cdot \eta_T$$

The power recovery rate x is,

$$x = \frac{W_T}{W_P} = \frac{P_T \cdot Q_T}{P_P \cdot Q_P} \eta_P \cdot \eta_T = \frac{P_T}{P_P}(1-\alpha)\eta_P \cdot \eta_T$$

(W: Power kW, Q: Flow rate m^3/S, H: Head m, P: Pressure kg/m^2,: Recovery rate of treated water, η: Efficiency, The subscripts of p and T indicate a concern of the pump and the hydraulic turbine respectively.)

By this equation, the calculation of the merit from the operating data is as follows:

(1) If the recovery rate of the treated water is taken as 43% and the efficiencies of the pump and the hydraulic turbine are taken both as 70%, the power recovery rate is as follows:

$$x = \frac{27}{38}(1 - 0.43) \times 0.7 \times 0.7 = 0.20$$

(2) Since the input of the motor is 75 kW as the measured value, the recovered power is $75 \times 0.20 = 15$ kW. That is, the annual recovered power is $15 \times 24 \times 363 = 130{,}680$ kWh/year. Converted it to the cost, 130,680 x 1.45 = 189,486 Bt/year.

The investment cost of the power recovery unit is estimated as 100,000 Bt. The investment recovery time is 0.52 years. Therefore, this investment is expected to have a large merit.

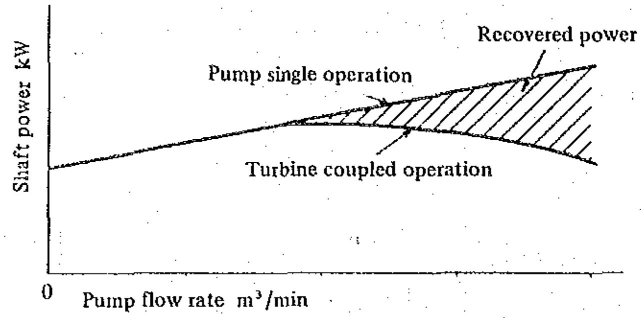


Fig. 7—7 Reduced Pump Shaft Power by Hydraulic Turbine

An example of power recovery by the RO method is shown in Figure 7-7. In this figure, the shaft power decrease as flow rate increase in a certain flow rate range, because the pump shaft power does not change in a large degree but the output of the hydraulic turbine changes depending upon the flow rate.

9. Summary

	(Fuel oil equivalent) kl/year	%
Condensate recovery	21.6	1.3
Heat recovery of hot water in the formalin process	165.9	10.4
Subtotal	187.5	11.7

	10^3kWh/year	%
Improvement of power factor	2.5	0.1
Service voltage change of motor	7.1	0.2
Discharge pressure drop in air compressor	14.5	0.3
Power recovery by RO	130.7	3.1
Subtotal	154.8	3.7

Report No. 8: Plastic & Chemical

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thai Silicate Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Thai Silicate Co., Ltd. —

1. Outline of the Factory

Address	8 M. 3 T. Klongmadua Kratumban Smutsakorn 74110	
Capital	1 Million Bt	
Type of industry	Chemical	
Major products	Sodium silicate	
Annual product	4,800 ton	
No. of employees	32	
Annual energy consumption	Electric power	60.1×10^3 kWh
	Fuel	Bunker C 864 kℓ
Interviewees	Factory manager Mr. Ananta	
Date of diagnosis	July 23, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

The company belongs to the "We Are" group of Thai capital composed of the six enterprises (others: steel materials selling, automobile parts selling, machinery selling, gunpowder export and import selling and manufacturing of palm oil), and the factory was established nine years ago.

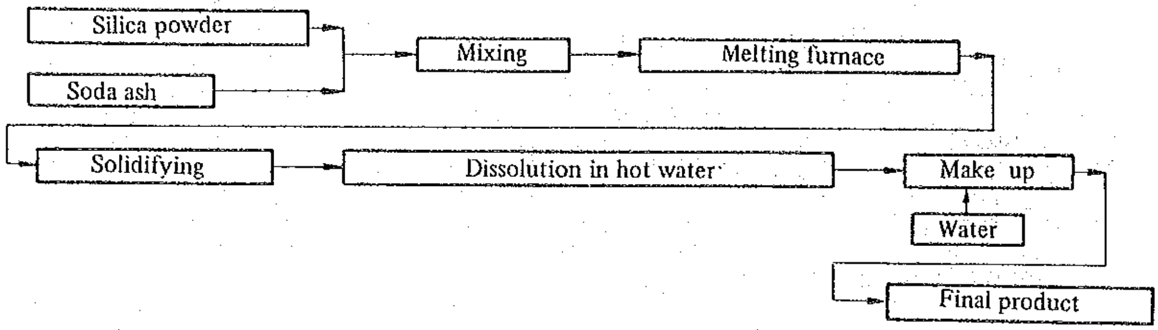
The current products are sodium silicate and powder mortar, and the former is a main product. The white carbon manufacturing plant is under construction with the schedule of operation before long.

Sodium silicate is used in a wide application such as a detergent, adhesive or auxiliary for casting. The domestic demand of it is in a prosperous condition and so the factory is operating in a condition of almost full production. Some part is imported and there are three other domestic companies in the same line of business. The company is in the third rank on output.

Because the process is a high temperature chemical reaction though simple this type of industry has many research subjects concerning the energy conservation. The factory is studying positively the subject and is already obtaining excellent results in a short time. The factory is an enterprise hopeful for further progress in future.

2. Manufacturing Process

Sodium silicate



Powder mortar

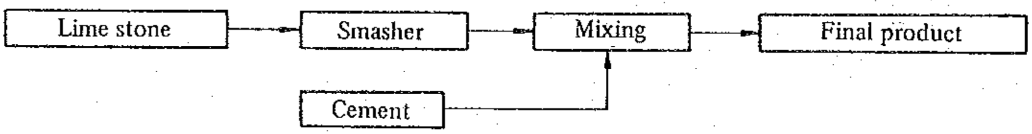


Fig. 8–1

3. Major Equipment

3.1 Major Equipment

Table 8–1

Name	No. of units installed	Type, etc.
Melting furnace	3	10 t/day unit, Batch system
Waste heat boiler	1	Fire tube (under construction)
Final product tank	11	Over head
Product tank	2	Under ground
Smasher	1	for powder mortar manufacturing

3.2 Layout

1 Fuel tank
2 Final product tank
3 Product tank
4 Melting furnace
5 Dissolution tank
6 Waste heat boiler
7 Stack
8 Office

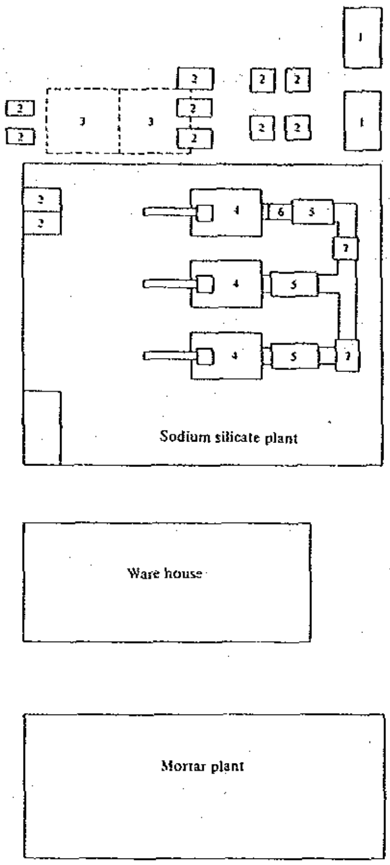


Fig. 8–2

4. State of Energy Management

4.1 Policy for Energy Conservation

The manufacturing process is composed of only two processes of the chemical reaction in molten phase and the dissolution to water. The preparation of raw material is worked by manual labor, and the facility are simplified to the irreducible minimum of demand. But, because of a high temperature operation, a large influence may come out in the energy consumption and the furnace life according to the operating condition. Accordingly, the plant involves many engineering subjects for study and improvement.

The plant manager entered upon the duties four months ago is a Japanese university graduate and wrestles positively with the rationalization of operation and the measures for energy conservation. He places emphasis also on the education of the employees. The results put in an appearance by the definite mark. The energy cost has been reduced by nearly 40% from 1,300 Bt/t to 800 Bt/t during the four months.

The effective measures, such as the improvement of combustion by an increase of r.p.m. of the fuel atomizer of burners and the gradual reduction of fuel oil, are carried out in succession.

For the equipment without instruments installed, the improving action within the production is a work accompanied with risk and requiring utmost carefulness. The success mainly depends on the plant manager's technical ability and management capacity.

One furnace is designed to heat directly the dissolver by the exhaust gas of furnace. For another furnace, a waste heat boiler for the exhaust gas and an equipment in order to utilize its generated steam to the dissolving process have being constructed. These investment is scheduled with about 50,000 Bt. The investment is expected with the pay back time within two years.

The life of a chamotte brick of the furnace is so far six months. This extremely short life has made the productivity decrease compared with that of the other zirconia brick furnace having four or five years.

4.2 Participation by All Employees

There is no self active organization such as a QC circle. Because of a small number of persons, the organization is simplified and the foremen support the plant manager to control effectively the operation in day and night without a staff system. In the ease of this factory the small scale organization acts effectively to lead the success of the shop management.

The plant manager appeals always the energy conservation to all the employees. As to posters an arrangement was made to be furnished from NEA because a proper poster cannot be prepared by themselves.

4.3 Control through Data

The fuel consumption is recorded every day from the measurement of the stock. The power consumption is grasped from the reading of the incoming watt-hour meter once a month.

The each consumption rate is calculated and the control chart is prepared. This thing evinces the earnest attitude to the study for cost reduction.

Because the final product of the sodium silicate has various specifications in concentration and composition, it is stored systematically in the tanks according to a respective specification, and is arranged so that the product can be shipped in answer to the customer's specification.

The energy cost per month is displayed graphically to facilitate visual management and understanding.

Because the operation of this plant provided with no instrument depends upon the intuition, an improvement of the operating condition is inevitably to be trial and error with a difficulty and a long time. It is desirable to install the minimum instruments such as a thermometer and a fuel oil meter, etc.

4.4 Education and Training for Leveling-Up of Employees

The plant manager takes the lead in the study for an operating improvement with the technical information in domestic and foreign affairs, and receives the instruction from a professor of a university in Bangkok once a week.

Because the foremen are the core of the plant operation, the instruction and education to the foremen are carried out intensively. The training in the company is carried out twice a week by the plant manager as a lecturer. The participation in the outsiders' training is carried out in eight times annually according to the annual periodical schedule sponsored by MOI and TPA.

The outside visit and study is brought into operation with 12 to 13 times annually to the other type industry such as a glass or a paper industries similar to or relative to this industry.

The aforementioned heat recovery of exhaust gas and its utilizing system was planned and designed by the plant manager himself. His engineering ability is valued highly and his contribution is anticipated toward growth of the company in future.

5. State of Fuel Consumption

5.1 Fuel Consumption

Most of fuel oil C is consumed as fuel of the melting furnace for producing the sodium silicate. The consumption in 1982 was 864 kl/year.

The melting furnace is operated by a batch system for 12 hours per furnace and the production of a batch varies with the product type. However, the average fuel consumption is about 800 l/batch according to the recent data.

Fuel oil C 864 kl/year ―― (Three melting furnaces)

Breakdown: 1.6 kl/Furnace/day × 1.5 Furnace/day × 365 day/year

5.2 Fuel Oil Consumption Rate

The fuel oil consumption rate of the melting furnace calculated from the actual results of production and fuel oil consumption is as follows:

$$\text{Fuel oil consumption rate} = \frac{864 \times 10^3 \text{ l/year}}{4{,}800 \text{ t/year}} = 180 \text{ l/t}$$

This value results in an improvement of the consumption rate to a large extent by the improvement of combustion and the rationalization of operation compared with the past results. With a much more improvement of the energy conservation, the fuel oil consumption rate should be reduced.

(Reference) In Japan, the fuel consumption rate of a continuous melting furnace with a regenerator is 100 to 115 l/t.

5.3 Heat Balance of Melting Furnace

Data required to the heat balance cannot be got by reason of no measuring port. But, a trial calculation is as Table 8-2 and Figure 8-3, though it is no better than a conjecture.

Table 8–2 Heat Balance at Melting Furnace

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	768.32	99.66	Heat of reaction	96.97	12.64
Sensible heat of fuel	2.65	0.34	Heat loss in exhaust gas	425.00	55.13
			Heat release from furnace body, others	249.00	32.23
Total	770.97	100	Total	770.97	100

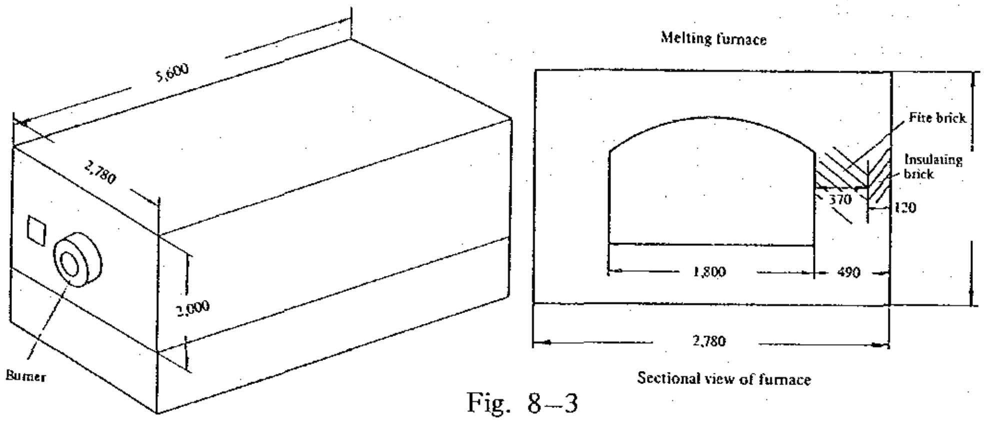


Fig. 8–3

Data Given for Calculation of the Heat Balance

Fuel type		Fuel oil C
Fuel consumption	(F)	78.4 kg/h (800 l/Batch,10 h)
Heating value of fuel (low value)	(Hl)	9,800 kcal/kg
Specific gravity of fuel	(SG)	0.98
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	110°C
Reference temperature	(To)	35°C
Oxygen content in exhaust gas	(O_2)	5%
Temperature of exhaust gas	(Tg)	1,200°C
Temperature in furnace (Estimation)	(Ti)	1,200°C
Total furnace wall area (Based on Fig. 8-3)	(A)	166 m^2
Thermal conductivity of refractory brick	(λf)	1.2 kcal/mh°C
Thickness of refractory brick	(Si)	0.12 m
Thermal conductivity of insulating brick	(λi)	0.3 kcal/mh°C
Thickness of insulating brick	(Sf)	0.37 m
Furnace wall temperature	(Ta)	140°C

Equation for Calculation of the Heat Balance

Input

Heat of fuel combustion (Qc) 768.3×10^3 kcal/h

$Qc = F \times Hl$

Sensible heat of fuel (Qs) 2.6×10^3 kcal/h

$Qs = F \times Cp(Tf - To)$

Output

Heat loss in exhaust gas (Qe) 425×10^3 kcal/h

$Qe = F \times G \times 0.33(Tg - To)$

Theoretical amount of air (Ao)

$Ao = 0.85\ Hl/1{,}000 + 2.0 = 10.33\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11\ Hl/1{,}000 = 10.33\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 1.31$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 14.08\ Nm^3/kg$

Heat release from furnace body (Qr) 249×10^3 kcal/h

$Qr = Q_1 \times A$

Heat passing through furnace wall (Q_1)

$Q_1 = (T - T)/(S/\lambda + S/\lambda) = 1{,}500\ kcal/m^2h$

Thermal efficiency of melting furnace (n)

$$\eta = (1 - \frac{249 \times 10^3 + 425 \times 10^3}{768.32 \times 10^3 + 2.65 \times 10^3}) \times 100 = 13\%$$

6. Problems in Heat Control and Potential Solutions

6.1 Combustion Control

6.1.1 Control of a Proper Air Amount

The oxygen concentration in exhaust gas could not be measured because of no measuring port in the outlet of the melting furnace. But, the oxygen concentration in combustion gas in the furnace was measured from the raw material charging hopper. Its result was 5.0 to 4.0%. This value is a relatively proper air ratio. But the control of secondary air for combustion is controlled only by an openness of the air intake. Accordingly, a fine control of air amount is difficult. For a measure to this, it is desirable to install a damper to control the furnace pressure. At the same time, the entry of atmospheric air from the burner tile part should be prevented as much as possible.

6.1.2 Installation of Combustion Control Instrument

To control more properly the combustion state without an operation by intuition, the following instrument is required to be installed as the minimum.

(1) Pressure gauge in the furnace

(2) Exhaust gas thermometer

(3) Thermometer in the melting furnace

A nozzle (about 2" diameter) for analysis of exhaust gas such as oxygen concentration should be installed other than these instruments.

A measuring meter of fuel consumption is not in installation, but the meter should be installed to control the energy consumption rate by a batch.

6.1.3 Installation of Fuel Oil Preheater

A preheating of fuel oil is necessary because fuel oil C is used. In the furnace, energy has been used in a good manner which a fuel oil is heated with utilization of a radiant heat from the ceiling. For more improvement of the combustion efficiency, the temperature of fuel oil at the burner is necessary to be controlled properly at all times. As the measures, an electric preheater for fuel oil should be installed at the inlet of burner. This preheater is usable also at start-up of the furnace.

6.2 Improvement of Waste Heat Recovery

The heat recovery rate of exhaust gas at the dissolver is possible to estimate by measuring the temperature of exhaust gas at the inlet and the outlet of the dissolver. But its temperature could not be measured because of no measuring port.

After calculating the required heat in the dissolver, if the remaining heat of exhaust gas has an allowance, the air for combustion should be preheated by the exhaust gas.

The merit of higher combustion efficiency by preheating of air for combustion is remarkable. The reduction of fuel oil consumption due to the preheating of air can be calculated by the following equation.

If the preheating temperature of air is taken as 200° C and the fuel oil consumption is taken as x' kg/h,

$$\frac{770{,}970}{78.4}x' + 1.31 \times 10.33 \times x' \times 0.35(200 - 35) = (96{,}970 + 249{,}000) + \frac{425{,}000}{78.4}x'$$

$x' \fallingdotseq 66.6$ kg/h

The reduction rate of fuel oil is,

$$(1 - \frac{66.6}{78.4}) \times 100 = 15.1\ (\%)$$

The annual reducting quantity of fuel oil is 864 kl/year × 0.151 = 130.5 kl/year.

Converted to the cost,

$130.5 \times 10^3 \times 4.3$ Bt = 561,150 Bt/year.

Furthermore, the following incidental effect can be expected, that is, the temperature in furnace rises by preheating of air and the heat efficiency of the melting furnace is improved by an elevation of the heat transfer rate. In the present installation, the exhaust gas is utilized as a heat source for the dissolver installed on the underground flue. But there is a gap between the dissolver and the brick wall, so air enters into the flue from the gap to lead a drop of the exhaust gas temperature. Therefore, some repair to keep the tightness is required. The waste heat boiler under coustruction is a good method. But the waste heat boiler cannot take a larger resistance because the melting furnace is a natural draft system. This should be considered at the planning stage.

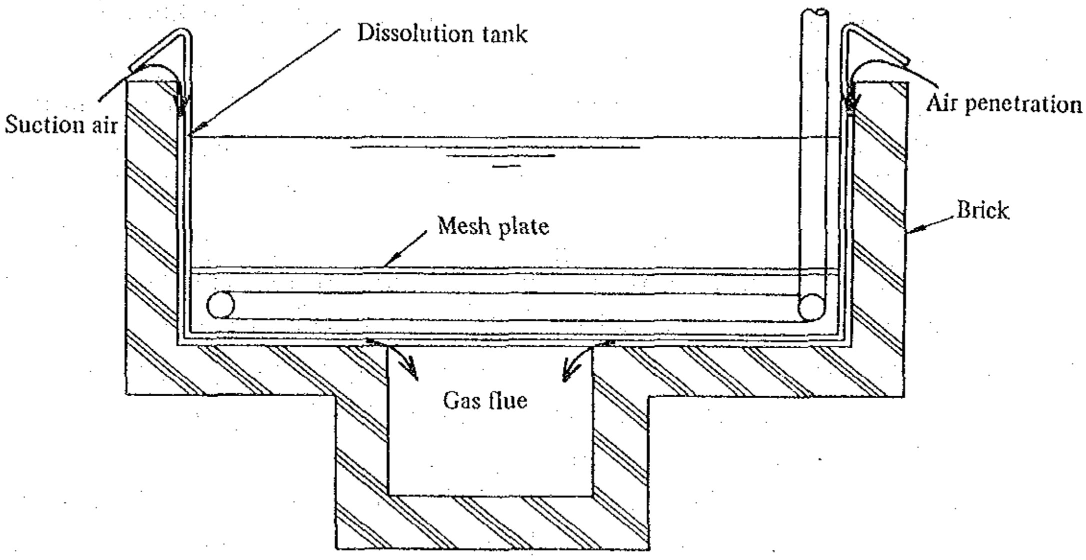


Fig. 8–4

6.3 Recovery of Flash Steam out of the Dissolver by Waste Heat Boiler

How to use of steam in the dissolver by the waste heat boiler constructing now should be paid with attention as follows.

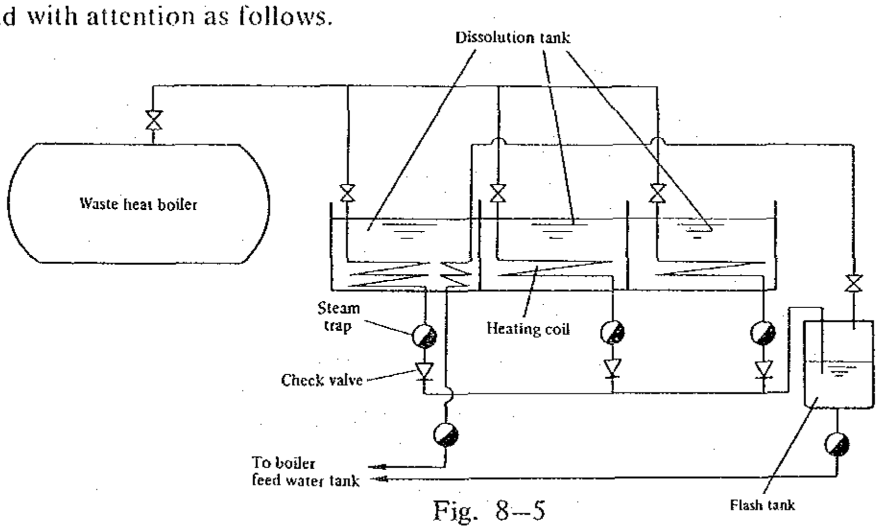


Fig. 8–5

In case of an indirect heating by steam, only the latent heat of vaporization is used and the rest remains in the condensate. When the pressure of condensate is reduced to an atmospheric pressure through the trap, some part is evaporated and hot water of 100°C remains.

For example, a heat flow in the steam of 2 kg/cm^{2}G is illustrated as follows.

Heat of 2Kg/cm^{2}G steam (1.00)

Utilization to heating (0.79) —— Condensate of 2 kg/cm^{2}G (0.21)

Flash steam (0.06) —— Condensate of atmospheric pressure (0.15)

Therefore, it is recommendable to integrate the steam condensate discharged from the heat exchangers of each dissolver into the collecting pipe through the individual steam trap and check valve and install a flash tank as shown in Figure 8-5 to utilize again the flash steam as a heat source of the dissolver. As the pressure of flash steam is lower than the primary pressure, the flash steam can be used to the heat exchanger for preheating.

6.4 Refractory Brick of Melting Furnace

Since the internal wall of the existing furnace is installed with a chamotte brick, its life is short of about six months. Moreover, some parts of the brick is eroded to mix in the product which does not agree to the specification for detergent. The electrocasting bricks such as zirconia or alumina are a very little eroded and has a longer life but the cost is higher.

With views of the quality improvement of the product and the improvement of the productivity, the electrocasting brick of zirconia or alumina is not always a high cost. The relationship among the specification of an electrocasting brick, the cost and the profit should be investigated in detail. The each brick cost is estimated as a reference below.

In the case of that the bottom and each side surface in the inner wall of a melting furnace are installed with bricks of 370 mm in the thickness. The cost comparison between three type bricks of chamotte, zirconia and alumina (Mullite) is as follows. The quantity of brick is 13 m^3 to a furnace.

Chamotte brick:

Density = 2.2 t/m^3, Price = 5,000 Bt/t

The cost of brick = 13 × 2.1 × 5,000 = 136,500 Bt (A)

Life = 0.5 years (a)

Zirconia electrocasting brick:

Density = 3.5 t/m^3, Price = 55,000 Bt/t

The cost of brick = 13 × 3.5 × 55,000 = 2,502,000 Bt (B)

Life = 4 to 5 years (Average 4.5 years) (b)

Alumina electrocasting brick:

Density 3.0 t/m^3, Price 35,000 Bt/t

The cost of Brick = 13 × 3.0 × 35,000 = 1,365,000 Bt (C)

Life = 2 to 3 years (Average 2.5 years) (c)

Each ratio when the chamotte is taken as 1 is as follows;

	Zirconia	Alumina
Cost	18.3[(B)/(A)]	10.0[(C)/(A)]
Life	9.0[(b)/(a)]	5.0[(c)/(a)]

Note: The cost is only for the brick not including the construction charge.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company : PEA

Peak Demand : 34 kW

Power Consumption : 60,120 kWh/year

Load Factor	:	20.6% (The low load factor is based on the reason of 8 hours operation in the crusher and 24 hours operation in the silicic acid which is a low load.
Penalty Fee	:	No
Power Factor	:	66% to 69%
Transformer	:	3ϕ 315 kV/400V
Power Consumption Rate	:	16.7 kWh/t Mortar
Power Cost	:	2.14 Bt/kWh

7.2 One Line Diagram

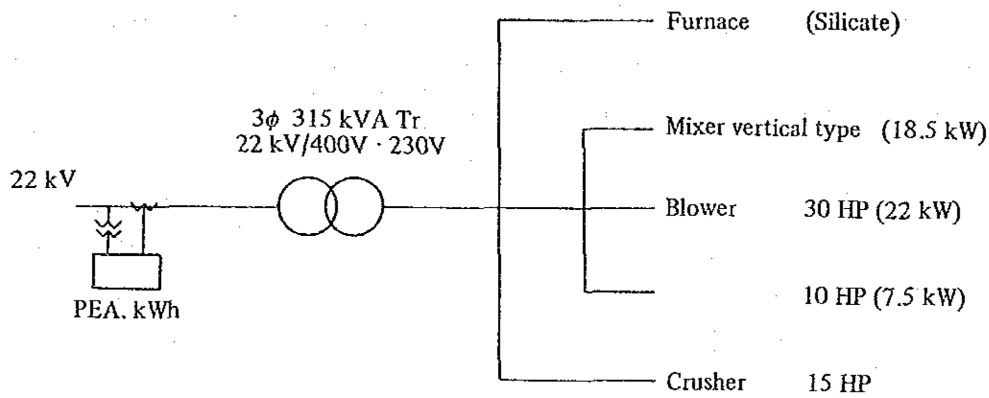


Fig. 8–6

8. Problems of Power Control and Potential Solutions

8.1 Power Factor

The factory is no penalty because of receiving from PEA. And because the load is smaller compared with the capacity of transformer, and the mixer and the blower of the main load are operated only for 8 hours every day, the power factor improvement by an insertion of a condenser does not bring any merit and the pay back time goes to a longer in spite of the low power factor of 60 to 75%.

Table 8–3 Measurement for Main Circuit

Time	V	A	kVA	cos ϕ	kW	kWh
11:30 AM	420V · 415V · 408V	55.2A · 58.7A · 66.5A	42	0.68 0.66 0.73	29	28
0:30 PM						28
1:30 PM	415V · 405V · 401V	53A · 56A · 64A	39	0.73 0.63 0.65	26	4
2:30 PM						32
3:30 PM	408V · 415V · 403V	54A · 75A · 66.8A	47	0.66 0.6 0.73	31	28

8.2 Service Voltage of Motor

Table 8–4 Actual Load for Each Motor

Using for	Rated out put	Measuring in put kW	Rated voltage V	Measuring voltage V	Rated current A	Measuring current A	Power factor	No. of pole
Mixer	25 HP (18.5 kW)	14	380	410	35	26.4	0.75	6
Crusher	15 HP (11 kW)	5.1	380	414	23	11.5	0.62	4
Blower	30 HP (22 kW)	7	380	414	41.7	16.3	0.6	4

The actual load of motor is light and the service voltage is too much higher. The service voltage of three motors are high by 8 to 9% to the rated voltage of 380 V. When the load is less than 50% of the rated output and the voltage is reduced by 10% to the rated voltage of motor, the efficiency is improved by about 2%. If the service voltage comes down to 370 to 375 V, the following energy conservation can be expected for the motors of 11 kW and 22 kW.

$(5.1 + 7)\text{kW} \times 0.02 \times 2{,}880 \text{ hr} = 697 \text{ kWh/year}$ .... (8.2)

8.3 Capacity of Motor

Each load is light to the rated output of motor. The motor of 11 kW should be rather replaced to 5.5 kW and the motor of 22 kW replaced to 7.5 kW. But the replacement to a new purchased motor is little economical merit. Accordingly, these motors should be replaced with some spare one, if stocked.

8.4 Lighting

The intake of daylight is good. If the fluorescent lamps are replaced to a good luminous efficiency type white fluorescent lamp, the energy conservation is as in the followings.

$5 \text{ W} \times 20 \text{ Lamps} \times 10 \text{ h} \times 360 \times 10^{-3} = 360 \text{ kWh/year}$ .... (8.2)

8.5 Control of Peak Demand (See Table 8-5)

Table 8–5 Peak Demand & Energy Consumption

Month	Peak demand kW	kWh	Month	Peak demand kW	kWh
1982					
1	12	3,840	7	34	5,268
2	32	5,360	8	28	3,812
3	34	5,760	9	30	7,200
4	34	6,240	10	32	4,920
5	32	4,120	11	32	4,320
6	32	4,880	12	30	4,400

The data of electric energy is arranged well. Moreover, the measurement of kWh every hour makes the peak and the off-peak to know. Based on the data, the operating procedure should be improved to control the peak demand.

9. Summary

The effect when the above measures are performed is as follows:

	(Fuel oil equivalent) Kl/year	%
Air preheating	130.5	15.1
Subtotal	130.5	15.1
	10^3kWh/year	%
Service voltage lowering of motor	0.7	1.2
Use of energy conservation type white fluorescent lamp	0.4	0.6
Subtotal	1.1	1.8

Report No. 9: Plastic & Chemical

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— The Bangkok Chemical Industrial Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
-- The Bangkok Chemical Industrial Co., Ltd. --

1. Outline of the Factory

Address	76 Area 3 Sukhumvit Rd. New-bangpoo Town Dist. Samutprakan	
Capital	12 Million	
Type of industry	Chemical	
Major products	Sulfuric acid, Sulfur powder/roll, Alum, Copper sulfate, Ferrous sulfate	
Annual product	Sulfuric acid 10,000 ton, Sulfur powder 470 ton, Alum 3,000 ton, Cupric sulfate 800 ton, Ferrous sulfate 500 ton	
No. of employees	65	
Annual energy consumption	Electric power	812.6 x 10^3 kWh
	Fuel	Bunker A 3 kℓ
Interviewees	Factory manager Mrs. Suwannee Technical staff Mr. Kuang Chieng	
Date of diagnosis	July 26 ~ 27, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

The company is an enterprise of Thai capital and is engaged only in manufacture of products. The company is a member of the group including a separate company for selling the products. The factory was constructed 16 years ago and the sulfuric acid plant was designed and fabricated by the know-how of Taiwan and the operation was instructed by the engineers of Taiwan.

The raw material sulfur depends on a natural sulfur imported from Canada. So the product cost is higher than the imported sulfuric acid, but the higher cost of raw material is compensated by the production of alum, cupric sulfate and ferrous sulfate manufactured from the sulfuric acid as a main raw material. The company has succeeded to realize a profit through the production of these products. Since the copper and iron as an auxiliary material come of scraps, these product costs turn into a possibility to control these products in a low cost. An ingenuity of the product composition of the company exists here.

The production of sulfuric acid by the company is the smallest among the six domestic companies of the same industry. In the alum production, however, the company is the biggest among the private companies excepting MOI. Also, in the ferrous sulfate production, the company has maintained the top production among the domestic companies of the same industry. Cupric sulfate is produced by one company other than this company, but its producing scale is very small.

Although the sulfuric acid production of the company is in the lowest rank, the production of the inorganic products applying sulfuric acid is in the top position. Therefore, the company is regarded as a representative enterprise in a specific field of the chemical industry of Thailand.

2. Manufacturing Process

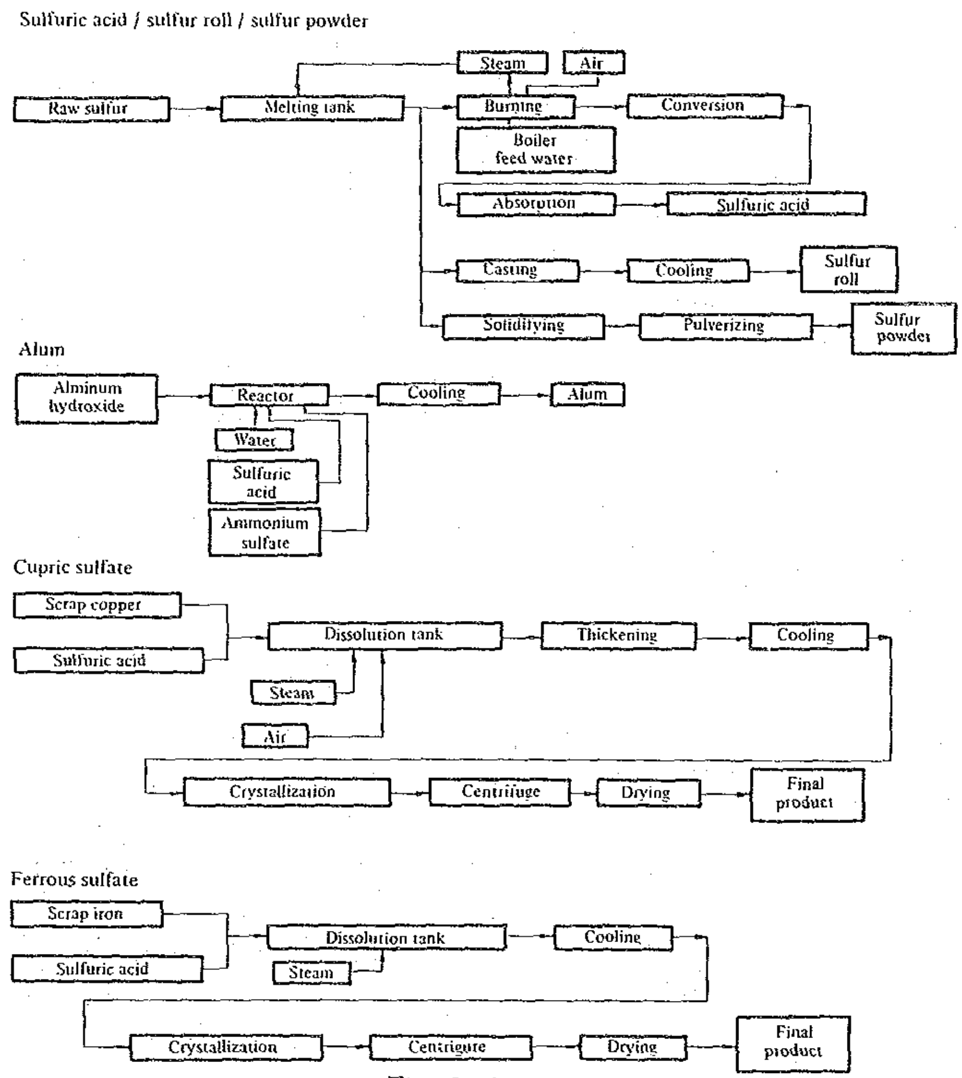


Fig. 9–1

3. Major Equipment

3.1 Major Equipment

Table 9–1

Name	No. of units installed	Type, etc.
Sulfuric acid plant	1	30 t/day, sulfur burning, contact conversion
Sulfur roll facility	1	
Sulfur powder plant	1	1.5 t/day
Alum plant	1	300 t/month, batch reactor
Cupric sulfate plant	1	70 t/month
Ferrous sulfate plant	1	50 t/month
Boiler	1	1 t/h, fire tube

3.2 Layout

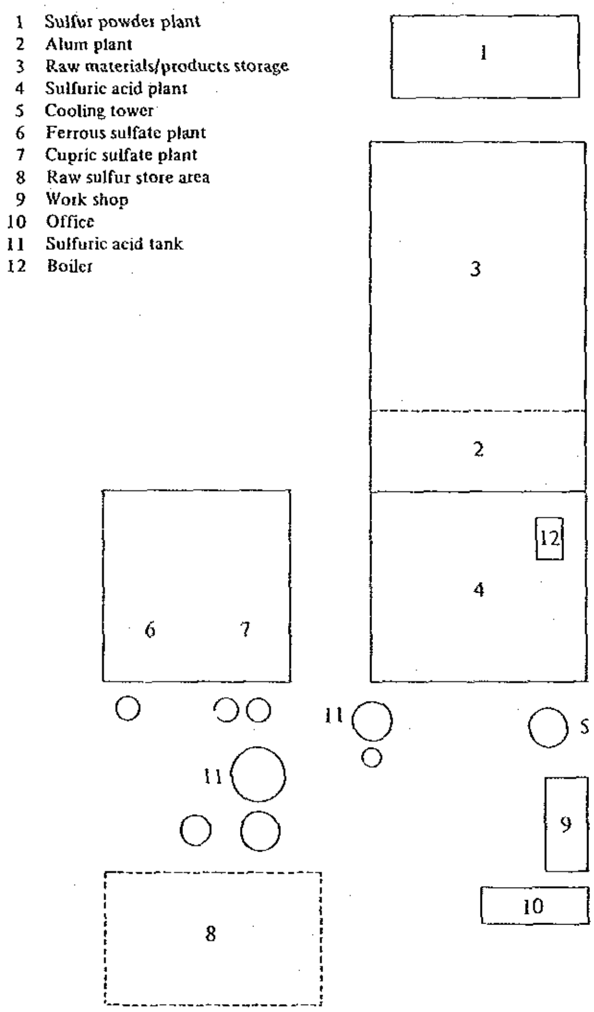


Fig. 9–2

4. State of Energy Management

4.1 Policy for Energy Conservation

The sulfuric acid plant and other plants of the inorganic chemicals derived from the sulfuric acid are connected organically. These plants are operated efficiently with the very simplified installation.

Since the credit steam generated in the sulfuric acid plant supplies all the heat energy required to the melting of sulfur and the cupric sulfate and ferrous sulfate plants, fuel oil does not need for these plants other than the time the sulfuric acid plant does not operate.

The dryer for cupric sulfate was completed through utilization of cooler exhaust air in the sulfuric acid plant by the own-technique with the investment of 20,000 to 30,000 Bt four years ago. Therefore, the heat source for drying became useless. Besides the piping has been installed to use a hot drainage as boiler feed water from the bearing jacket of air blower.

The quantity of credit steam is in some shortage for the demand in the day, but leaves some surplus at night. The surplus of steam is balanced through consumption to melting of sulfur to hold the heat energy in the liquid state at night. Thus, since the inauguration of the company, an effectual utilization method of the recovered energy in the sulfuric acid plant has been investigated and implemented under the policy to a positive energy conservation. At present, a special investment to the energy conservation is not scheduled and it is limited to repair of the insulation.

The quantity of credit steam is able to come approximately 1.2 tons to 1 ton of sulfuric acid. However, some part of the heat of reaction is not still recovered in this plant. And the quantity remains at 0.8 to 0.96 tons per 1 ton of sulfuric acid. Accordingly, there is room for improvement.

Although the operation is a batch system of the mixture of liquid and solid and almost a manual or hand operation, a leakage or a dispersion of the raw material, intermediate and product are very small, except sulfur powder plant. Accordingly, the energy loss accompanied with these is very small. The operation is kept with great expertness and control.

4.2 Participation by All employees

There is no self-control activity such as a QC circle and there are no improvement suggestion system and awarding system. The employees are composed of three staffs and workers and the division of duties is defined. The workers are demanded only with the reliable operation according to the operation standard and the instruction of technical staff. The plant manager appeals the energy conservation to all the employees.

4.3 Control through Data

Fuel oil is consumed only during the stop of the sulfuric acid plant and at the start-up. And so the consumption is grasped from the purchasing quantity each time but the proportion in the manufacturing cost is very small. The power consumption is grasped from the reading of the watt-hour meter every day in the sulfur powder plant. With the other plants the power consumption is grasped in a lump by the bill of the power company every month. However, the watt-hour meters for the latter plants are already purchased and the measurement of the power consumption to all the plants is scheduled to turn into a possibility one of these days.

The energy consumption rate in the sulfur powder plant is calculated every day. The average consumption rate to the sulfuric acid plant is calculated as 31.7 kWh/t. (This value is considered to be higher compared with 10 kWh/t of the large scale plant.) The energy cost has been accounted only to the sulfur powder every day. The consumption rate of sulfur as the main raw material is calculated every day. In other plants, only a few instruments are installed because of the batch operation, but the maintenance of these instruments is in a good condition and the work is operated exactly according to the operation standard.

4.4 Education and Training for Leveling-Up of Employees

There is no organized energy conservation committee, but the two technical staffs work hard to get an improvement of the operating technique. They have obtained excellent results such as the establishment of the own-know-how to a cupric sulfate manufacturing process. The results is shown in the rational attitude to produce efficiently the profitable products by the low cost facilities as simplified as possible.

Participation in the training course held by an outsider and a study-visit are not carried out. In the industrial association, representations for common interests to the government are taken up, though the technical information is not exchanged.

5. State of Fuel Consumption

5.1 Fuel Consumption

Fuel oil A 3 kl/year Boiler (1 t/h)

Consumed for 20 days during the stop of the sulfuric acid plant.

Balance of steam (Waste heat boiler of sulfuric acid plant)

1 to 1.2 t/h × 80 psig
- Sulfur melting tank
- Cupric sulfate plant
- Ferrous sulfate plant

5.2 Heat Balance of Boiler

Table 9–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	1,004.67	96.1	Heat of steam	698.77	66.8
Sensible and latent heat of fuel	13.18	1.2	Enthalpy of exhaust gas	280.00	26.8
Air	28.22	2.7	Heat loss in blow water	14.28	1.4
			Heat release from boiler body, others	52.30	5.0
Total	1,046.07	100.0	Total	1,046.07	100.0

Data Given for Calculation of the Heat Balance

Consumption of sulfur	(F)	$= \frac{Ps \times 10^3}{Su \times 24} = 454.6$ kg/h
Heating value of sulfur	(H)	2,210 kcal/kg
Latent heat of fusion	(L)	12.8 kcal/kg
Specific heat of sulfur	(Cp)	0.18 kcal/kg°C
Temperature of sulfur	(Tf)	125°C
Reference temperature	(To)	35°C
SO_2% in combustion gas	(SO_2)	7.5%
Temperature of combustion gas	(Tg)	235°C
Quantity of blow down water	(B)	116 kg/h
Temperature of blow down water	(Tb)	163°C
Quantity of feed water	(W)	1,245 kg/h
Temperature of feed water	(Tw)	40°C
Steam pressure	(P)	5.6 kg/cm^2G
Quantity of steam (S = W − B)	(S)	1,129 kg/h
Enthalpy of steam	(Es)	658.9 kcal/kg
Enthalpy of feed water	(Ef)	40 kcal/kg
Sulfur consumption rate	(Su)	2.75 t. Sulfuric acid/t. Sulfur
Production of sulfuric acid	(Ps)	30 t/day

Equation for Calculation of the Heat Balance

Input

Heat of sulfur combustion	(Qc)	$1,004.67 \times 10^3$ kcal/h

$Qc = F \times H$

Sensible and latent heats of sulfur	(Qs)	13.18×10^3 kcal/h

$Qs = F \times [Cp\,(Tf - To) + L]$

Output

Heat of steam	(Qv)	673.22×10^3 kcal/h

$Qv = Qc + Qs - (Qe + Qr + Qb)$

Heat loss in exhaust gas	(Qc)	$280{,}00 \times 10^3$ kcal/h

$$G = F \times (22.4/32)/(SO_2/100) = 454.6 \times \frac{22.4}{32} \times \frac{100}{7.5} = 4{,}243\ Nm^3h$$

$$Qe = G \times 0.33\,(Tg - To) = 4{,}243 \times 0.33 \times (235 - 35)$$

Heat loss in blow down water	(Qb)	13.74×10^3 kcal/h

Assuming Qb to be 2% of the available heat,

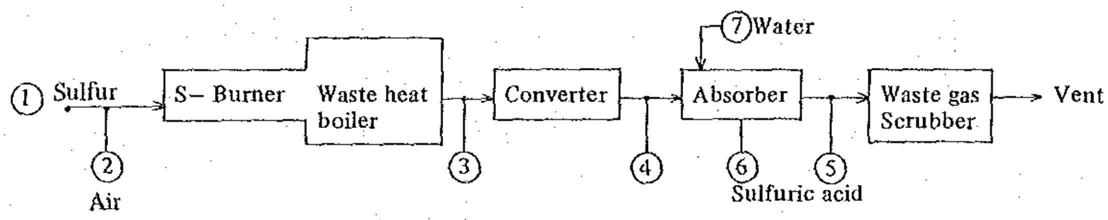
$Qb = [(Qc + Qs) - (Qe + Qr)] \times 0.02$

Heat release from body and other	(Qr)	50.89×10^3 kcal/h

Assuming Qr to be 5% of input

$Qr = (Qc + Qr) \times 0.05$

Table 9-3 Material Balance at Sulfuric Acid Plant



① 454.6 kg/h = 14.2 kg-mol/hr
② 4,243 N m^3/h
⑥ 30 t/day = 1,250 kg/h (as 100% H_2SO_4)
⑦ 229.6 kg/h

②/① = 2.75 kg/kg

		SO_2 +	SO_3	O_2	N_2	Tot.
②	Vol % N m^3/h	– –	– –	21.0 891.0	79.0 3,352.0	100.0 4,243.0
③	Vol % N m^3/h	7.5 318.2		13.5 572.8	79.0 3,352.0	100.0 4,243.0
④	Vol % N m^3/h		7.8 318.2	10.1 413.7	82.1 3,352.0	100.0 4,083.9
⑤	Vol % N m^3/h		0.8 32.5	10.9 413.7	88.3 3,352.0	100.0 3,798.2

Note. Cold air injection to converter is omitted for simplification.

6. Problems in Heat Control and Potential Solutions

6.1 Waste Heat Boiler

6.1.1 Improvement of Efficiency

The waste heat boiler is a boiler installed with the object of recovery of the waste heat in the sulfuric acid manufacturing process, and the process efficiency is considered more essential than boiler operation. With improvement of the heat balance, however, it is possible to increase the quantity of steam generated in the boiler. The following improvement plan which accelerates effectual utilization of heat energy should be studied.

(1) Reinforcement of insulaton of the converter

The SO_2 concentration in the combustion gas generated from the furnace is controlled to 7 to 8% in volume and fed to the converter. Some part of the gas generated is by-passed the waste heat boiler to ensure the process temperature. Accordingly, reduction of the heat loss in the converter enables to decrease the by-passed quantity and the quantity of steam generated in the waste heat boiler is increased.

When the insulation to the converter is reinforced as a prevent measures of heat radiation, the reduction of heat loss is as follows: Let the heat loss at the converter be 800 kcal/m^2h and one after insulation be 100 kcal/m^2h, the reduction of heat loss is 49.5 $m^2 \times (800 - 100)$ kcal/m^2h = 34,650 kcal/h. It is possible to drop the temperature of exhaust gas from 235°C to 210°C according to the boiler heat balance.

(2) Recovery of condensate and temperature raising of feed water

Since condensate is not recovered, the temperature of feed water is around 40°C.

Easy recoverable condensate is one in the steam heater and the piping jacket in the sulfur melting process.

The temperature raising of feed water due to the recovery of condensate is calculated as in the following.

Let the steam consumption in the sulfur melting process be 50% of the total consumption. Since the heat loss by flash steam out of the condensate is 12%, the effective utilizing heat is,

1,129 kg/h × 0.5 × 0.88 × 100 kcal/kg = 49,680 kcal/h.

When the quantity of feed water is 1,245 kg/h, the temperature raising is,

$$\frac{49{,}680}{1{,}245} \fallingdotseq 40^\circ C$$

Consequently, the temperature of feed water raises from 40°C to 80°C. In this case, the feed water tank should be insulated.

The increased quantity of steam due to the heat recovered by both measures of (1) and (2) is calculated by the following equation.

Let the quantity of steam generated after the heat recovery be $x$kg/h, the quantity is calculated according to the boiler heat balance.

$$x = \frac{698.77 \times 10^3 + 34.65 \times 10^3}{658.9 - \left(\frac{49{,}680}{x + 116} + 40\right)}$$

$x \fallingdotseq 1{,}258$ kg/h

The increased quantity of steam generation is 1,258 − 1,129 = 129 kg/h.

If the spare boiler have to be operated to generate this quantity of steam, the required quantity of fuel oil, when the evaporation multiple is 10, is,

$$\frac{129}{10} \fallingdotseq 13\ l/h$$

The annual required quantity of fuel oil is,

13 l/h × 8 h × 335 days ≒ 34.8 kl/year.

It is advantage of $34.8 \times 10^3 \times 4.3$ Bt = 149,640 Bt/year.

It is considerable to recover heat of the boiler blow water and the SO_3 gas cooler in addition.

6.1.2 Boiler Control by Evaporation Multiple

The waste heat boiler is recommendable to be managed daily by the evaporation multiple similar to the general boiler as a good rating of the efficient control. The evaporation multiple in this case is represented by the following equation. The quantity of feed water to the boiler should be measured by installation of a flow meter.

$$\text{Evaporation multiple} = \frac{(\text{Quantity of feed water}) - (\text{Quantity of blow down})}{\text{Production of sulfuric acid}}$$

This typical value is usually 1 to 1.2.

6.2 Utilization of Hot Air from SO_3 Gas Cooler

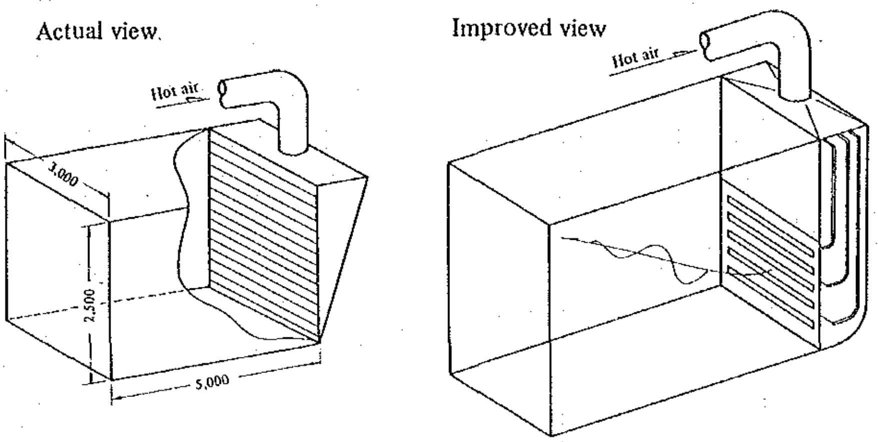


Fig. 9–3 Dryer of Cupric Sulfate

The fact that some part of hot air from the cooler is utilized effectively as a heat source of the dryer in the cupric sulfate manufacturing plant is a very good energy conservation measure. To make more advancement, it is recommendable to reduce the blow off of the hot air, and to take improvement of the heat efficiency by reduction of the temperature difference between the ceiling and the bottom through a modification of the blow-in port of the dryer as shown in Fig. 9-3.

6.3 Treatment of Boiler Feed Water

Untreated well water is now used as feed water to the boiler. This increases the quantity of blow down. The heat transfer is hindered by the deposition of scale on the heat transfer surface and the efficiency of energy recovery is reduced.

For the same reason, the efficiency of the sulfuric acid absorber drop by an obstruction of the cooling effect in the cooler and it is connected to increase of the energy consumption.

Therefore, a water softening unit should be provided.

6.4 Other Points to Pay Attention for Safety

6.4.1 Installation of Emergency Measures for the Boiler Low Water Level

An alarm for level lowering of the boiler water by trouble of the feed water pump and an automatic stop device of the combustion equipment are not equipped to both of the waste heat boiler and the auxiliary boiler. If the feed water pump should stop by trouble, the boiler water is exhausted and a serious accident occurs. The above safety devices should be provided at any cost.

6.4.2 Hazard of Sulfur

(1) Influence to human body

If powdered sulfur enters into the eye and the respiratory organs, various symptoms are developed. A proper safety goggles and dust mask should be worn in the handling of sulfur. When the sulfur attaches the skin, the skin should be washed with soap and water because the skin is inflamed as the case may be.

(2) Explosion

When a powdered sulfur of 35 g/m^3 is contained in the air, the sulfur burns explosively by an ignition source. The ignition sources are a spark by shock of metal or a friction of belt in the usual workshop. This type of explosion occurred in many cases. In the sulfur powder plant, a preventive measure against formation of explosive mixture by sufficient ventilation and a removing measure of ignition sources should be taken.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	160 kW
Power Consumption	:	812,640 kWh/year
Load Factor	:	63.2%
Penalty Fee	:	3,780 Bt/year
Power Factor	:	75% to 81%
Transformer	:	1 ϕ 75 kVA × 3
Power Consumption Rate	:	1.67 Bt/kWh

7.2 One Line Diagram

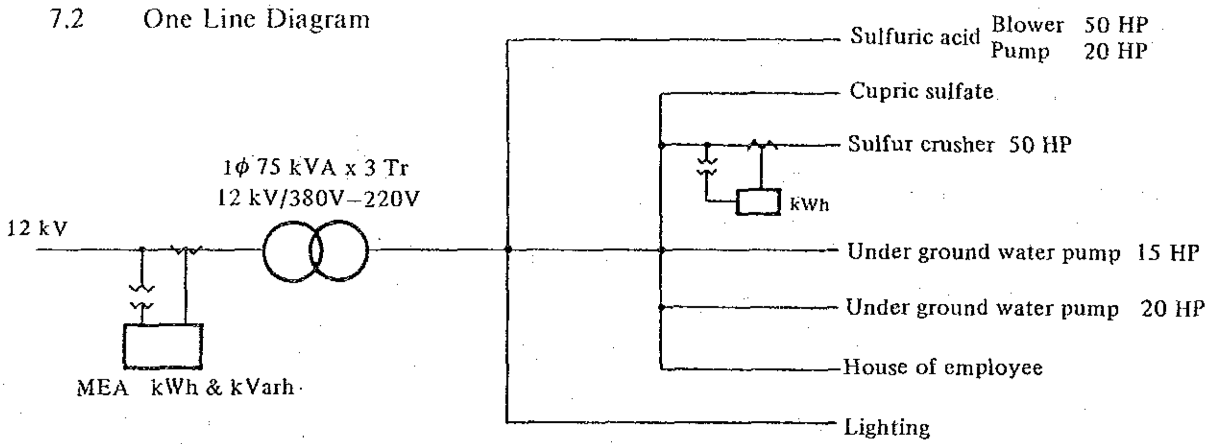


Fig. 9–4

8. Problems of Power Control and Potential Solutions

8.1 Improvement of Power Factor

Penalty has been paid every month because of a low power factor. Table 9-4 shows the power factor estimated from the monthly power bill. The average power consumption was calculated to be 335 operating days through a year, 24 operating hours per day and 2 or 3 holidays in every month. Table 9-5 is the values measured by MEA's watt-hour meter and integrated reactive power meter by every hour for 24 hours between 26th and 27th of July. Table 9-6 is an instantaneous value measured by the meter we brought. The power factor may be improved by insertion of a condenser. But because the distribution line is longer to the sulfur powder plant, it is better to connect 10 kVar to the bus of panel in the sulfur powder plant, 15 kVar to the panel in the alum plant and 15 kVar to the panel in the sulfuric acid plant. For the cupric acid plant, a condenser is not needed to insert because of little load.

Table 9–4 Peak Demand to Power Factor

Month	kWh	Average power kW	Peak demand kW	P.D x 0.63 kVar	Peak kVar kVar	Penalty kVar	kVA	cos φ
1982								
1	63,600	95	138	87	105	18	173	0.798
2	64,400	103	138	87	109	22	176	0.784
3	75,280	112	146	92	118	26	188	0.777
4	68,640	102	160	101	118	17	199	0.804
5	57,680	86	146	92	114	22	185	0.789
6	65,680	98	141	89	104	15	175	0.806
7	73,040	105	134	84	102	18	168	0.798
8	67,760	101	141	89	104	15	175	0.806
9	67,840	101	136	86	108	22	174	0.782
10	67,920	101	137	86	104	18	172	0.797
11	72,000	107	137	86	121	35	183	0.749
12	68,800	102	137	86	110	24	176	0.778
Total	812,640	101				252		

Penalty 15 x 252 = 3,780 Bt/year
Max. Peak demand 160 kW

Table 9–5 Hourly Record by MEA Meters

Time	kWh/h	kVarh/h	kVA	cos φ	Time	kWh/h	kVarh/h	kVA	cos φ
7–26					7–27				
1 PM	130	99	163	0.798	1 AM	136	80	158	0.861
2	130	99	163	0.798	2	96	72	120	0.8
3	140	102	173	0.809	3	88	64	109	0.807
4	136	104	171	0.795	4	40	64	75	0.533
5	128	104	165	0.776	5	144	72	161	0.894
6	96	72	120	0.8	6	80	80	113	0.707
7	112	88	142	0.789	7	96	56	111	0.865
8	96	72	120	0.8	8	120	80	144	0.833
9	104	72	126	0.825	9	104	96	142	0.732
10	96	80	125	0.768	10	144	112	182	0.791
11	24	72	76	0.316	11	140	104	174	0.805
12	120	56	132	0.909	12	132	104	168	0.786

Total kWh for 24 hours = 2,632 kWh
Total kVarh for 24 hours = 2,004 kVarh

$$\text{Average Power Factor for 24 hours} = \frac{2{,}632}{\sqrt{(2{,}632)^2 + (2{,}004)^2}} = 0.796$$

Average Apparent Power = 138 kVA

Table 9–7 Value After Power Factor Improved

Time	Plant	kVar Before improvement	kVar After improvement	kW	kVA After improvement		cos φ	Working hour per day
7–26 2 PM	Alum	61	46	78	91	140* (Main)		8
	Sulfuric acid	47	32	58	66			24
	Powder sulfur	16	6	22	23			16
7–27 10 AM	Alum	54	39	84	93	134 (Main)	0.903	8
	Sulfuric acid	41	26	55	61		0.902	24
	Powder sulfur	19	9	23	25		0.920	16

Table 9–6 Instantaneous Value of Main & Branch Circuit

Time	Measuring place	V	A	kVA	cos ϕ	kW	Remark
7–26 2 PM	Main circuit breaker	386	239	160 *	0.8	128	Reactive power 96 kVar
	Alum	386	145.8	97	0.8	78	Panel for alum
	Cupric sulfate	386	14.3	10	0.78	7	Panel for cupric sulfate
	Sulfuric acid	393	109.7	75	0.78	58	
	Powder sulfur	361	43.9	27	0.8	22	
7–27 10 AM	Main circuit breaker	394	223	152	0.82	125	Reactive power 87 kVar
	Alum	394	147	100	0.84	84	
	Cupric sulfate	385	22	15	0.76	11	
	Sulfuric acid	390	101.5	69	0.8	55	
	Powder sulfur	362	48	30	0.78	23	

The improvement of power factor results in non-payment of the penalty fee and the power loss in the transformer and the distribution line is reduced.

8.1.1 Decrease of Loss in Transformer

Premise of calculation

Annual average power 101 kW (Table 9-4)

Average power factor 0.796 (Table 9-5)

Load loss of transformer 1.3 kW

Inserted condenser Total 40 kVar

Apparent power

Before improvement

$$\frac{101}{0.796} = 127 \text{ kVA}$$

After improvement

$$\sqrt{\{\sqrt{127^2 - 101^2} - 40\}^2 + 101^2} = 108 \text{ kVA}$$

Loss reduction in transformer

$$1.3 \times 3 \times \{ (\frac{127}{75 \times 3})^2 - (\frac{108}{75 \times 3})^2 \} \times 24 \times 335 = 2{,}766 \text{ kWh/year}$$

8.1.2 Loss Reduction in Conductor

(1) Alum turnout point ~ sulfur powder

Conductor 38 mm^2 × 150 m

Conductor resistance (33° C)

$0.502 \times [1 + 0.00393(33 - 20)] = 0.528\ \Omega/\text{km}$

Current

Before improvement of power factor 48A

After improvement of power factor

$$\frac{23}{\sqrt{3} \times 0.362 \times 0.920} = 40 \text{ A}$$

Loss reduction

$$3 \times (47^2 - 40^2) \times 0.528 \times \frac{150}{1,000} \times 16 \times 335 \times 10^{-3} = 775 \text{ kWh/year}$$

(2) Transformer ~ Alum turnout point

Conductor 100 mm² × (60 + 40)m

Conductor resistance (33° C)

$0.185 \times [1 + 0.00393(33 - 20)] = 0.194\ \Omega/\text{km}$

Current

	(Before improvement)			(After improvement)		
	Active current	Reactive current	Apparent current	Active current	Reactive current	Apparent current
Sulfur powder	37	30	48	37	15	40
Alum	123	80	147	123	58	136
Cupric sulfate	17	14	22	17	14	22
Transformer~ Cupric sulfate	177	124	216	177	87	197
Cupric sulfate ~Alum	160	110	194	160	73	176

Loss reduction

Daytime

$$3 \times \{(194^2 - 176^2) \times \frac{40}{1,000} + (216^2 - 197^2) \times \frac{60}{1,000}\} \times 0.194$$

$$\times 8 \times 335 \times 10^{-3} = 1,150 \text{ kWh/year}$$

Night time

$$3 \times \{(48^2 - 40^2) \times \frac{100}{1,000}\} \times 0.194 \times 8 \times 335 \times 10^{-3} = 97 \text{ kWh/year}$$

(3) Transformer ~ Sulfuric acid plant

Conductor 60 mm² × 100 m

Conductor resistance (33° C)

$0.313 \times [1 + 0.00393(33 - 20)] = 0.329\ \Omega/\text{km}$

Current

Before improvement 102A

After improvement $\frac{55}{\sqrt{3} \times 0.390 \times 0.902} = 90$ A

Loss reduction

$$3 \times (102^2 - 90^2) \times 0.329 \times \frac{100}{1,000} \times 24 \times 335 \times 10^{-3} = 1,828 \text{ kWh/year}$$

(1) + (2) + (3) = 3,850 kWh/year

The loss reduction of the transformer and the conductor is 6,616 kWh/year of 9,590 Bt/year. The advantage of the power factor improvement added with the reduction of penalty fee is 13,370 Bt/year. The expenses for the condensers and the switchgear are estimated as around 20,000 Bt. The expenses can be paid back in 1.5 years.

8.2 Unbalance of Voltage and Current

Unbalance of voltage in the load side was 3 to 5 V per phase. And unbalance of current in the sulfuric acid plant was also about 20 A. Measures to these unbalances are considered to be the following.

(1) Change alternatively the relative position of the three electric wires by every pole. (Transposition)

(2) Connect a single load with balance to each phase.

8.3 Load of Motor

The load condition of motor and the terminal voltage are shown in Table 9-8. Concerning to the actual load (measured input × efficiency), only the crusher in the sulfur powder plant shows 50% below and the others 60% or more. Then, there is not so much problem.

Table 9–8 Actual Load of Motors

Using for	Rated out put	Measuring in put kW	Rated voltage V	Measuring voltage V	Rated current A	Measuring Current A	Power factor	No of pole
Air blower	50 HP (37 kW)	31	380	384	70	57.2	0.81	4
Sulfur crusher	50 HP (37 kW)	20	380	363	70	43.1	0.75	4
Sulfur pump	20 HP (15 kW)	11	380	387		21.9	0.75	
Sulfur induced blower	10 HP (75 kW)	5.9	380	387		11.3	0.78	
Sulfur pump for burner	5 HP (3.7 kW)	2.8	380	387		5.7	0.72	
Underground water pump	20 HP (15 kW)	12.6	380	355		22.7	0.9	

8.4 Control of Peak Demand

The fluctuation of peak demand in 1982 was the maximum 160 kW in April and 136 kW in September. To control the peak demand, a watt-hour meter should be provided to the sulfuric acid plant and the alum plant having large load and the following data should be collected by every hour.

kWh of incoming power (by MEA's meter)

kWh of each plant

Start-up and closed time or off duty time in each plant

These data enables to draw a daily load curve, to shift the operating time, to improve the operating method and consequently to control the peak load. The power loss in the transformer and the distribution line is reduced by improving the load factor as well as reduction of the demand fee.

8.5 Location of the Transformer

Since the transformer is located outside of the gate and the distance to each plant is long, the power loss in the electric wires is much. If the transformer is trasferred at the location of the pole of A point shown in Figure 9-5 at the center of load, the following loss disappears in a condition after improvement of the power factor.

$$3 \times (197^2 + 40^2) \times \frac{75}{1{,}000} \times 0.194 \times 8 \times 335 \times 10^{-3} = 4{,}727 \text{ kWh/year}$$

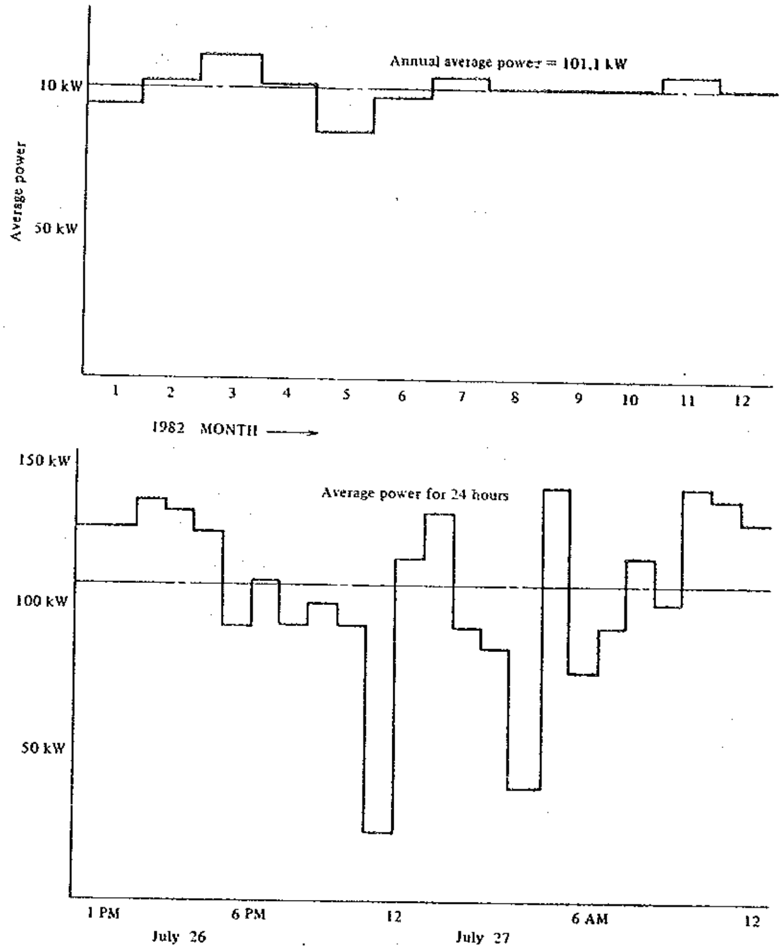


Fig. 9–5 Load Curve

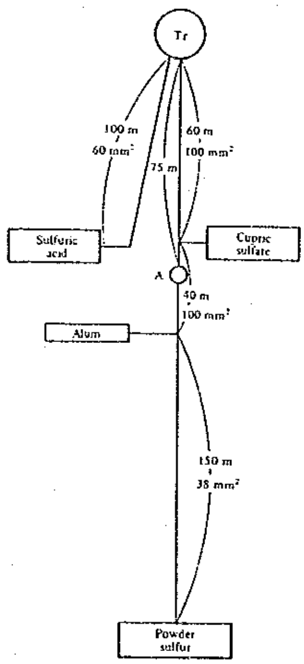


Fig. 9–6 Distribution Line

Consequently, the advantage is 6,850 Bt/year. On the other hand, the expenses are the total of 20,000 Bt of 230m × 60 Bt/m = 13,800 Bt of the bare wire, 2,000 Bt of one set of the insulators, fittings and arms and 4,200 Bt of the working because of use of the existing pole.

This expense can be paid back in about 3 years. The loss increased by extension of the wiring on the high pressure side is very small and negligible.

9. Summary

The above-mentioned improvement measures, if actually taken, will bring about energy conservation effects as shown below.

	(Oil Equivalent) kl/year	%
Improvement of efficiency of waste heat boiler	34.8	—
Subtotal	34.8	—

	10^3kWh/year	%
Improvement of power factor	6.6	0.8
Installation change of transformer	4.7	0.6
Subtotal	11.3	1.4

Report No. 10: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Sang Som Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Sang Som Co., Ltd. —

I. Outline of the Factory

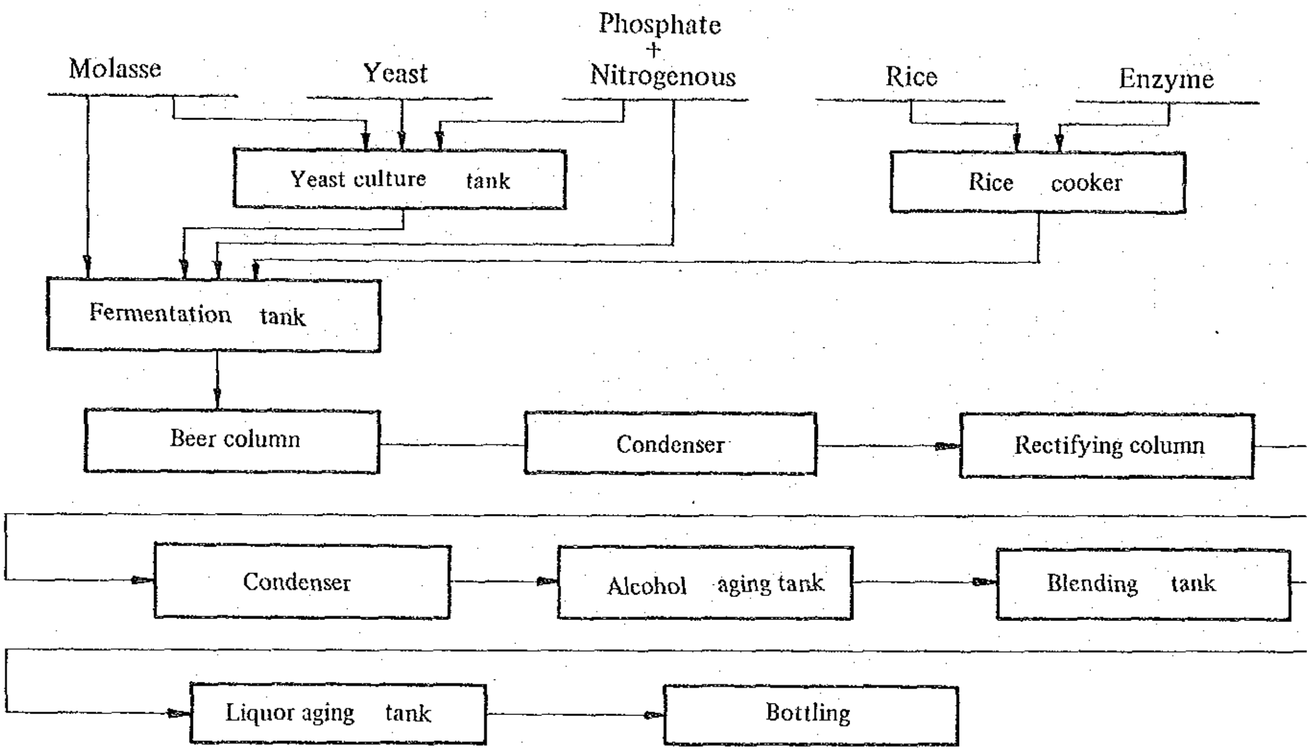
Address	49 Area Homkret A. Sanpran Nakorn-Patuch	
Capital	150X10^6 Bt	
Type of industry	Food	
Major products	Sang Som, Hong Tong	
Annual product	800,000 Doz/year	
No. of employees	395	
Annual energy consumption	Electric power	2,295,000 kWh/year
	Fuel	H.O.(C) 5,400 kℓ/year
Interviewees	Plant Manager : Mr. Arporn Asst. Plant Manager : Mr. Chalern	
Date of diagnosis	July 4 ~ 5, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

The factory was constructed 11 years ago. In the factory ethanol has been produced by fermentation of molasses as the major raw material. The raw ethanol is purified by distillation and then blended with demineralized water, caramel and essence to produce an alcoholic beverages called as SANG SOM, HONG TON.

Although the operation rate of the plant went into full production in the period from October 1982 to March 1983, the rate has shifted in 20 to 30% since April 1983.

A new plant construction is permitted by the Government and its concrete plan is in a step to move ahead. Therefore, consideration to the existing plant situation looks attenuating in some degree.

2. Manufacturing Process



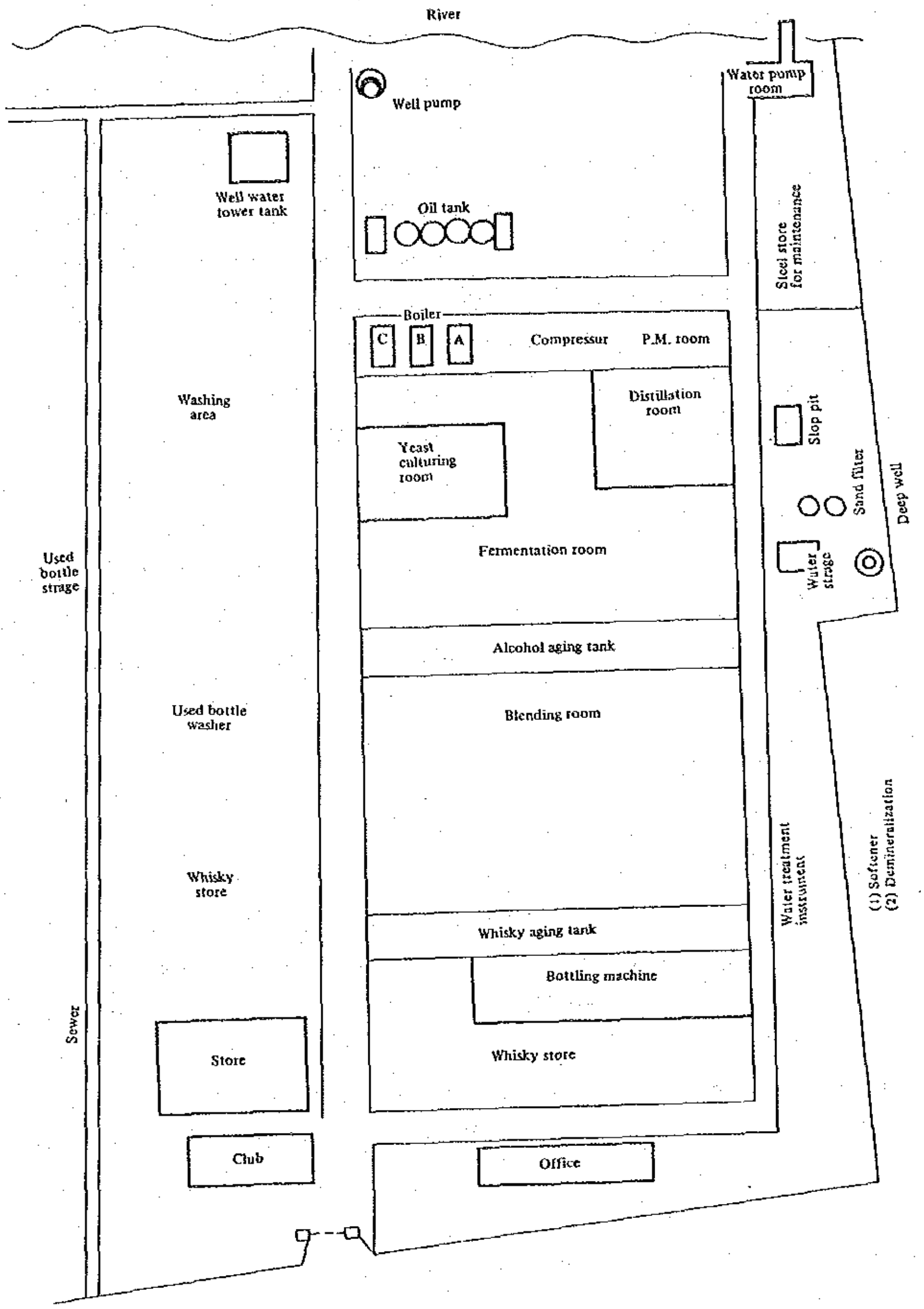
3. Major Equipment

3.1 Major Equipment

Table 10–1

Name	No. of units installed	Type, etc.
Boiler	3	Flue tube boiler 11 t/hr, 15 kℓ/cm²
Rice cooker	2	Jacket steaming
Yeast culture tank	8	
Beer column	3	Direct steaming 21 stages ϕ: 1,100 mm, h: 10,320 mm Vapor-Beer heat-exchange
Rectifying column	4	60 stages ϕ: 1,100 mm, h: 8,260 mm 1. Preheater (steam-alcohol liq.) 2. Reboiler

3.2 Layout



4. State of Energy Management

4.1 Policy for Energy Conservation

The factory is under the government control for an alcohol production. With the construction of the new plant just ahead, however, it is in the situation that even a target and investment plan for an improvement of this plant is not yet decided. They have understood the necessity of energy conservation. And so they consider that this diagnostic result should be utilized for the construction program of the new plant.

4.2 Participation by All Employees

The plant manager has appealed the importance of energy conservation to all employees in a direct manner or by a posters. The manager has been trying every means possible for an advancement in the employee's qualification; such as letting the persons in charge of each section participate in the seminars of TPA with two or three times per year. However, the intention seems not to spread throughout all of the employees so that the suggestion system is inactive.

To compete on an equal footing with the new and powerful plant to be constructed in the near future, there is no way but improvement of the efficiency and the productivity through the establishment of the management system. For this purpose, also an advancement of the skill in the average employees should be developed. The term of a seasonal low operation rate is just a capital opportunity for enforcement of the employee's education. The education of all employees is recommendable to put into practice through a careful program in cooperation with the personnel and the production departments.

4.3 Control through Data

Although the energy cost is accounted once a month in the head office, the data required to execute the energy control in the plant are impossible to be grasped due to the defective instruments. Some measuring instruments, such as a flowmeter for fuel oil and a temperature recorder for the distillation column, should be equipped.

4.4 Education and Training for Leveling-Up of Employees

The quality of the technical staffs is situated in a high rank among the various industries in the Kingdom of Thailand. Accordingly, it is easy to level up the quality of all employees through education. The capable men having a leading ability chosen out of the technical staffs are necessary to be trained as a talented person possible to educate the employees for leveling-up of the quality of all employees and possible to plan energy conservation program with arrangement of the required control data. It is better to educate the persons with a training of the debottlenecking method by several participations of plural persons to some outside training courses and by setting a task from the plant manager.

Although the plant manager makes efforts, if there is no person moving at the beck and call of the manager, even the half of the manager's efforts may be made with the best use. A means in hand for the technical improvement is to train the employees, who understand the real state of the factory, so as to work at the beck and call of the manager.

5. State of Fuel Consumption

5.1 Fuel Consumption

Fuel oil C 5,400 kl/year

Breakdown: HONG TON plant .....75% (4,050 kl)

SANG SOM plant .....25% (1,350 kl)

At present, only the SANG SOM plant is operated but the above fuel consumption per year is the value for the production of 800,000 dozen by the full operation in both plants.

The fuel consumption rate varies with the output and reduces in the month of a higher operation rate.

	Fuel oil	Output of product	Fuel consumption rate
	(lit.)	(lit.)	(lit./lit.)
Dec. 1982	535,100	934,800	0.57
Jan. 1983	478,850	748,200	0.64
Feb. 1983	484,200	866,800	0.56

The output after that was 849,933 liter in March of 1983 and 851,000 liter in April of 1983. The product has been produced in only the SANG SOM plant since June of 1983. In June of 1983, the consumption of fuel oil C was 165,000 liter and the output amount was 212,500 liter. Accordingly the fuel consumption rate increased to 0.78. When the average fuel consumption rate in the three months from December 1982 to February 1983 is compared with the annual average value, the fuel consumption rates in the months of the lower operation rate are a considerable worse value. If the operation throughout the year is possible with the fuel consumption rate in the above three months, the consumption of fuel can be reduced by 21%:

$$\frac{0.75 - 0.59}{0.75} \times 100 = 21\%$$

The consumption rate of fuel oil C in the plant producing 95% ethanol from molasses in Japan is approximately 0.45 l. heavy oil C/95% ethanol l.

If the out put (alcohol concentration as 35%) of whiskey produced in this factory is converted to 95% ethanol in order to compare with the result in Japan, the fuel consumption rate becomes 2.14 l in the average annual value and 1.69 l in the full operation. These values are known to be larger by 4 to 5 times than the value in Japan. Although the kingdom of Thailand is more advantageous in an atmospheric temperature than Japan, this large difference involve many questions.

Although a question may exist in the exactness of the pick up data and in the set points of the assuming conditions, this fuel consumption rate is higher even with consideration of these. Consequently, there is enough room for energy conservation.

5.2 Heat Balance of Boiler

The heat balance was calculated from the practical data of boiler at July 3, 1983. These values are described in Table 10-2.

Table 10-2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	2,270.0	99.8	Heat of steam	1,671.1	73.5
Sensible heat of fuel	4.7	0.2	Heat loss in exhaust gas	550.3	24.2
			Heat loss in blow water	23.0	1.0
			Heat release from boiler body, others	30.3	1.3
Total	2,274.7	100.0	Total	2,274.7	100.0

Data given for Calculation of the Heat Balance

Fuel type		Fuel oil C
Fuel consumption	(F)	237.5 kg/h
Heating value (low value)	(Hl)	9.558 kcal/kg
Specific gravity of fuel	(SG)	0.950
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	82°C
Reference temperature	(To)	38°C
Oxygen content in exhaust gas	(O_2)	11.0%
Temperature of exhaust gas	(Tg)	361°C
Quantity of blow down water	(B)	192 kg/h
Temperature of blow down water	(Tb)	166.9°C
Quantity of feed water	(W)	2,917 kg/h
Temperature of feed water	(Tw)	47°C
Steam pressure	(P)	6.5 kg/cm^2G
Quantity of steam (S = W − B)	(S)	2,725 kg/h
Enthalpy of steam	(Es)	660.2 kcal/kg
Enthalpy of feed water	(Ef)	47 kcal/kg

Equation for Calculation of the Heat Balance

Input

Heat of fuel combustion (Qc) $2,270.0 \times 10^3$ kcal/h

$Qc = F \times Hl$

Sensible heat of fuel (Qs) 4.7×10^3 kcal/h

$Qs = F \times Cp(Tf - To)$

Output

Heat of steam (Qv) $1,671.1 \times 10^3$ kcal/h

$Qv = S(Es - Ef)$

Heat loss in exhaust gas (Qc) 550.3×10^3 kcal/h

$Qe = F \times G \times 0.33(Tg\text{-}To)$

Theoretical amount of air (Ao)

$Ao = 0.85Hl/1,000 + 2.0 = 10.12\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11Hl/1,000 \quad 10.61\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 2.10$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 21.74\ Nm^3/h$

Heat loss in blow down water (Qb) 23.0×10^3 kcal/h

$Qb = B(Tb - To)$

Heat release from body and others (Qr) 30.3×10^3 kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Boiler

6.1.1 Improvement of Combustion

The oxygen content in exhaust gas is 11.0%. This value is extraordinarily high. The oxygen content should be maintained within 4% by adjustment of the air damper. The temperature of exhaust gas is also high. The amount of exhaust gas should be decreased by adjustment of the air ratio. And cleaning of the inside and outside surfaces of boiler tubes is required. A provisional adjustment test of the air ratio was carried out by means of a temporary throttling to air feed. The result suggested a possibility that the oxygen content could be reduced. Cleaning of chip in the burner was insufficient with two times per month. Soot blow and scale elimination were only once in three months.

Because of an insufficient cleaning of the burner, the boiler was in a slightly smoke discharging condition. The maintenance and check of the burner should be intensified. If the oxygen content in exhaust gas and the temperature of exhaust gas are improved to 4% and 210° C respectively, the boiler efficiency will be increased and the consumption of fuel will be decreased by 17.9% of 966.6 kl/year.

Air ratio after betterment: $m' = 1.24$

Amount of exhaust gas after betterment:

$G' = 13.04$ Nm^3/kg oil

If the quantity of fuel after betterment is taken as X kg/h, the following result is obtained from the boiler heat balance chart.

$$\frac{2{,}274.7}{237.5}\cdot x = (1{,}671.1 + 23.0 + 30.3) + \frac{13.04 \times 0.33 \times (210 - 38)x}{1{,}000}$$

$\therefore x = 195.1$ kg/h

Energy conservation rate:

$$\frac{F - x}{F} = 0.179$$

Possible amount of fuel reduction:

5,400 kl × 0.179 = 966.6 kl/year.

6.1.2 Leakage of Steam in Steam Valve

The three feed water tanks are a horizontal cylinder type and the capacity is 2.7 m^3 respectively. These tanks were installed in the side of the three boilers as a pair respectively. These tanks were installed in a near location with each another and the steam piping was arranged to each tank. At the time of this examination, only No.1 boiler was operated. Unexpectedly, No.3 feed water tank not operated was in a high temperature of 80° C. Since each feed water tank was not insulated, heat was extremely lost. It was caused by leakage of steam in the steam valve for No.3 feed water tank. When the steam valve is repaired, the heat quantity lost out of the leaked steam is reduced and this heat quantity results in energy conservation.

Surface area of one feed water tank: 10.6 m^2

Radiant heat loss

$Q = 4.88\epsilon\ A\ \{(\frac{T_1}{100})^4 - (\frac{T_2}{100})^4\} = 4.88 \times 0.9 \times 10.6(156 - 94)$

$= 2{,}886$ kcal/h

Convective heat loss

$Q = \alpha c \times A \times \Delta t = 2.2 \times A \times \Delta t^{1.25} = 2.2 \times 10.6 \times 105 = 2{,}449$ kcal/h

Radiant heat loss + Convective heat loss = 5,335 kcal/h

5,335 kcal × 24h × 242day = 30,985.7 × 10^3 kcal/year

When this value is converted to fuel oil C by the boiler efficiency in the heat balance calculation and the specific gravity of fuel oil C,

30,985.7 × 10^3/(9,558 × 0,95 × 0.735) = 4.6 kl/year

External leakage was seen at the connecting valve of 4" to No.2 boiler and steam blew up from the stuffing part toward the ceiling. If the pressure is taken as 6.5 kg/cm^2G and the diameter of hole is taken as 1.0mm, the leaking steam is 3.2 kg/h. When this valve is repaired,

660 kcal/h × 3.2 × 24 × 242 days = 12,266.5 × 10^3 kcal/year

When this is converted into fuel oil C,

$$\frac{12{,}266.5 \times 10^3}{9{,}558 \times 0.95 \times 0.735} = 1.8 \text{ kl}$$

The loss due to leakage in the valve is 4.6 + 1.8 = 6.4 kl/year equivalent to fuel oil C.

Energy conservation rate: $\frac{6.4}{5{,}400} \times 100 = 0.1\%$

6.1.3 Recovery of Condensate from Fuel Oil Tank and Fuel Oil Heater

The condensates in the three tanks of 4.8m^3 fuel oil service tank and in the fuel oil heaters for each boiler have not ben recovered. The condensate should be recovered in the feed water tank.

If the consumption per year of fuel oil C is taken as 5,400 kl/year and the heating efficiencies of the tanks and the heaters are taken as 60% respectively, the required steam for heating is as follows:

5,400 kl/year × 0.45 × (82 − 38)/0.6 = 178,200 × 10^3 kcal/year

Assuming that its 15% is condensed, if this condensate is recovered,

178,200 × 10^3 kcal × 0.15 = 26,730 × 10^3 kcal/year

Rising of the feed water temperature:

$26{,}730 \times 10^3/(5400 \times \frac{2{,}917}{237.5} \times 10^3) = 0.4°C$

Reduction of fuel oil C:

26,730 × 10^3/(9,558 × 0.95 × 0.735) = 4.0 kl/year

Energy conservation rate:

4.0/5,400 × 100 = 0.1 %

6.1.4 Insulation of Fuel Oil Heater

The insulating material of the fuel oil heater of 22 cm in the diameter and 135 cm in the length was damaged and the area of 120° C in the surface temperature was exposed. Since its heat loss is 1,675 kcal/ m^2h, the insulation should be renewed.

$1,675 \times 0.7 \times 0.93m^2 \times 24 \times 242 = 6,333.2 \times 10^3$ kcal/year

When this value is converted to fuel oil C,

$6,333.2 \times 10^3/(9,558 \times 0.95 \times 0.735) = 0.9$ kl/year

If insulated with 25mm glass wool, the release of heat is reduced to 80 kcal/ m^2h. Accordingly, the consumption of fuel oil can be reduced by:

$$0.9 \text{ kl/year} \times \frac{1,675 - 80}{1,675} = 0.9 \text{ kcal/year}$$

and the energy conservation rate results into $0.9 \text{ kl} \times 100/5,400 = 0.02\%$. If the heat quantity of fuel oil C is taken as 4.3 Bt/l, the fuel cost of 3,870 Bt/year can be saved. The insulating cost is 930 Bt. Accordingly the insulating cost can be recovered within 0.24 years.

6.2 Insulation of steam piping system

The steam pipes and the headers are insulated, but the valves, pressure reducing valves and flanges are little insulated. And also the tower and reboiler of the distillation room and the feed pipe of liquid are not insulated. The valves from the boiler room to the distillation room --- Total 15 valves i.e. 6 valves of 6" attached to the boiler, 4 valves of 6" around the header and 5 in the pressure reducing valve and the strainer ---are not insulated. And also 23 valves of 4" and pressure reducing valve located at the three headers in the distillation room are not insulated. The calculation of these heat loss is shown in Table 10-3.

Table 10–3 Radiation Heat Loss of Valve

Valve		No. of units		Heat loss	
Size	Location			No insulation	Insulation *
Stop valve 6"	Boiler room	15 Include Reducer 1 Strainer 1		1,900 kcal/h x 15 = 28,500 kcal/h	130 kcal/h x 15 = 1,950 kcal/h
Stop valve 4"	Accumulator	3	23	1,100 kcal/h x 23 = 25,300 kcal/h	100 kcal/h x 23 = 2,300 kcal/h
	Distillation room	20 Include Reducer 2 Strainer 2			
		Total		53,800 kcal/h	4,250 kcal/h

* Insulation material
Glass wool 50 mm

Insulation effect (As heavy oil C) $= \frac{(53,800 - 4,250)\text{kcal/h} \times 24\text{h} \times 365 \text{ days}}{9,600 \text{ kcal/kg} \times 0.735 \times 0.95} = 64.8$ kcal/year

Savable fuel cost:

$4.3 \text{ Bt/l} \times 64.8 \times 10^3 \text{ l/year} = 280.0 \times 10^3 \text{ Bt/year}$

Energy conservation rate:

$$\frac{64.8}{5,400} \times 100 = 1.2\%$$

When the valves of the above steam piping system are insulated with a 50mm thick glass fiber and then covered with aluminum sheet on it, the heat loss may be cut by 92% and the fuel saved is 64.8 kl annually. This value is equivalent to approximately 1% of the total fuel consumption. When the value is converted to cost, it is about 280,000 Bt/year. The cost to insulate these valves and cover with aluminum sheet can be obtained as follows;

Elements of various expenses for the glass fiber iinsulation are shown in Table 10-4.

Table 10-4

	Distillation column	Rectifier
Skin temperature	Average 86°C	Average 80°C
Dimensions		
Diameter	1.1m	1.1m
Height	10.3m	8.3m
Surface area	$35.58m^2$	$28.67m^2$
Heat loss per hr.	$813\ kcal/m^2h \times 35.58m^2 = 28.9 \times 10^3\ kcal/h$	$759\ kcal/m^2h \times 28.67m^2 = 21.8 \times 10^3\ kcal/h$
No. of unit upon run		
During half year	1 unit	1 unit
During half year	3 units	4 units
Heat loss per year	506.3×10^6 kcal/year	477.4×10^6 kcal/year
Equivalent fuel oil	75.9 kl/year	71.6 kl/year

The are of glass fiber blanket is required with 1.6 m^2 for the 6″ valve and 1.2 m^2 for the 4″ valve. These total installation cost is;

$$(182 \times 268 \times 300) Bt/m^2 \times [(1.6m^2 \times 15) + (1.2m^2 \times 23)] + 105Bt \times 38\ pcs. = 42,615\ Bt$$

This installation cost is possible to recover within 0.15 years by the reduction cost of fuel.

The valves in other equipment such as the rice cooker, yeast culture, fermenter, oil service tank and feed water tank are not insulated. Lowering of the insulation effect due to damage is found to most of the existing insulating materials for the steam pipes and the heating equipment. When you bring the insulation in good order after searching and inspecting the defects such as no-insulated wetted, cracked or damaged parts, you can reduce at least by 5% of the total fuel consumption.

6.3 Insulation of Distilling column and Rectifier

Because the distilling column and rectifier are not insulated, heat loss is extreme. The loss of fuel reaches 147.5 kl/year of 634,200 Bt/year. This is equivalent to 2.7% of the total fuel consumption (See Table 10-5.)

Table 10–5 Monthly Power Consumption

By PEA Meter

Month/year	Maximum power demand kW	Monthly power consumption kWh	Average power kW	Load factor %
1 / 82	432	179,676	242	56.0
2	396	168,084	250	63.0
3	432	190,680	256	59.0
4	432	192,780	268	62.0
5	420	172,320	232	55.0
6	420	177,336	246	59.0
7	432	190,548	256	59.0
8	444	196,500	264	59.0
9	444	201,576	280	63.0
10	492	221,520	298	61.0
11	456	206,976	284	62.0
12	444	196,752	264	59.5
1 / 83	456	206,796	278	61.0
2	456	190,008	283	62.1
3	504	226,524	304	60.3
4	492	230,820	321	65.2
5	504	217,008	292	57.9
6	456	186,336	259	56.8

Average power through the year $\frac{2{,}294 \times 10^3 \text{kWh}}{8{,}760 \text{ h}} = 262 \text{ kW} (1982)$

To cut 80% of this heat loss, an insulation of glass wool having the thermal conductivity of 0.037 kcal/mh°C should be examined. The thickness of glass wool to maintain 35°C in the surface temperature is

$$\frac{0.037 \text{ kcal/mh°C } (86°\text{C} - 35°\text{C})}{813 \text{ kcal/m}^2\text{h} \times 10^3(1 - 0.8)} = 12 \text{ mm}$$

Accordingly, a thickness of 1" (25mm) is sufficient.

The insulation working cost is

$(87 + 268 + 300 + 280) \text{ Bt/m}^2 \times (35.6\text{m}^2 \times 3 + 28.7\text{m}^2 \times 4) = 207{,}200 \text{ Bt}.$

(See Table 10-3) (Provided that the price of 25mm thickness glass fiber is taken as 87 Bt/m^3).

The reducing possible fuel by the insulation is

147.5 kl/year × 0.8 = 118.4 kl/year.

Energy conservation rate is

$$\frac{118.4}{5{,}400} \times 100 = 2.2\%$$

Accordingly, the reducible cost is

4.3 Bt/l × 118.4 kl/year = 507,400 Bt/year.

This insulation cost can be amortized with about three months. So the insulation should be executed at any cost. The insulating material should be examined sufficiently together with vendor.

The insulation makes the reflux ratio of the rectifier to be a constant throughout the top and the bottom and the rectifying effect is improved in expectation of energy conservation. A heat exchanger is not installed in the rectifier. In general process, the feed liquid is heated with utilization of the heat of the overhead product and the bottom. This heat recovery system should be examined.

6.4 Others

The theoretical yield of alcohol from sugar in molasses is 85%. The mean yield result is 83% as 95% ethanol. In case of this plant, it is said that the yield is less than 80%. Improvement of the yield is the most important factor to improve the fuel consumption rate. The daily control procedure mainly compose of the yield improvement in Japan is described as example below. The daily management should refer to this example.

In Japan, a fine control to grasp the yield of one fermenter is an ordinary procedure in the alcohol industry. The operator is working as follows;

(1) Procedure 1. Record the situation in the fermenter. Record the temperature and the concentration in the upper, middle and bottom of the fermenter every hour (Record in the daily report).

(2) Procedure 2. At the end of fermentation, grasp the amount of liquid and the alcohol concentration. Measure the liquid depth in the fermenter to obtain the amount of liquid by Tank Table. Obtain the concentration of alcohol by measuring the specific gravity.

Calculate the amount of alcohol in the fermenter and record its amount to the daily report.

(3) Procedure 3. Record every hour the amount of liquid fed to the distilling column,the amount of distillate and the amount of distillation residue.

Calculate the material balance of alcohol.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	: PEA
Peak Demand	: 504kW (March 1983)
Power Consumption:	: $2{,}294 \times 10^3$ kWh/year
Load Factor:	: Monthly load factor 55 to 65%
Penalty Fee:	: No
Power Factor:	: Monthly Power Factor 93 to 96%
Transformer:	: 3ϕ 1,250 kVA 1
	3ϕ 250 kVA 1
Final Power Cost	: Annual average 1.8 Bt/kWh

7.2 One Line Diagram

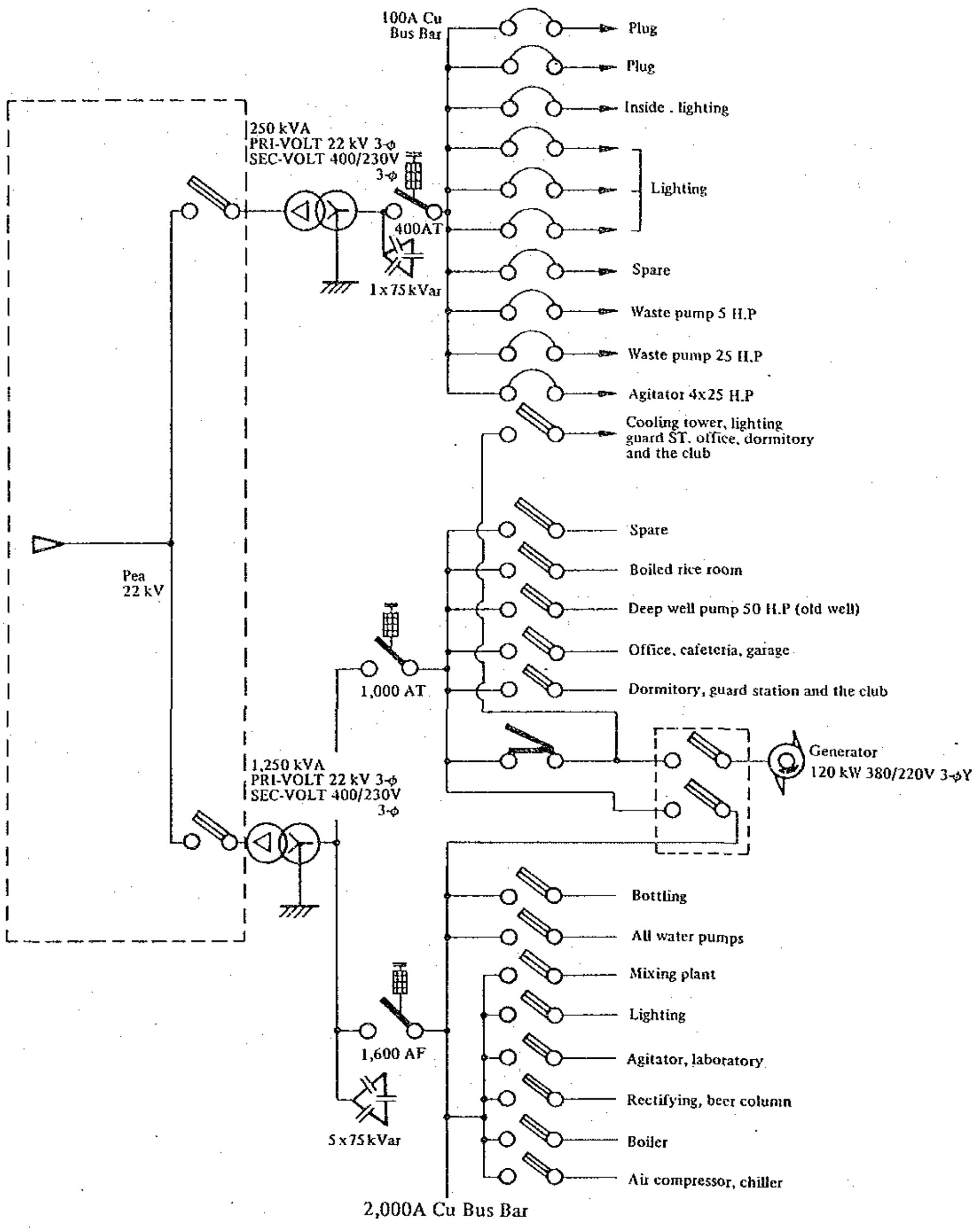


Fig. 10–3

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 10–6

5 July

Machine	Rated kW	Actual kW	V	AR	As	AT	Ao	Cos φ	L. F
Trans former 1,250 kVA 11°30' PM →		174.6	388	248	200	260	47	0.93	15.0
(5 x 75 kVar condenser 13°40' PM →		178.7	403	281	186.3	235	99	0.96	14.9
Trans former 250 kVA open cap 75 kVar		10.8	407	80.2	75.7	81.8	0.2	0.19	4.3
(1 x 75 kVar condenser) close cap 75 kVar		15.8	401	30.3	30.7	30.0	0.2	0.75	8.4
Load of trans 250 kVA									
1. Agitator, 15 kW, 380V, 30A	15	12.23	401	24.2	24.0	22.9		0.73	81.5
2. Waste water pump, 5HP, 380V, 8.5A	3.7	0.45	401	4.76	5.37	4.73		0.14	12.1
Load of trans 1,250 kVA									
1. Air compressor, 45 kW, 380V, 84A	45	36.9	384	64.3	584	64.8		0.89	82
2. Water feed pump, 30 kW, 380V, 56A	30	28.7	395	46.9	47.2	44.8		0.89	95.7
3. Deep well pump, 75 kW, 380V, 141A operate 6 Hr/D	75	598	391	98.4	106.3	95.7		0.89	79.6
4. Water pump, 7.5 kW, 380V, 15A 1,430 rpm	7.5	5.86	388	11.16	11.75	12.0		0.75	78.13
5. Feed water pump, 30 kW, 380V, 56A	30	36.6	399	61.5	58.5	61.0		0.74	122
6. Beer pump, 4.4 kW, 380V, 8.2A	4.4	2.2	399	4.67	5.12	5.16		0.63	50
7. Beer pump, 5.5 kW, 380V, 11A	5.5	4.46	400	8.58	8.60	8.70		0.75	81.1
8. Air compressor, 30 kW, 380V, 58A (Operate 20 min/T x 3 = 60 min/day)	30	19.57	399	40.9				0.69	65.2

7.3.2 Monthly Load Curve

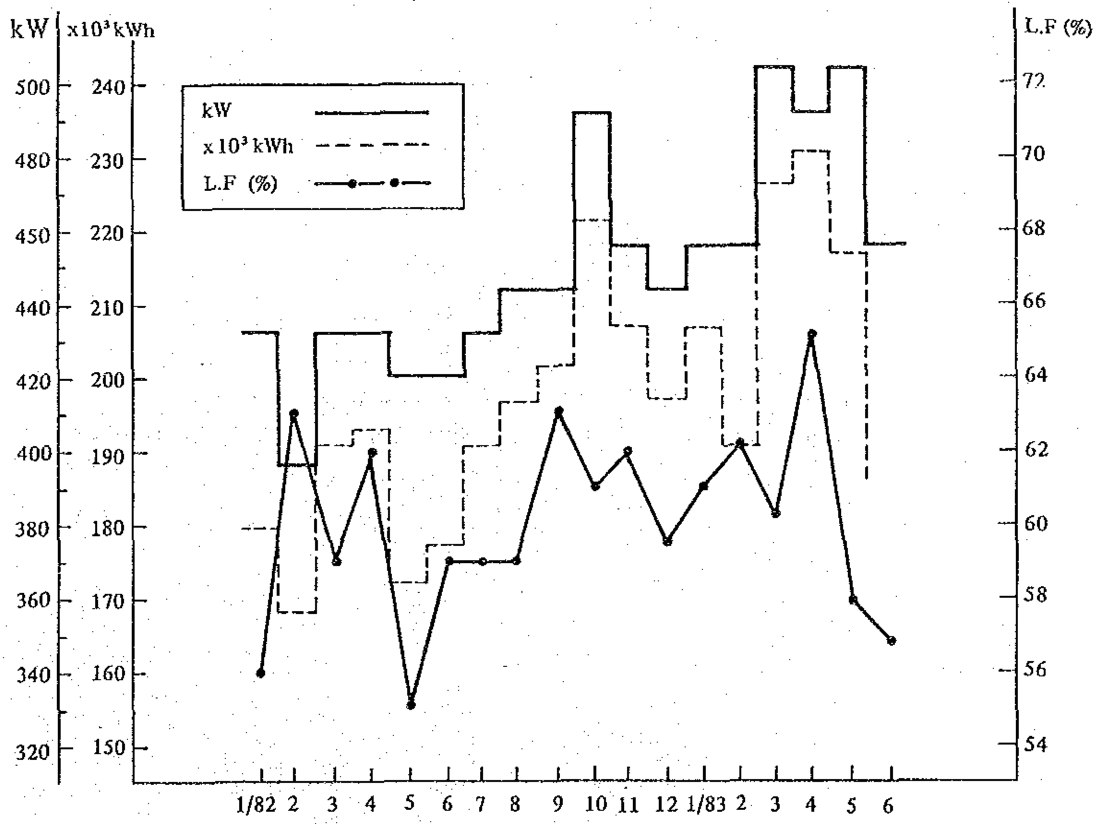


Fig. 10–4 Monthly Curve

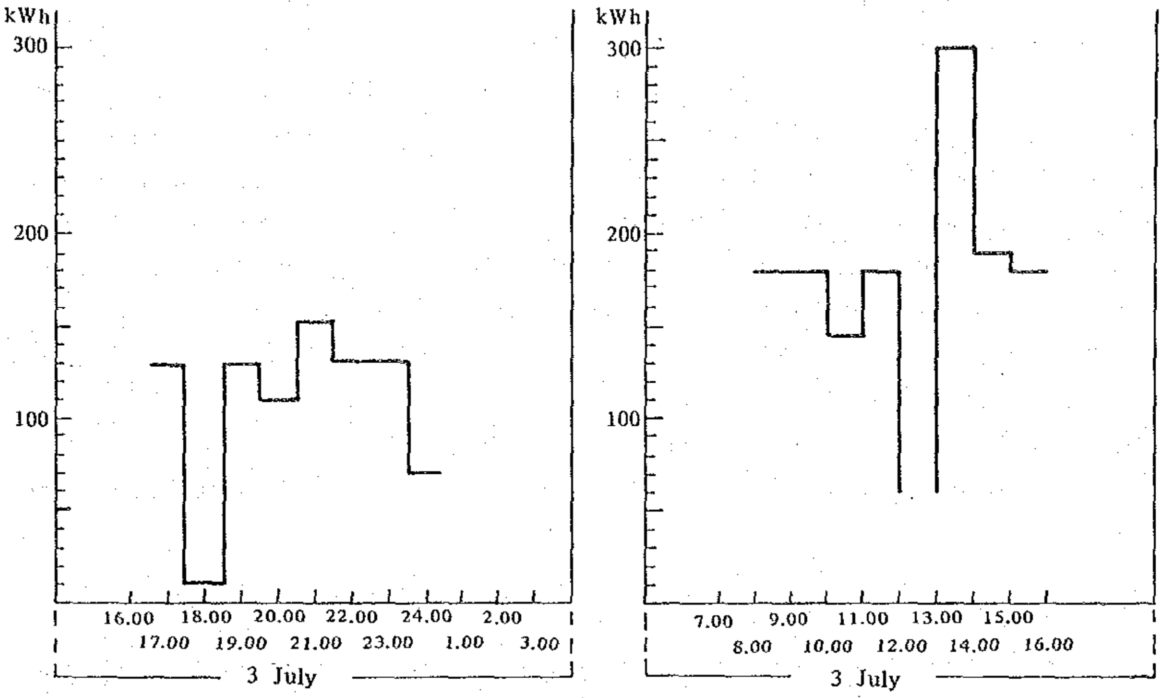


Fig. 10–5 Monthly Load Curve

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 10–7

5. July

Machine	Rated kW	Actual kW	V	AR	AS	AT	AO	cosφ	L.F
Trans former 1250 kVA 11°30' PM→		174.6	388	248	200	260	47	0.93	15.0
(5 x 75 kVar condenser) 13°40' PM→		178.7	403	281	186.3	235	99	0.96	14.9
Trans former 250 kVA open cap 75 kVar		10.8	407	80.2	75.7	81.8	0.2	0.19	4.3
(1 x 75 kVar condenser) close cap 75 kVar		15.8	401	30.3	30.7	30.0	0.2	0.75	8.4
Load of Trans 250 kVA									
1. Agitator 15 kW 380V 30A	15	12.23	401	24.2	24.0	22.9		0.73	81.5
2. Waste water pump 5HP 380V 8.5A	3.7	0.45	401	4.76	5.37	4.73		0.14	12.1
Load of Trans 1250 kVA									
1. Air compressor 45 kW 380V 84A	45	36.9	384	64.3	584	64.8		0.89	82
2. Water feed pump 30 kW 380V 56A	30	28.7	395	46.9	47.2	44.8		0.89	95.7
3. Deep well pump 75 kW 380V 141A operate 6h/day	75	59.8	391	98.4	106.3	95.7		0.89	79.6
4. Water pump 7.5 kW 380V 15A 1430 r.p.m.	7.5	5.86	388	11.16	11.75	12.0		0.75	78.13
5. Feed water pump 30 kW 380V 56A	30	36.6	399	61.5	58.5	61.0		0.74	122
6. Beer pump 4.4 kW 380V 8.2A	4.4	2.2	399	4.67	5.12	5.16		0.63	50
7. Beer pump 5.5 kW 380V 11A	5.5	4.46	400	8.58	8.60	8.70		0.75	81.1
8. Air compressor 30 kW 380V 58A (Operate 20 min/T x 3 = 60 min/day)	30	19.57	399	40.9				0.69	65.2

8.2 Power Distribution

8.2.1 Peak Demand

The hourly maximum power in the examination day was 300 kWh/h according to the daily load curve by hour in Fig 10-5. In the maximum power for 15 minutes, approximately 400 to 450 kW will be recorded. That day was a light-load and further control of the peak demand may be possible. For reduction of the peak demand, the starting times of (1) the large pumps for a short time operation, (2) the large equipment (compressor etc.) in the maintenance shop and (3) the air-conditioning equipment in the office should be shifted by degrees not to pass a large current in a short time. If the peak demand can be reduced by 50 kW, the power cost may be saved by

95 Bt/kW × 50 kW × 12 month/year = 57,000 Bt/year

This is equivalent to approximately 1.4% to the annual power cost of 4,118,618 Bt/year (1982).

8.2.2 Transformer

The capacity of the transformer seems to be excessive according to the estimation of the peak demand 504 kW and the mean power 321 kW in Table 10-6. An expected merit in case of reduction of this capacity will be done with a trial computation.

If the mean power is taken as 321 kW (monthly max.), the power factor as 90%, the apparent power as 357 kVA, the operating hours ,760 h/year, the iron loss of transformer as 0.3% and the copper loss as 1.4%, for the premise condition, the merit is shown on Table 10-8.

Table 10–8

Transformers kVA		Load 357 kVA	Iron loss 10^3 kWh/year	Copper loss 10^3 kWh/year	Total 10^3 kWh/year	
Present state	1,250	300	33	9	42	51
	250	57	7	2	9	
Improved state	600	300	16	18	34	41
	100	57	3	4	7	
Difference			Δ21	+11	Δ10	

That is, the merit results in $(51 - 41) \times 10^3 = 10 \times 10^3$ kWh/year and 10×10^3 kWh/year × 1.45 Bt/kWh = 14,500 Bt/year. If it costs 300,000 Bt to purchase 600 kVA and 50,000 Bt for 100 kVA, the investment recovery period is

$$\frac{300{,}000 + 50{,}000}{14{,}500} \fallingdotseq 24 \text{ years}$$

Accordingly this is no merit in the economical evaluation.

8.2.3 Unbalanced Current

As the secondary current of 1,250 kVA and transformer is 200 to 278 A, the unbalance is approximately 40%. This measurement was taken in the daytime, the operation rate was 20 to 30% and the load factor was 15%. Accordingly, to the aboves, the following matter could not be confirmed.

(1) Is current balanced at lighting hours in night ?

(2) Does the air-conditioning equipment in the office during the daytime cause the unbalance ?

Considering the power loss of the reversing direction torgue due to the unbalanced current, each equipment of single-phase load should be connected in a balanced condition.

8.2.4 Power Distribution

The power distribution system and the power distribution equipment (transformer, switchboard and control board) are generally a good condition. But the largest problem is to cause often accident by power failure.

Table 10–9

Cause \ Year	1980	1981	1982	Total
Fuse blow-out	2	1	2	5
Over-load	1	4	26	31
Over voltage	3	8	5	16
Miscellaneous	12	11	12	35
	18	24	45	

For the overload trouble increased rapidly in 1982 of the troubles in Table 10-9, the overheat deterioration due to a poor contact of the fuse and the contactor, the starting condition (star-delta system) or the relay protecting-harmony (current-time characteristic) of the large equipment must be immediately re-checked. The service interruptions of 45 times in 1982 gave the loss of about 2,200,000 Bt/year in the both of the direct and indirect expenses. The equipment should be checked and repaired to reduce the trougle by half at least.

8.3 Power Application

8.3.1 Voltage

According to Table 10-7, the service voltage to the motor of 380 V rating is slightly higher of 388 to 401 V. If a low operation extend over a long period, the secondary side voltage should be dropped to 370-380V by changeover the tap of transformer. And after that the change of power consumption and the rising temperature of the motor should be checked.

In a low load operation, if the voltage is lowered by 5%, it is said that the loss of power in the distribution line, transformer and the motor will be reduced by about 2 to 3%. Now, if the merit is taken as 2% and the annual power consumption is as $2{,}294 \times 10^3$ kWh/year, its merit is

$2{,}294 \times 10^3$ kWh/year $\times$ 0.02 = 45.9×10^3 kWh/year

45.9×10^3 kWh/year $\times$ 1.45 Bt/kWh = 66,700 Bt/year.

8.3.2 Feed Water Pump

According to Table 10-7, the 30 kW feed water pump was measured as 36.6 kW. This is an overload of about 22%.

Its causes are considerable to be the following.

(1) Unbalance due to fouling of the impeller.

(2) Wear of the seal for prevention of inner leak makes circulating flow in the casing.

(3) Overclosing of the valve in the discharge side or increasing of the resistance in the piping system (in case of constant volume pump).

(4) No good centering of the coupling

(5) Disagreement of the specifications between the pump and the motor.

These should be immediately checked and examined.

8.3.3 Air Compressor

The operation was 20 minutes in once, 3 times per day, that was, the actual operating hour was a hour per day. Even in the no-load operation of 23 hours, the pressure changes according to the valve leak etc shown in fig 10-6 and the compressor operated in a short hour.

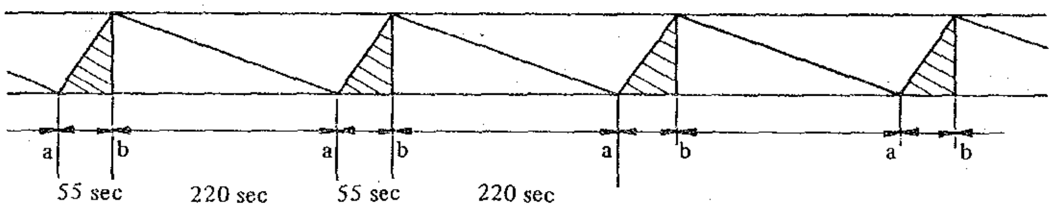


Fig. 10–6

That is, the area of an oblique line in Fig 10-6 is considerable to be a leakage loss. For an estimation, if ab: ba is taken as 1:4, as the actual load is 20 kW according to the measuring value in Table 10-7, its loss due to the leakage is

$$20\ kW \times 23\ h/day \times (\frac{1}{1+4}) \times 365\ days/year = 33{,}580\ kWh/year$$

$$33.6 \times 10^3\ kWh/year \times 1.45\ Bt/kWh = 49{,}300\ Bt/year$$

Now, as the reducing measure of the leaked loss, a prevention plan shall be worked out with check of the temperature of the compressor body (more leakage, higher temperature) of the check of the "leaking noise" of the check valve, the piping connection and the service valve in a no-loading time of an operation stop or a mealtime.

8.4 Others

8.4.1 Management of Operation and Maintenance

Since the factory is equipped with a facility for repair and arranged with a maintenance personnel, the troubleshooting and the restoration seem to be smoothly executed. But the execution of a preventive maintenance could not be confirmed from the check list. A reduction of the stop due to trouble by the preventive maintenance is also important for energy conservation. Cleaning of the cable duct in the substation should be executed at once and the riser part of cable and the iron sheet cover on the upper section of duct should be immediately repaired.

9. Summary

When the above measures are executed, the effect is as follows:

	(Fuel oil equiv.) kl/year	%
Improvement of boiler combustion	966.6	17.9
Steam leakage from valves	6.4	0.1
Condensate recovery	4.0	0.1
Insulation of fuel oil heater	0.9	0.0
Insulation of steam piping system	64.8	1.2
Insulation of distiller	118.4	2.2
Subtotal	1,161.1	21.5
	10^3 kWh/year	%
Lowering of motor service voltage	45.9	2.0
Repair of air compressor system	33.6	1.5
Subtotal	79.5	3.5