Report No. 17; Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Star Feed Mill Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Star Feed Mill Co., Ltd. —

I. Outline of the Factory

Address	29/8 Mue. 3 Lagsong Nongkaen Bangkok 10160	
Capital	4 Million Bt	
Type of industry	Food	
Major products	Livestock feed	
Annual product	55,000 ton	
No. of employees	80	
Annual energy consumption	Electric power	837,000 kWh
	Fuel	H.O. A. 158 kℓ
Interviewees	Mr. Apira : Factory Manager	
Date of diagnosis	July 18 ~ 19, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

Twelve years ago, this factory was established jointly by Thai capital and RALTON PURINA, USA. However, four years ago, the company came under the control of the C.P. Group (CHAROEN POCKAPHAN), and is now manufacturing various types of animal feed, espcially for chicken and pig. Raw materials are mostly corn, soya bean cake, crushed rice, fish meal, rice bran, calcium, sodium, molasses, nutritives such as vitamins. These ingredients are mixed and manufactured into 22 kinds of livestock feed. There are two different forms of the feed: pellets and powder. The former accounts for 92% and is packed in a 30-kg bag.

The factory has a 60,000 t/year year production capacity, but now maintains it at the level of 55,000 t/year. The operators are working on a two-shift basis and for 16 h/day. The number of operating days per year is 300 days.

2. Manufacturing Process

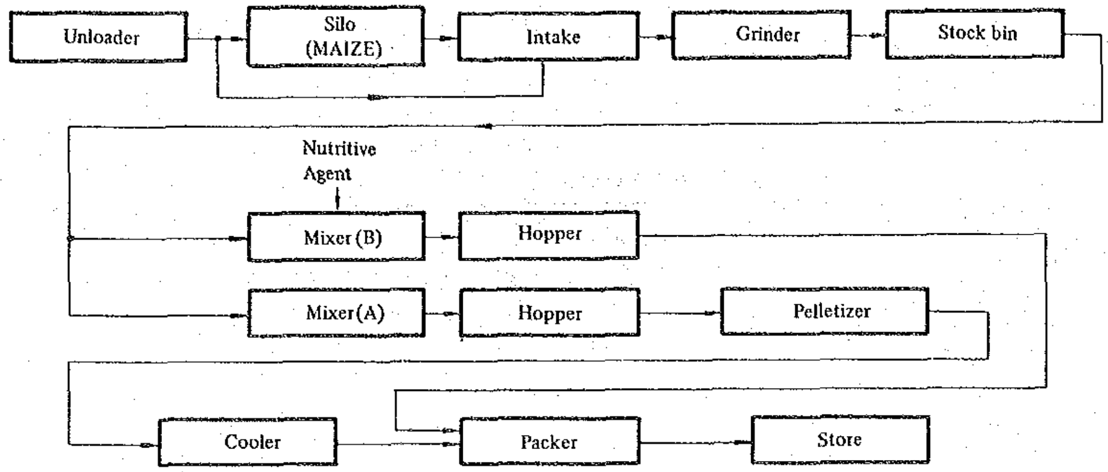


Fig. 17–1

3. Major Equipment

3.1 Major Equipment

Table 17–1

Name	No. of units installed	Type, etc.
Boiler	1	Flue tube boiler 0.5 t/h, 6 kg/cm^2
Pelletizer	1	U.S.A. CPM Made

3.2 Layout

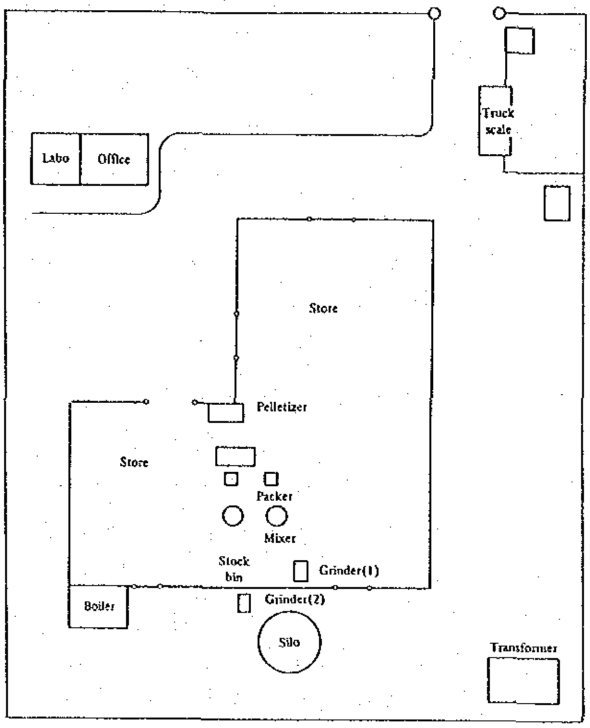


Fig. 17—2

4. State of Energy Management

4.1 Policy for Energy Conservation

The forward-looking attitude of the factory general manager for factory management is laudable. However, we were a little concerned about the lone activities of the general manager, because he himself had to cover an extensive range of works from routine management to future planning. We suggest that he keep his assistant staff, transfer his authority about a part of routine work to them, and limit the scope of his duties to listening to their reports and instructing them, and that in the meantime, he devote himself toward the solution of major problems of long-term and high-level nature such as rationalization of factory operation and planning of future developments.

With regard to energy conservation, the company set in 1981, a target for the achievement of a 10% energy conservation by the end of 1983. The company has put the following into practice:

- Heat Control
  - (1) Recovery of condensate
  - (2) Preheating of fuel
  - (3) Repair and replacement of steam traps
  - (4) Periodical checkup of boilers
- Electric Power Control
  - (1) Removal of unnecessary lights
  - (2) Improvement of switches for electric equipment
  - (3) Prevention of motor idling

(4) Induction of solar light through ceiling

The investment in the above improvement was 600,000 Bt. The company has reached an energy conservation level of 12% up to now, thus achieving the set target.

4.2 Participation by All Employees

The company, highly interested in employees' education, encourages the employees to participate in seminars by MOI and TPA. However, unfortunately, the staff members are not capable of making the best of knowledge which they have acquired at the seminars. Therefore, actually the general manager himself participated in the seminars and utilizes what he has learned there for improvements.

Through the daily operation, the employees are requested to cooperate in a safety campaign, activities aimed at achieving the target "clean workshop and office". They are also requested to be mindful about energy conservation. For the suggestion system, the company awards incentives to the employees for their broached excellent ideas, but is not actively making the most of the system.

In order to promote participation in the activities by all the employees, it is important to first appoint the staff members who assist in the general manager and encourage "small group activities" at the workshop mainly under the guidance of the staff members. It is observed that the factory has many subjects for study which are suitable to the small group activities, namely, maintenance of insulation, prevention of steam leakage and reduction of a loss in handling the products.

4.3 Control through Data

The general manager makes it a rule to seek data on energy consumption rate from individual work results, prepare a control chart, evaluate fluctuations in the variables, analyze causes for the fluctuations and take necessary actions.

In this way, control through data is carried out satisfactorily. However, we recommend that henceforth, staff members be educated through the preparation of control data, and control through data be promoted on an organizational basis.

Thus it will be possible to arouse all the employees' interest in production control and make the best of the wisdom and knowledge of many people.

It is suggested that the company clarify the relationships between the factors such as raw material mixing, moisture content, grain size, pelletizing temperature and pressure, and the yield and quality of finished product, and energy consumption amount according to accumulated data, and that the company try to improve its technological level.

4.4 Technological Leveling-Up of Employees

As the animal feed factory is one of the "Process industry", and productivity is highly valued. On account of its untiring efforts, the factory enjoys the most favorable level of unit fuel and electric power consumption rate. Nevertheless, the labor productivity is low as shown in Table 17-2.

Table 17–2 Feed Mill Consumption Ratio

	Fuel ℓ/t	Electricity kWh/t	Productivity t/month/1 person
Star feed mill	2.85	16.84	57
(Comparison) Hokkaido, Japan feed mills average	4.02	16.7	23.7

It is considered that in future, the company would face the necessity of further increasing the productivity following its development. In such a case, the company would have to minimize troubles by measures such as rationalization of transportation through improved layout and mechanization, and through perfect equipment maintenance services. At the factory, the general manager is only the person who supports its technological side. However, in future, the company will have to manage the factory by organizing a specialized system or using specialists. The problem which the general manager has to solve is to bring up technical staff and equipment engineers as quickly as possible.

5. State of Fuel Consumption

5.1 Fuel Consumption

Heavy oil A 158 kl/year

Breakdown of use ┬ Pelletized feed 95% (Pelletizer) (150 kl)
└ Compounded feed 5% (mixer) (8 kl)

Fuel for compounded feed is used for heating when mixing fats and molasses. However, it is not used now.

Fuel consumption rate: 158 kl/55,000 t = 2.8 l/t finished product

5.2 Heat Balance of Boiler

On July 18, 1983, we calculated the heat balance based on the results of boiler diagnosis as shown in Table 17-3.

Table 17–3

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	293.6	99.8	Heat of steam	247.9	84.2
Sensible heat of fuel	0.7	0.2	Heat loss in exhaust gas	31.1	10.6
			Heat loss in blow water	11.1	3.8
			Heat release from boiler body, others	4.8	1.4
Total	294.3	100.0	Total	294.3	100.0

Elements for Calculation of Heat Balance

Fuel type		Heavy oil A
Fuel consumption	(F)	30.5 kg/h
Heat content of fuel (low value)	(Hl)	9,625 kcal/kg
Specific gravity of fuel	(SG)	0.975
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	83°C
Reference temperature	(To)	31°C
Oxygen content in exhaust gas	(O_2)	1.0%
Temperature of exhaust gas	(Tg)	307°C
Quantity of blow down water	(B)	89 kg/h
Temperature of blow down water	(Tb)	159.1°C
Quantity of feed water	(W)	486 kg/h
Temperature of feed water	(Tw)	34°C
Steam pressure	(P)	5.2 kg/cm^2G
Quantity of steam (S = W − B)	(S)	397 kg/h
Enthalpy of steam	(Es)	658.4 kcal/kg
Enthalpy of feed water	(Ef)	34 kcal/kg

Equation for Calculation of Heat Balance

Input

Heat of fuel combustion (Qc) 293.6×10^3 kcal/h

$Qc = F \times Hl$

Sensible heat of fuel (Qs) 0.7×10^3 kcal/h

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

Output

Heat of steam (Qv) 247.9×10^3 kcal/h

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

Heat loss in exhaust gas (Qc) 31.1×10^3 kcal/h

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

Theoretical amount of air (Ao)

$Ao = 0.85\,Hl/1{,}000 + 2.0 = 10.18\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11\,Hl/1{,}000 = 10.68\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 1.05$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 11.19\ Nm^3/kg$

Heat loss in blow down water (Qb) 11.1×10^3 kcal/h

$Qb = B \times (Tb - Tw)$

Heat release from body and others (Qr) 4.2×10^3 kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Control of Combustion in Boiler

At present, each boiler is operated for 16 hours a day and 300 days a year. We diagnosed the boiler by analyzing the exhaust gas of boiler three times.

Temperature of exhaust gas	°C	337	238	345
Oxygen content of exhaust gas O_2	%	0.7	0.8	1.1

The temperature of exhaust gas is high. In the meantime, the air supply for combustion tends to be short. However soot is not blown down and the burners and tips are cleaned only once a month. This frequency is not enough. The sight of a slight rising smoke is suggestive of the fouling of inner tubing with soot. Therefore, it is necessary to increase the frequency of cleaning services to approx. once a week and adjust the quantity of air for combustion so that the oxygen content of exhaust gas may be approx. 4% and subsequently the generation of soot be prevented. At the same time, the temperature of exhaust gas must be lowered by cleaning boiler tubing.

If the temperature of exhaust gas is decreased at 250° C, the fuel consumption will be reduced as follows:

Assuming that the oxygen content of exhaust gas is 4%, we calculated the conserved fuel amount according to the heat balance table.

$m' = 1.25$

$G' = 13.07\ Nm^3/kg$

Assuming that the amount of fuel combustion after adjustment is x kg/h, the results are represented by the following equation:

$$\frac{294.3}{30.5} \cdot x = (247.9 + 11.1 + 4.2) + \frac{13.07 \times 0.33\,(250 - 31)x}{1{,}000}$$

$\therefore x = 30.2$ kg/h

Energy conservation rate

$$\frac{30.5 - 30.2}{30.5} \times 100 = 1.0\%$$

Annual amount of conserved heavy oil

158 kg/year × 0.01 = 1.6 kl/year

6.2 Decrease in Quantity of Blow Down Water

The quantity of blow down water for boiler is equivalent to approx. 18% of the quantity of feed water. The electric conductivity of boiler water is low at 1,000 μS/cm and the pH value is also low at 8.9. The tolerable electric conductivity of boiler water is up to approx. 6,000 μS/cm. Therefore, the quantity of blow down water equivalent to 1/3 of its present quantity may be sufficient. The pH value needs to be maintained at 11 to 11.8, and also the consumption of chemicals may be small, if the quantity of blow down water is decreased.

If the quantity of conserved energy when the quantity of blow water is decreased from the present 89 kg/h to 30 kg/h, is calculated according to the heat balance table, the results will be as follows:

$$\frac{294.3}{30.5}x = (247.9 + 4.2) + \frac{30 \times (159.1 - 34)}{1{,}000} + \frac{31.1}{30.5}x$$

$\therefore x = 29.6$ kg/h

Energy conservation rate

$$\frac{30.5 - 29.6}{30.5} = 3.0\%$$

Annual quantity of conserved heavy oil

158 kl × 0.03 = 4.7 kl/year

6.3 Insulation of Boiler Body

The back wall of the boiler has a surface temperature of 135°C and the under-mentioned heat release occurs. The dimensions are 1.2 m for diameter, 0.038 m for thickness and 1.27 m^2 for surface area.

- Radiation heat loss

$$Q = 4.88\,\epsilon A\ \{(\frac{T_1}{100})^4 - (\frac{T_2}{100})^4\} = 4.88 \times 0.8 \times 1.27\ \{(\frac{273+135}{100})^4 - (\frac{273+31}{100})^4\}$$

$= 947$ kcal/h

- Convection heat loss

$Q = ac \times A \times \Delta t = 2.2 \times A \times \Delta t^{1.25} = 2.2 \times 1.27 \times 104^{1.25} = 930$ kcal/h

Total 1,877 kcal/h

If the said part of the boiler is insulated by 30mm calcium silicate and galvanized iron sheet to lower the surface temperature to 50° C, the heat release amount will be represented by the following equation:

Radiation heat loss $= 4.88 \times 0.3 \times 1.27\ \{(\frac{273+50}{100})^4 - (\frac{273+31}{100})^4\} = 43$ kcal/h

Convection heat loss $= 2.2 \times 1.27 \times 19^{1.25} = 111$ kcal/h

Total 154 kcal/h

Therefore, if the quantity of energy conserved by insulation in converted into equivalent Heavy oil A, the results will be as follows:

$$\frac{(1{,}877 - 154) \times 16 \times 300}{9{,}625 \times 0.975 \times 0.842} = 1.0 \text{ kl/year}$$

Energy conservation rate 1.0/158 × 100 = 0.6%

While the cost of conserved heavy oil is 4,300 Bt/year, that of insulation is approx. 1,300 Bt. The cost of its installation will be recovered in approx. 4 months.

6.4 Conversion from Heavy Oil A to Heavy Oil C

At present, heavy oil A is used as boiler fuel after being heated at 83°C. The specifications of heavy oil A are specific gravity 15/15°C 0.975(max.), viscosity - Redwood second (38°C) 500 to 600 and calorific value 9,625 kcal/kg.

If this heavy oil A is converted to heavy oil C, the latter has viscosity of 1,100 to 1,500 and calorific value of 9,514 kcal/kg, it is necessary to raise the temperature by 15°C so that the viscosity for use may be the same as heavy oil A.

The relationship between fuel oil viscosity and price is as follows: (according to Shell Oil data)

~ 80 cst 50° C (RWI 600 sec 38° C) 4.32 Bt/l heavy oil A

~ 145 cst 50° C (RWI 1,200 sec 38° C) 4.17 Bt/l heavy oil C

~ 180 cst 50° C (RWI 1,500 sec 38° C) 4.09 Bt/l

~ 230 cst 50° C (RWI 2,000 sec 38° C) 4.04 Bt/l

~ 280 cst 50° C (BWI 2,500 sec 38° C) 3.99 Bt/l

If "A" and "C" heavy oils are compared in terms of price per calorific value, they show the following values:

Heavy oil A 4.32 Bt/9,625 = 0.449 Bt/10^3 kcal

Heavy oil C 4.17 Bt/9,514 = 0.438 Bt/10^3 kcal

An estimated deficiency due to temperature rising of heavy oil C at an assumed efficiency of 50% is:

$$\frac{0.45 \times 15 \times 0.99}{0.5} = 13.3 \text{ kcal/l}$$

If this deficiency is put into consideration, the price per calorific value of heavy oil C will be as follows:

4.17 Bt/(9,514 − 13) = 0.439 Bt/10^3kcal

The existing burners are of a low-pressure atomizing type, so that if heavy oil heater is provided with more effective insulation, it is possible to change the fuel from heavy oil A to heavy oil C.

Cost reduction rate

$$\frac{0.449 - 0.438}{0.449} = 2.4\%$$

6.5 Recovery of Heat Release from Stack

Combustion exhaust gas from the boiler is discharged from the burner side of the boiler to the stack, and the air intake is near the stack fortunately. The stack, made of iron, releases a large amount of heat, so that the ambient temperature near the stack stands at 34° C or higher. For this reason, it is suggested that the existing air intake be turned to the opposite with a simple enclosure provided and as much high-temperature air around the stack as possible be taken in. Then it is possible to economize the fuel.

6.6 Insulation of Steam Piping and Valves

It is observed that valves and piping around the machine has a damaged insulation and some spots are uninsulated. The insulation effect anticipated when the 2 1/2" pipe of equivalent 8 m is more effectively insulated, is as follows:

360 kcal/mh × 8 × 16 × 300 = 13,824 × 10^3 kcal/year

In this case, steam temperature is 140° C

If the above-mentioned part is insulated with 25 mm glass wool, thus preventing the 80% heat release, the quantity of conserved heavy oil A will be as follows:

$13,824 \times 10^3 \times 0.8 / (9,625 \times 0.975 \times 0.842) = 1.7$ kl/year

Energy conservation rate $1.7/158 \times 100 = 1.1\%$

The estimated cost reduction of heavy oil A will be 7,300 Bt/year at a unit price of 4.32 Bt/l. On the other hand, the estimated cost of insulation will be approx. 1,500 Bt and recovered in three months. The fact that the steam pipe is insulated is a good example. However, this pipe is insulated combined with the condensate recovery pipe. As the condensate is reduced to an atmospheric pressure at 100°C, it has an effect of cooling the steam. For this reason, it is recommended that both pipes be insulated separately.

6.7 Others

At the factory, a blow out of powder from the bag filter, a spilling and scattering of the finished products during the handling and are almost a routine sight. Therefore, it is effective for energy conservation to prevent this loss. It is desired that the Company put its efforts to maintain the equipment in good condition by cleaning the bag filter, repairing the leakage and tightly closing the openings of the machine. It is also desired to prevent the breakage of bags by quality control of bags. As a result of carrying out the above-mentioned matters, there will be an improvement of the working environments.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	300 kW (January, 1983)
Power Consumption	:	837×10^3 kWh/year (1982)
Load Factor	:	Monthly load factor 47 to 66%
Penalty Fee	:	18,720 Bt/year (1982)
Power Factor	:	Monthly power factor 62 to 73%
Transformer	:	3ϕ 500 kVA × one unit
		3ϕ 315 kVA × one unit
Final Power Cost	:	Annual average 1.90 Bt/kWh

7.2 One Line Diagram

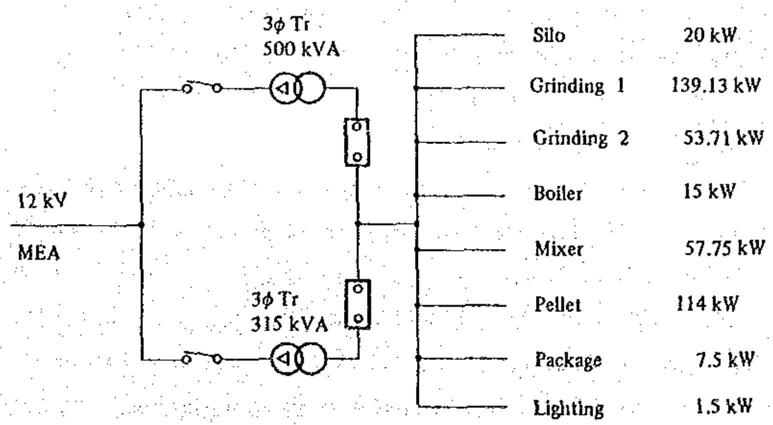


Fig. 17-3

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 17–4

By MEA Meter

M / Year	Power consumption kWh	Maximum demand power kW	Reactive power kVar	Power factor P.F (%)	Load factor L.F (%)	Average power kW
1 / 83	62,000	300	280	73	51.7	148
2	55,000	290	269.7	73	47.4	145
3	66,000	300	280	73	55.0	157
4	7,000	270	280.1	69	65.7	187
5	58,000	220	279.6	62	65.91	138
Total	312,000					

$$\text{Average power per year } \frac{837 \times 10^3 \text{ kWh}}{4{,}800 \text{ h}} = 174 \text{ kW}$$

7.3.2 Monthly Load Curve

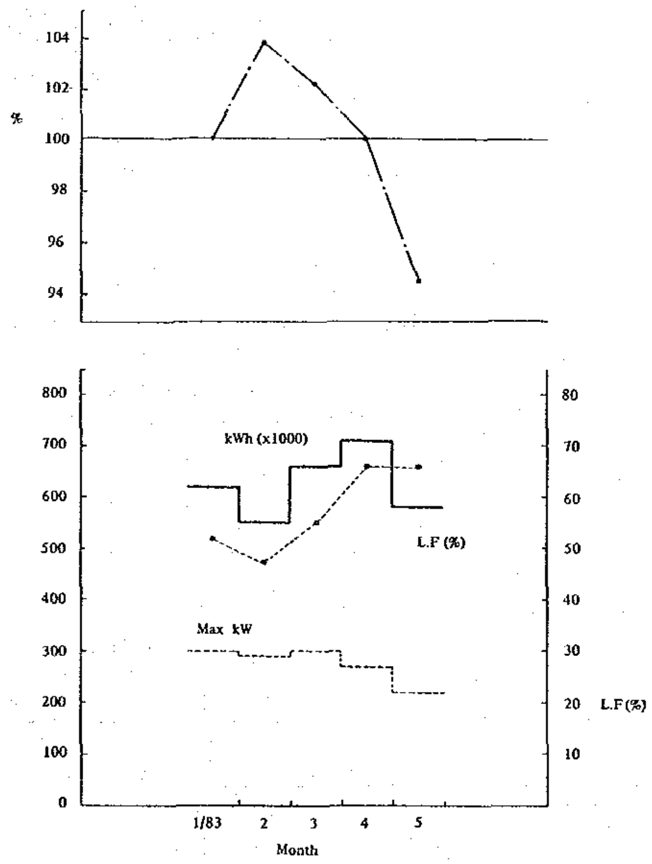


Fig. 17–4

7.3.3 Hourly Power Consumption

Table 17–5

By MEA Meter

Time	Active power kWh	Reactive power kVar
8.30		
9.00	200	200
9.30	100	100
10.00	100	100
10.30	100	100
11.00	100	100
11.30	100	100
12.00	100	100
12.30	0	0
13.00	100	100
13.30	100	100
14.00	100	100
14.30	110	300

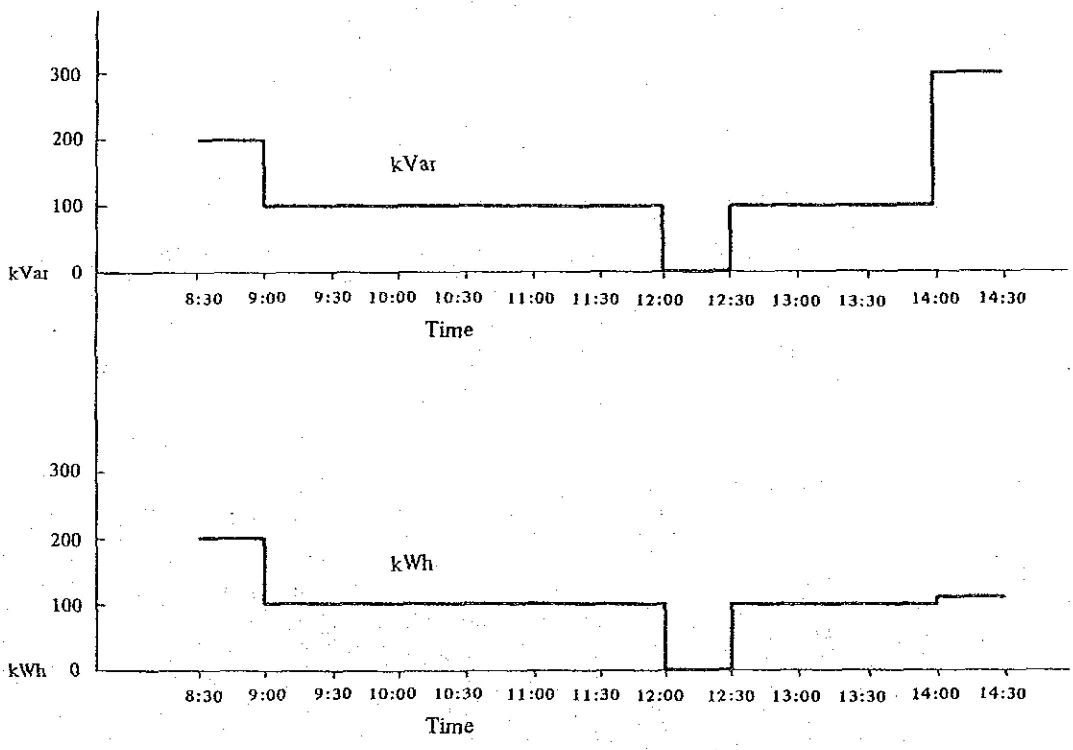


Fig. 17–5

7.3.4 Hourly Load Curve

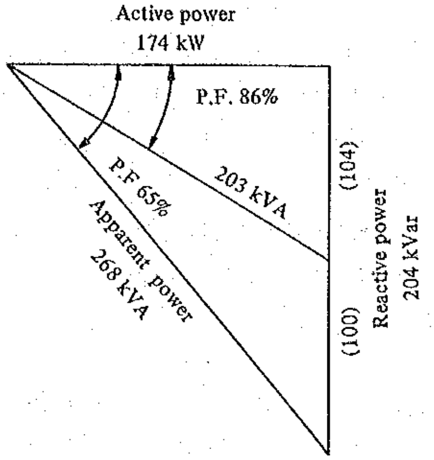


Fig. 17–6

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 17–6 Instantaneous Value

19 July

	Measurement					
	kW	V	AR	As	AT	cos ϕ P.F %
Transformer 3ϕ 500kVA	176.1	419	358	393	341	65

Use for	Name Plate			Measurement			P.F (%)	L.F (%)
	kW	V	A	kW	V	A		
Grinding No. 1	110	380	195	13.3	412	56.3	33	12.1
Pellet	90	380	168	91.9	411	152	85	102.1
Cooler Fan	18.5	380	37	14.4	415	27.1	74	78
Pellet	7.5	440	133	2.0	411	5.1	56	27.0
Mixer No. 1	15	380		6.3	413	21.9	40	42
Mixer No. 2	15	380		10.2	415	20.4	69	68.3

Use for	Name Plate			Measurement			P.F (%)	L.F (%)
	kW	V	A	kW	V	A		
Crumbear	7.5	400	14	No load	406	3.8	30	10.5
Mixer	7.5	440	13.3	1.8	404	4.73	54	23.6
Bucket elevator	7.5	440		1.8	405	5.6	46	23.7
Whirly feed	15	440		1.3	410	7.8	24	8.5
Bucket elevator	3.7	440		0.5	414	2.4	26	12.9
Boiler blower	1.5	410	3.8	0.8	415	2.3	49	50.7

8.2 Power Distribution

8.2.1 Transformer

As shown in Fig. 17-3 "One Line Diagram", there are one unit of the 500 kVA transformer and one unit of the 315 kVA transformer. At present, the unit of the 315 kVA transformer is disconnected both on the primary and secondary, hence contributing toward energy conservation.

If necessary, the two transformers are able to be connected easily for parallel operation. However, there are problems as follows:

(1) Electric power loss due to the cross current between the two transformers in parallel.

The specifications of the transformer are as follows:

500 kVA	primary winding	12,000 V	11,700 V	11,400 V	11,100 V	10,800 V	
	secondary winding	416V/696A	%Z = 3.58%				
315 kVA	primary winding	11,550 V	11,275 V	11,000 V	10,725 V	10,450 V	
	secondary winding	416V/438A (Estimated)	%Z = 3.91%				

There is a difference in the tap voltage on the primary windings between them. Therefore, if the same voltage is applied to the primary, some difference voltage will occur in each secondary winding, resulting in the generation of an electrical power loss between the two transformers due to the traversal current flow. The typical example of this case is shown below.

Note; Assuming that the operating time as 4,800 hours per year, iron loss as 0.3% and copper loss as 1.4%. The transformer's impedance (ZΩ) per phase is:

$$Z(\Omega) = \frac{\frac{\%Z}{100} \times [\text{Secondary Voltage kV}]^2}{\text{Transformer kVA}/1,000}$$

Based on the above equation, Z_1 is 0.01239Ω for 500 kVA and Z_2 is 0.02148Ω for 315 kVA. Then assuming that the working tap voltage is 11,700V/416V for 500 kVA and 11,550V/416V for 315kVA, the difference ratio to be

$$\frac{11,700}{11,550} \doteqdot 1.0129$$

If the same voltage is applied to the primary winding, the voltage differential of approx. 1.3% will occur on the secondary winding. Accordingly the traversal current flow Ic will be:

$$Ic = \frac{(416 \times 1.0129)v - 416v}{\sqrt{3}(Z_1\Omega + Z_2\Omega)} = \frac{5.3664v}{0.05866\Omega} \doteqdot 91.5 \text{ A}$$

On the other hand, the resistances per phase of each transformer R_{500}, R_{315} according to the copper loss $= 3I^2R$, will be as follows:

$$R_{500} = \frac{500 \times 0.014}{3 \times 696^2} = 0.00482\ \Omega$$

For 315 kVA

$$R_{315} = \frac{315 \times 0.014}{3 \times 438^2} = 0.00766\ \Omega$$

That is, the loss (equivalent to 3 phases) of transformer due to Ic will be:

$P = 3 \times 91.5^2 \times (0.00482 + 0.00766) = 0.3135$ kW

The annual loss will be:

0.3135 kW $\times$ 8,760 h/year $\fallingdotseq 2.7 \times 10^3$ kWh/year.

Consequently, the parallel operation of transformers should be refrained except for the emergency case.

(2) The power loss when one unit of transformer to be operated or two units to be operated respectively (not parallel operation) is calculated as follows:

Assuming that 4,800 h/year for operating time, 174 kW for average electric power, 70% for power factor and 249 kVA for apparent electric power, the result is as shown in Table 17-7.

Table 17–7

	Transformers kVA	Load	Iron loss 10^3 kWh/year	Copper loss 10^3 kWh/year	Total 10^3 kWh/year	
Case No. 1	500 315	159 90	13 8	3.4 1.7	16.4 9.7	$= 26 \times 10^3$ kWh/year
Case No. 2	500	249	13	8.3	21.3	$= 21 \times 10^3$ kWh/year
Difference						5×10^3 kWh/year

That is, the difference power loss between two ways will be 5×10^3 kWh/year $\times$ 1.45 Bt/kWh = 7,250 Bt/year. The present single unit operation of the 500 kVA transformer is the best way of operation.

8.2.2 Power Factor

Based on the value of Table 17-4 the effect of power factor improvement when a 100 kVar condenser being equiped is shown in Fig. 17-6 and Table 17-8.

Table 17–8

Average power kW	Condenser kVar	Apparent power kVA	Reactive power kVar	Power factor %
174	0	268	204	65
	100	203	104	86

That is, if the 100 kVar condenser is installed, the power factor will be improved to 86% and no penalty instead of the present 18,720 Bt/year.

In the meantime, the expected advantage due to the reduction of copper loss in the 500 kVA transformer will be as follows:

If the given data of 4,800 h/year for operating time, 174 kW for average electric power, 65%

for power factor, 268 kVA for apparent electric power, 86% for improved power factor and 203 kVA for apparent electric power after improvement are as preconditions,

$$500 \text{ kVA} \times 0.014 \{ (\frac{268}{500})^2 - (\frac{203}{500})^2 \} \times 4{,}800 \text{ h/year} \fallingdotseq 4.1 \times 10^3 \text{ kWh/year}$$

$$4.1 \times 10^3 \text{kWh/year} \times 1.45 \text{ Bt/kWh} = 5{,}950 \text{ Bt/year}$$

Energy conservation rate $4.1 \times 10^3/(837 \times 10^3) \times 100 = 0.5\%$

The estimated installation cost of one unit of 100 kVar condenser is approx. 50,000 Bt. Therefore, the time required for the recovery of the said cost will be:

$$\frac{50{,}000}{18{,}720 + 5{,}950} \fallingdotseq 2.0 \text{ years}$$

8.3 Application of Electric Power

8.3.1 Voltage

The total capacity of all the motors are approx. 400 kW. However, as shown in Table 17-6, the motors are composed of old and new units including 17 units at a rated voltage of 400V or higher amounting to approx. 60 kW. For this reason, we explain two problems concerning the voltage of electric motors as follows:

(1) If a 380V of voltage is supplied to the motors rated at 400V or higher, the torque will be reduced by approx. 10 to 20%, and the full-loaded speed reduced by 1 % or more. Despite this slight disadvantage, the efficiency will be increased by 2 % or more and the power factor improved by 4% or more because the load factor of the electric motor is approx. 50% or less. It is concluded, therefore, that the above-mentioned voltage supply will be advantageous as a whole.

Table 17–9

	Iron loss	Copper loss	Total
15 kW	$15 \times 0.016 \times \frac{380}{440}^2 = 0.18$ kW	$15 \times 0.05 \times (\frac{8}{15})^2 = 0.21$ kW	0.39 kW
11 kW	$11 \times 0.016 = 0.18$ kW	$11 \times 0.05 \times (\frac{8}{11})^2 = 0.29$ kW	0.47 kW

No merit in exchanging motor

(2) If the electric motor rated at 440 V, 15 kW is replaced by the electric motor rated at 380V, 11kW, the change of power loss is as Table 17-9, and no merit is expected. In this calculation, each electric motor are 1.6% for core loss, 5% for copper loss, 380V for voltage, 8 kW for actual load and 4,800 h/year for operating time as preconditions.

The rated voltage of the electric motors amounting to 361 kW or approx. 85% of the entire motors of the factory is 380V, so that the voltage should be reduced according to the said rated voltage. At present, as each electric motor has a low load, the power loss for transformer, distribution line and electric motor will be reduced by approx. 2 to 3% by decreasing the voltage during a low-loaded operation.

Assuming the advantage as 2%, the annual electric power consumption 837×10^3 kWh/year and the unit cost as 1.45 Bt/kWh, the energy conservation amount due to the reduction of voltage will be as follows:

837×10^3 kWh/year $\times$ 0.02 = 16.7×10^3 kWh/year

16.7×10^3 kWh/year $\times$ 1.45 Bt/kWh = 24,200 Bt/year

Judging these points, generally, it will be the best way to set the service voltage at approx. 380V. But it is desired to confirm the power consumption and motor temperature rising after reducing voltage.

8.3.2 Power Consumption Rate

The monthly load curve as shown in Fig. 17-4 indicates the following trend:

During the period of April and May, the power consumption unit was ameliorated in accordance with the increase of the load factor to 65% or higher. In addition, despite the high load, the peak demand was held at low level. We suggest that the company study how to improve the power consumption rate and to restrain the peak demand, comparing the operating method for the period of February and March with that of April and May.

8.4 Others

8.4.1 Management of Operation and Maintenance

We were unable to confirm data on faults and accidents, but we would point out the common problems applicable to the factories handling powder.

(1) Accidents due to the deterioration of insulation caused by the moistening of powder depositing in the power board and the control board.

(2) Burning due to the deterioration of the cooling effect caused by the clogging of powder in the electric motor.

Because of the above, periodical cleaning and repair are necessary. Especially, the burning accident due to the insufficient cleaning of the motor are sometimes mistaken for an accident caused by an overload. Therefore, it is desired to pay attention to this point. In addition, a small spark in the powder by a deteriorated insulation or the burning of the electric motor may lead to a serious fire accident. For this reason, you are requested to be careful about the maintenance and control of operation.

9. Summary

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

	(Oil equivalent) kl/year	%
Control of combustion in boiler	1.6	1.0
Reduction of quantity of blow down water	4.7	3.0
Insulation of boiler body	1.0	0.6
Insulation of steam piping and valves	1.7	1.1
Subtotal	9.0	5.7
	10^3kWh/year	%
Improvement of power factor	4.1	0.5
Reduction of service voltage to electric motor	16.7	2.0
Subtotal	20.8	2.5

Report No. 18: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Central Food Products Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Central Food Products Co., Ltd. —

1. Outline of the Factory

Address	7/3 Pahol Yothin Rd. KM 33 Rangsit Pathumthani	
Capital	200 Million Bt	
Type of industry	Food	
Major products	Livestock feed	
Annual product	250,000 ton	
No. of employees	160	
Annual energy consumption	Electric power	6,000,000 kWh
	Fuel	H.O. (A) 850 kℓ
Interviewees	Mr. Johnny Chang : Plant Manager Mr. Pai Boon : Deputy Plan-Manager	
Date of diagnosis	July 26 ~ 27, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

This factory belongs to the Centaco Group and is the largest animal feed manufacturer of 250,000 tons per year in Thailand. Some of their production is exported. The major ingredient of the feed is corn blended with soya beans, crushed rice, fish meal, bone powder, plant seeds, vitamins and other. The feeds are shipped in the form of pellets or powder in paper bags. The company maintains silos capable of storing 34,000 tons of raw materials with conveyors which carry them. The hammer mill and pelletizer use steam which is generated by four units of boiler. In addition, the factory is provided with two units of dryer for drying corn containing a high percentage of moisture delivered during the humid season.

The factory goes in full operation during the period from July through December; that is, it continuously produces 24,000 tons per month for 24 hours a day on a 3-shift basis. However, during the period from January through June, the factory turns out the product at a rate of 18,000 tons per month for 16 hours a day on a 2-shift basis. Of the above-mentioned tonnage, approx. 80% is put into pellets.

The factory is manned with 40 employees assigned to the office and 120 to production, totaling 160.

2. Manufacturing Process

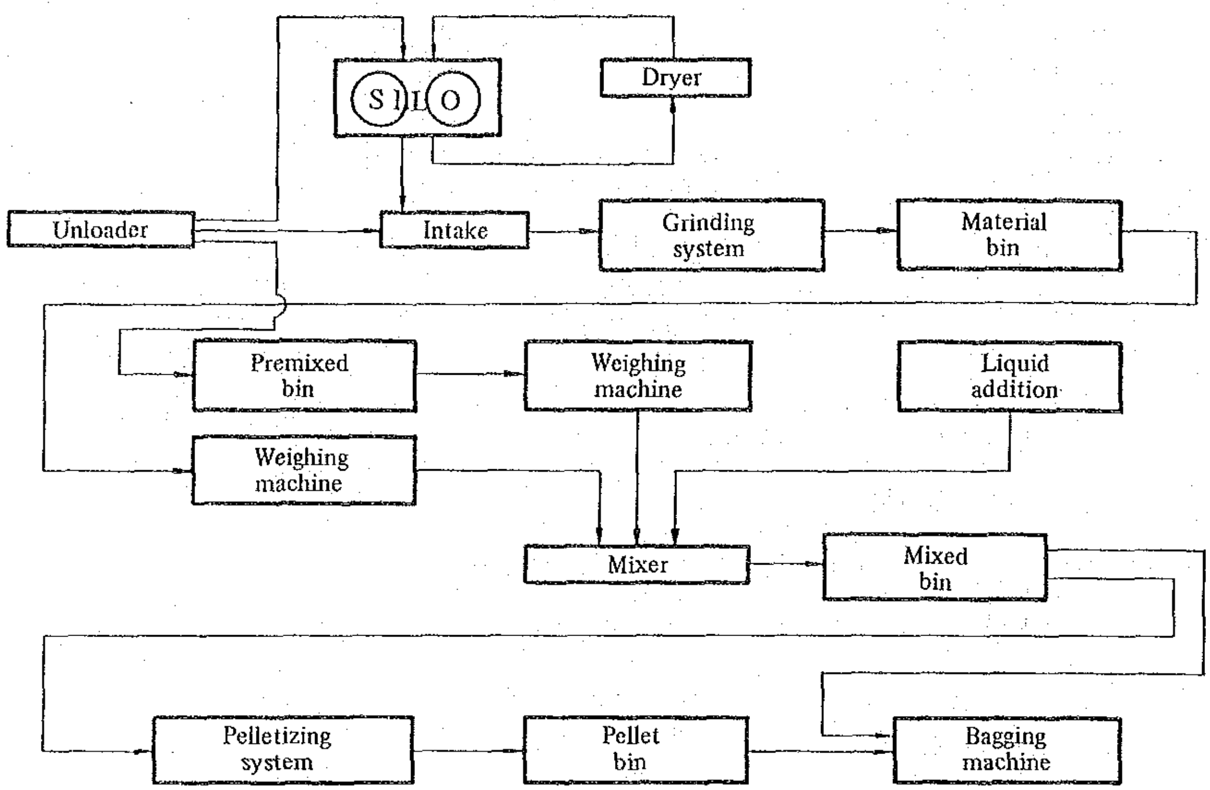


Fig. 18–1

3. Major Equipment

3.1 Major Equipment

Table 18–1

Name	No. of units installed	Type, etc.	
Boiler	2	Fire tube	20 HP
	2		100 HP
Hammer mill	2	270 HP	Electrical heating
	2	150 HP	Steam heating
Pelletizer	2	220 HP	Electrical heating
	2	150 HP	Steam heating
Dryer	2	50 t/day	Hot air dryer

3.2 Layout

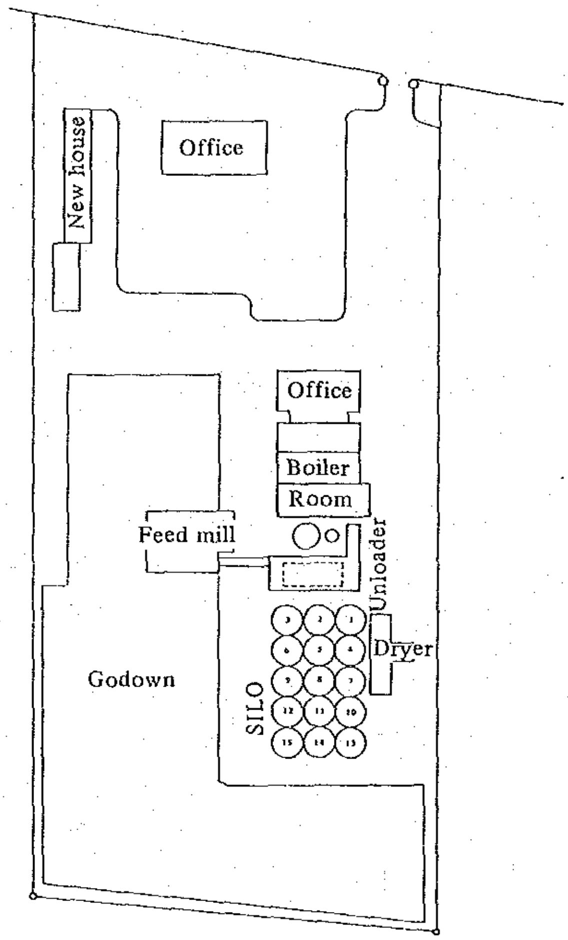


Fig. 18-2

4. State of Energy Management

4.1 Policy for Energy Conservation

The company, reflecting a general policy of management for the entire Centaco group, is seen strictly pursuing its essential target of improved profitability. In order to further reduce cost, it will be necessary to present concrete target for cost reduction and time of its achievement in future.

As an example of the recent energy conservation investment, in transfer equipment a bucket elevator system is now being used instead of the old pneumatic conveyor system. Although 250,000 Bt was spent, approx. 800,000 Bt has been saved in terms of electric power and repairs. This fact supports the adequacy of the project.

It is also observed that the entire organization is under good management: that is, employees are well disciplined and the application of system rule satisfactory.

4.2 Participation by All Employees

The Safety Committee and Quality Committee are established in each department. Even the employees at the lower echelon are encouraged to participate in the activities of the committees. Occasionally the factory general manager provides instructions to the members on given subjects, thus making a direct appeal to the employees for better factory management.

Although the improvement suggestion system is in force, active utilization is not observed. Nevertheless, the employees are sufficiently trained and as such, are considered well qualified for participation in the internal activities such as QC circle henceforth.

4.3 Control through Data

Data on factors involved in each process and facility are logged on an hourly basis. It is considered that the whole factory is accustomed to control through data collected through the determination of consumption rate and analysis of variation factors.

Only the regret is that a feed water meter is not yet installed and the actual state can not be grasped, although it is indispensable for the monitoring of boiler operating efficiency.

4.4 Education and Training, Technical Leveling-Up of Employees

The company is highly interested in employees' education and as a matter of fact, it sent employees to the external seminars fifteen times and the study visits to other industrial facilities two times last year.

The company is the largest manufacturer in the Thai animal feed industry and is proud of its high-level technology. Therefore, it is desired that the company be a leader in promoting technical information exchanges and thus raising the technical level of the whole industry. This will lead to the acceleration o each manufacturer's energy conservation and a subsequent stabilization of the entire industry.

5. State of Fuel Consumption

5.1 State and Breakdown of Fuel Consumption

Heavy oil A	: 850 kl/year			
Breakdown of Consumption	:	Pelletization	53% (boiler)	450 kl
		Dryig of raw maize	47% (dryer)	400 kl

Two boilers(100 HP) are normally operated on a two-shift basis, burning 35 kl of heavy oil A per month. During the busy season, they are operated on a three-shift basis, burning 40 kl of heavy oil A per month.

The dryer is usually used from September through December when corn containing a high percentage of moisture is delivered. It is dried with hot air prior to being stored in the silos.

Table 18–2 Energy Consumption Rate

Season	Jan. ~ Jun.	Jul. ~ Dec.	Hokkaido Japan
Working time / day	16 h (2 shift)	24 h (3 shift)	24 h (3 shift)
Production	18,000 t/month	24,000 t/month	—
Fuel oil for boiler	35 kℓ/month	40 kℓ/month	—
Boiler oil (ℓ)/Production (t)	1.94	1.67	4.0
* kWh/Production (t)	27.32	22.68	16.7
Productivity ton/month/person	112.5	150	237

* Dryer running power are included in the golden age electric power.

Fuel consumption rate (estimated on the actual production for the last fiscal year).

For pelletization 450 kl/153,000 t = 2.94 l/t

For drying raw corn 400 kl/12,750 t × 4 = 7.84 l/t

5.2 Heat Balance of Boiler

We calculated the heat balance of No.1 boiler based on its diagnostic results on July 27, 1983. The heat balance is partially based on an estimated value because there was not equipped flow meter for the feed water.

Table 18–3

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	402.1	99.8	Heat of steam	352.5	87.5
Sensible heat of fuel	0.9	0.2	Heat loss in exhaust gas	21.5	5.3
			Heat loss in blow water	8.8	2.2
			Heat release from boiler body, others	20.2	5.0
Total	403.0	100.0	Total	403.0	100.0

Data Given for Calculation of the Heat Balance

Fuel type		Heavy oil A
Fuel consumption	(F)	41.8*1 kg/h
Heat content of fuel (low value)	(kl)	9,619 kcal/kg
Specific gravity of fuel	(SG)	0.955
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	80°C
Reference temperature	(To)	30°C
Oxygen content of exhaust gas	(O_2)	5.3%
Temperature of exhaust gas	(Tg)	140°C
Quantity of blow down water	(B)	60*2 kg/h
Temperature of blow down water	(Tb)	175.9°C
Quantity of feed water	(W)	617.8 kg/h
Temperature of feed water	(Tw)	30°C
Steam pressure	(P)	8.3 kg/cm^{2}G
Quantity of steam (S = W − B)	(S)	557.8 kg/h
Enthalpy of steam	(Es)	662.0 kcal/kg
Enthalpy of feed water	(Ef)	30 kcal/kg

*1 Quantity of fuel: estimated at 35 kl/month (2 boilers), 16h/day and 25 days/month.

*2 Refer to Item 6.2.

Equation for Calculation of the Heat Balance

Input

Heat of fuel consumption	(Qc)	402.1×10^3 kcal/h
$Qc = F \times Hl$		
Sensible heat of fuel	(Qs)	0.9×10^3 kcal/h
$Qs = F \times Cp(Tf - To)$		

Output

Heat of steam	(Qv)	352.5×10^3 kcal/h
$Qv = S \times (Es - Ef)$		
$352.5 = S \times (662 - 30)$, $S = 557.8$ kg/h		
Heat loss in exhaust gas	(Qe)	21.5×10^3 kcal/h
$Qe = F \times G \times 0.33(Tg - To)$		
Theoretical amount of air (Ao)		
$Ao = 0.85\ Hl/1{,}000 + 2.0 = 10.18\ Nm^3/kg$		
Theoretical amount of exhaust gas (Go)		
$Go = 1.11\ Hl/1{,}000 = 10.68\ Nm^3/kg$		
Air ratio (m)		
$m = 21/(21 - O_2) = 1.34$		
Actual amount of exhaust gas (G)		
$G = Go + Ao(m - 1) = 14.14\ Nm^3/kg$		
Heat loss in blow down water	(Qb)	8.8×10^3 kcal/h
$Qb = B \times (Tb - Tw)$		
Heat release from body and others	(Qr)	20.2×10^3 kcal/h
(estimated as 5% of input)		

6. Problems in Heat Control and Potential Solutions

6.1 Control of Combustion at the Boiler

There are now installed four units (100 HP × 2, 30HP × 2) of boiler, out of which 2 units of 100 HP are in operation. If 1 HP is regarded as equivalent to 15.65 kg/h, a 100 HP boiler means 1,565 kg/h of steam generating capacity. However, as shown in the heat balance table, the boilers are actually operated at an extremely low load.

At present, the oil flow meter is faulty, so only the way to determine a heavy oil consumption is by a change in the tank content using a bob. In addition, through lack of flow meter of the feed water, it is impossible to calculate an evaporation multiple which indicates a combustion efficiency of boiler. Therefore, the factory cannot control the boiler combustion sufficiently everyday. It is desired that the flow meter of the fuel oil be repaired and a flow meter of the feed water also be installed so the data are collected from the meters and evaporation multiple may be logged for boiler control.

$$\text{Evaporation multiple} = \frac{\text{Amount of feed water} - \text{Amount of blow down water}}{\text{Fuel consumption}}$$

The boiler room is not cleaned up thoroughly and the pressure gauges around the boilers are not well maintained.

The oxygen content of boiler exhaust gas is rather high, so it is suggested that the air damper be adjusted to maintain the oxygen content at the level of 4% or less. In this case,

$m' = 1.24$

$G' = 13.12$

Assuming that the fuel amount after adjustment is x kg/h, the following equation is established according to the boiler heat balance:

$$\frac{403.0}{41.8} \cdot x = (352.5 + 8.8 + 20.2) + \frac{13.12 \times 0.33 \times (140 - 30)}{1,000} x$$

$\therefore x = 41.6$ kg/h

Energy conservation rate

$$\frac{41.8 - 41.6}{41.8} \times 100 = 0.5\%$$

If the same is true about a 3-shift operation, an annual heavy oil A conservation will be: 450 kl × 0.005 = 2.3 kl/year.

6.2 Reduction in Quantity of Blow Down Water for Boiler

At present, boiler water is blown down twice a day, each time lasting two minutes.

Although the quantity of blown-down water is unavailable through lack of flow meter, the estimated quantity will be 3.6 m^3/h × 4 = 14.4 m^3/h, if the liquid flow velocity through a 1 1/4" blow pipe is assumed to be 4 m/s.

It is estimated that the total quantity of blow down water in a day is 960 l based on a blow down frequency of 2 times, each time lasting two minutes during 16 hours, and therefore, the hourly blow down quantity is 60 l/h on the average. The pH and electric conductivity of boiler feed water are 7.15 and 897 μS/cm respectively. On the other hand, the pH and electric conductivity of boiler water are 11.17 and 1,000 μS/cm respectively. Judging from these values, the quality of water used is comparatively higher. Since the electric conductivity of boiler water is tolerable up to approx. 6,000 μS/cm, it will almost not affect the boiler body adversely, even if water is blown down once a day.

6.3 Insulation of Steam Line

Uninsulated parts of the steam piping and valves are seen through the factory. If these parts are insulated with 25-mm glass wool, the heat loss will be reduced as shown in Table 18-4.

If a reduction in the heat loss is converted to equivalent fuel oil, the following equation will be established:

$$\frac{(11,300 - 2,065) \times (16 + 24) \times 150}{9,619 \times 0.955 \times 0.875} = 6.9 \text{ kl/year}$$

6.9 kl/year × 4.3 = 29,700 Bt/year

Against the above, necessary cost for insulation is estimated at approx. 7,100 Bt. This cost will be recovered in approx. 3 months.

Table 18–4

Piping		Actual heat loss kcal/h	Heat loss after insulation kcal/h
Pelleter room header			
Glove valve	2" x 1	400	74
	4" x 3	2,400	438
	6" x 1	1,300	210
(Skin temperature 156°C)			
Steam piping			
Glove valve	2" x 10	4,000	740
Piping	9 m	3,200	603
Total		11,300	2,065

6.4 Recovery of Condensate and Reduction of Steam Pressure

Condensate generated in a total length of 100 m of four 4" pipes from the four boilers to the pelletizers is discharged straight into the pit through a blow pipe. And rising steam is conspicuous due to the faulty traps.

Assuming that heat loss in the 25-mm insulated 4" pipe is 115 kcal/mh, the following equation is established: $115 \text{ kcal/mh} \times 100\text{m} \times (16 + 24) \times 150 = 69{,}000 \times 10^3 \text{ kcal/year}$

As a steam of 8.3 $\text{kg/cm}^2\text{G}$ is fed, the latent heat of steam is 484.4 kcal/kg. Consequently, the quantity of generated condensate is represented by the following equation:

$$\frac{69{,}000 \times 10^3}{484.4} = 142 \times 10^3 \text{ kg/year}$$

If this condensate amount is released at an atmospheric pressure, approx. 14% will be evaporated as flash steam, losing 52% of its heat quantity. The heat quantity of the remaining condensate is represented by the following equation:

$$142 \times 10^3 \times 177.8 \times 0.42 = 10{,}604 \times 10^3 \text{ kcal/year}$$

If this heat quantity is recovered and utilized for boiler feed water, the energy of equivalent fuel oil to $10{,}604 \times 10^3/(9{,}619 \times 0.955 \times 0.875) = 1.3$ kl/year will be conserved.

$$\text{Energy conservation rate} = \frac{1.3 \times 100}{850} = 0.2\%$$

The hiher the steam pressure, the more heat of condensate is lost into the flash steam as above-mentioned. For this reason, it is advantageous to use steam at as low pressure as possible. If the steam pressure of 8.3 $\text{kg/cm}^2\text{G}$ is reduced to 3 $\text{kg/cm}^2\text{G}$, the heat effectively used for heating, that is, the latent heat of steam will be increased from 484.4 kcal/kg to 510 kcal/kg. Therefore, the estimated required steam quantity will be

$$\frac{484.4}{510} = 0.95$$

This means that the required steam quantity can be 5% less than when the steam pressure is high.

Heavy oil conservation $450 \text{ kl/year} \times 0.05 = 22.5 \text{ kl/year}$

6.5 Study on Production Method

Generally, continuous operation is advantageous for the process industry which utilizes heat. At this factory, the heavy oil consumption rate is 1.67 l/ton on a 3-shift operation base and 1.94 l/ton on a 2-shift operation base. Accordingly, it is recommended that a 3-shift continuous operation be adopted and after that, the operation be suspended, as far as issues such as delivery condition, inventory capacity, change of inventory quality and labor cost allow. The suspension period can be applied to equipment maintenance and employee education/training.

The expected effects will be : 18,000 tons/months × (1.94 − 1.67) l/t × 6 months = 29.2 kl/year.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	1,360 kw (March, 1982)
Power Consumption	:	6,000 × 10^3kWh/year (estimated from data for March)
Load Factor	:	Monthly load factor 60 ~ 68% (estimated)
Penalty Fee	:	36,000 Bt/year (estimated from data for March)
Power Factor	:	Monthly power factor 75 ~ 85% (estimated)
Transformer	:	3ϕ 1,250 kVA × 2 units....for factory 3ϕ 500 kVA × 1 units..for general office
Power Cost	:	1.72 Bt/kWh (March, 1982)

7.2 One Line Diagram

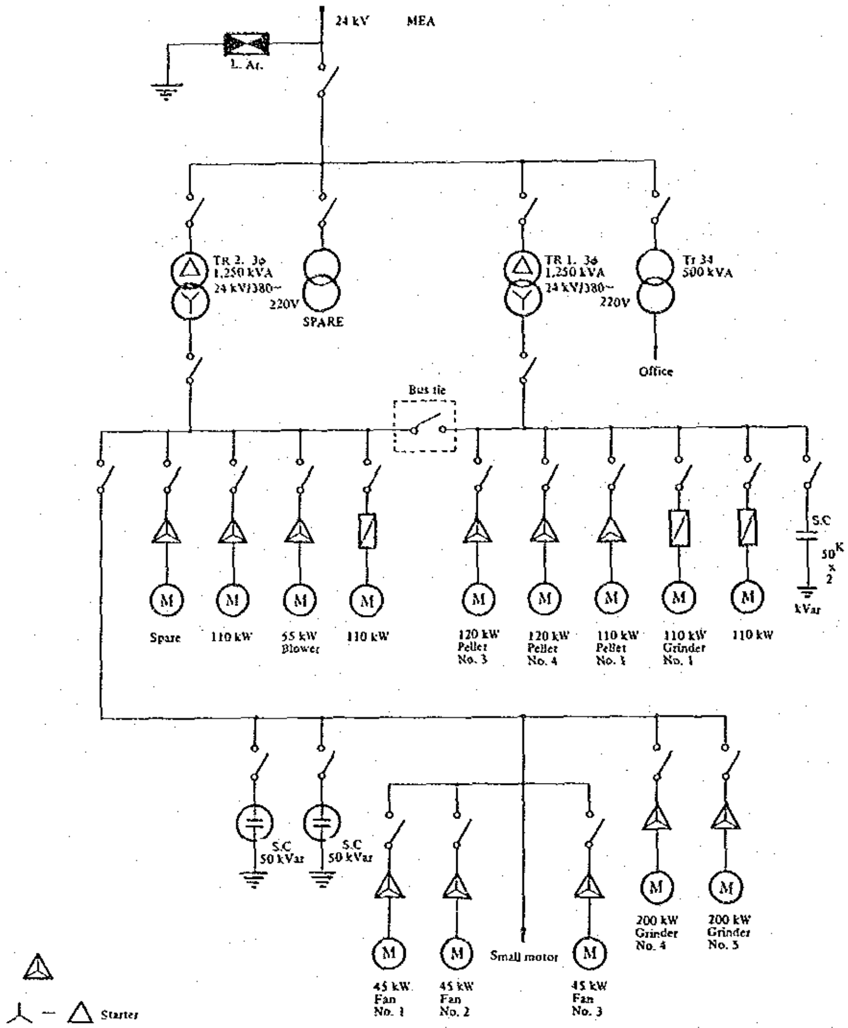


Fig. 18–3 One Line Diagram

7.3

7.3.1 State of Hourly Power Consumption

Table 18–5 Hourly Power Consumption

By MEA Meter

July 26

Time	Effective power kWh	Reactive power kVar	Power factor %
11:00 ~ 12:00	1,173	891	80
12:00 ~ 13:00	1,200	800	83
13:00 ~ 14:00	880	800	74
14:00 ~ 15:00	1,120	920	77
15:00 ~ 16:00	1,040	880	76

July 27

Time	Effective power kWh	Reactive power kVar	Power factor %
9:00	–	–	–
9:00 ~ 10:00	800	720	74
10:00 ~ 11:00	800	680	76
11:00 ~ 12:00	720	600	77
12:00 ~ 12:30	280	440	53
12:30 ~ 13:00	320	520	53
13:00 ~ 13:30	320	160	90
13:30 ~ 14:00	320	160	90
14:00 ~ 15:00	–	–	–

7.3.2 Hourly Load Curve

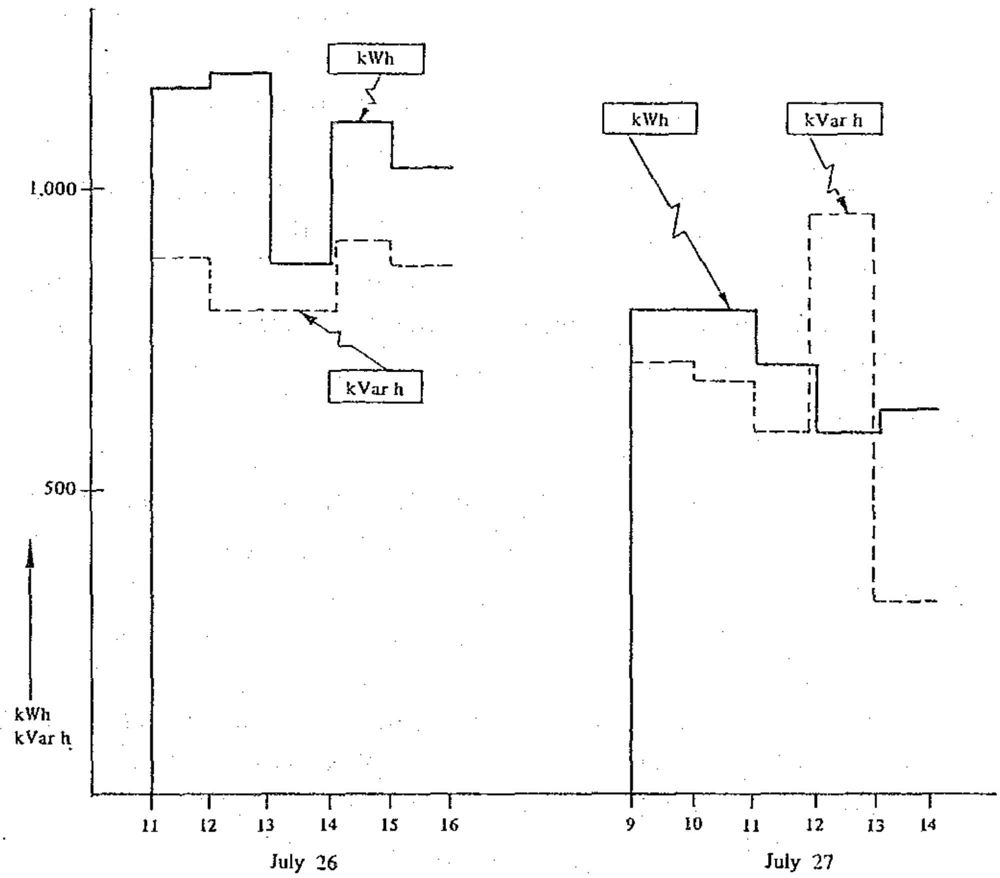


Fig. 18–4 Hourly Load Curve

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 18–6 Instantaneous Value

July 27

	Name plate			Measurement					
	kVA	V_1	V_2	kW	V	AR	AS	AT	P.F %
TR 1	1,250	22,800	400	506	393	940	957	1,005	76.8
TR 2	1,250	22,800	400	519	394	900	918	884	84.5

Use for	Name plate			Measurement			P.F (%)	L.F (%)
	kW	V	A	kW	V	AR		
Grinder IV	200	380	370	138	393	252	84	69
Grinder V	200	380	370	152.8	.392	234	91	76.4
Pellet III	120	380		112.5	392	192.1	83	93.7
Pellet IV	120	380						
Pellet I	110	380	204	59.1	394	104.2	82	537.3
Grinder I	110	380	185	30.8	395	70.7	75	28
Blower I	55	380	104	18.87	387	56.7	50	34.3
Blower II	55	380	104	32.9	393	62.8	75	59.8
Fan I	45	386	82	35.4	387	57.5	89	78.7
Fan II	45	380	82	36.8	388	66.1	78	81.8
Fan III	45	380	82	39.5	386	66.1	78	81.8
Air compressor	30	380	61	26.2	389	46.7	83	87.3

8.2 Power Distribution

8.2.1 Transformers

Two 1,250 kVA transformers are provided for the factory and one 500 kVA transformer is installed for the general office.

(1) 1,250 kVA × 2 units

We calculated an expected advantage of the case where the number of transformers shown in Table 18-6 is reduced by one transformer on the following preconditions:

Operating time — 6,000 h/year

Annual power consumption — $\{6{,}000 \times 10^3 - 1{,}000 \times 10^3(\text{for office})\} = 5{,}000 \times 10^3$ kWh/year

Average electric power

$$\text{Average electric power } \frac{5{,}000 \times 10^3\,\text{kWh}}{6{,}000\,\text{h}} \doteqdot 840\,\text{kW}$$

Assuming that the power factor as 78.9%, the apparent power as 1,065 kVA, the iron loss as 0.3 kW and the copper loss as 1.1 kW based on the case of March, 1982, the following equation is eatablished:

	Iron Loss	Copper Loss	Total
2,500 kVA (1,250 × 2)	65.7×10^3kWh/year	29.9×10^3kWh/year	95.6×10^3 kWh/year

1,250 kVA	32.8×10^3	59.9×10^3	92.7×10^3
Balance			$\Delta\ 2.9 \times 10^3$kWh/year

Thus the loss does not make much difference. Consequently, it is concluded that the present two transformer operating pattern is acceptable.

(2) 500 kVA × 1 unit

The transformer is for the general office, and there is no problem with capacity because the power consumption is 90~250 kWh/h according to information available on the day of our visit.

(3) According to data obtained in March, 1982, the overall peak demand of three transformers is 1,360 kW. In addition, assuming that the annual power consumption is $6,000 \times 10^3$kWh/year and the operating time 6,000 h/year, the estimated average electric power will be:

$$\frac{6,000 \times 10^3 \text{ kWh}}{6,000 \text{ h}} = 1,000 \text{ kW}$$

Further, since the maximum value of Table 18-5 is 1,200 kWh/h, the estimated peak demand will be approx. 1,000 kW to 1,500 kW. Accordingly, there is no problem with each transformer capacity particularly.

8.2.2 Unbalanced Current

According to Table 18-6, the phase current of the 1,250 kVA transformer is 940 ~ 1,005A for No.1 and 884 ~ 918A for No.2. These currents are not particularly significantly unbalanced (approx. 4 ~ 7%). However, considering an electric power loss by reverse direction current due to an unbalanced current, it is desired that connections be arranged for illumination and others so that the single phase load may be well balanced as far as possible.

8.2.3 Power Factor

In the case of March, 1982, a penalty for the power factor amounting to 3,000 Bt was paid. As the peak demand for that month is 1,336 kW, the mean power factor will be estimated as follows:

$$\{\text{Reactive electric energy} - 1,336 \times 0.63\} \times 15 = 3,000$$

$$\therefore \text{Reactive electric energy} = 1,042 \text{ kVar}$$

$$\text{Apparent power} = \sqrt{1,336^2 + 1,042^2} = 1,694 \text{ kVA}$$

$$\text{Power factor} = 1,336/1,694 = 78.9\%$$

In order not to be paid penalty, it is necessry to insert a 200 kVar condenser. As a result, it is estimated that the following improvement will be achieved:

$$\text{Apparent power} = \sqrt{1,336^2 + (1,042 - 200)^2} = 1,579 \text{ kVA}$$

$$\text{Power factor} = 1,336/1,579 = 84.6\%.$$

On account of a reduction of the apparent power, the copper loss of the transformer will be reduced as follows:

$$2,500 \times 0.011 \times \{(\frac{1,694}{2,500})^2 - (\frac{1,579}{2,500})^2\} \times 6,000 \text{ h/year} = 9.9 \times 10^3 \times 1.45 = 14,360 \text{ t/year}$$

Bt/year

The total cost saving including penalty will be approx. 50,000 Bt/year. On the other hand, cost involved in the installation of a 200 kVar condenser is estimated at approx. 80,000 Bt. This cost will be recovered in 1.6 years.

8.3 Power Application

8.3.1 Voltage

According to Table 18-6, the service voltage to motors is generally rather high such as approx. 390 V excepting some. On the other hand, the load factor varies from 28 to 94%, so it is difficult to determine it. Therefore, we cite an expected advantage when the tap of the transformer is switched to reduce the service voltage to approx. 370 V or 5% drop as a referential case. That is, it is generally said that reduction of loss in the transformer, distribution line and electric motor attributed to a drop of voltage during a light load operation, is approx. 2 ~ 3%. Then assuming that the expected advantage is 2% and the annual power consumption of the factory is $5{,}000 \times 10^3$ kWh/year, the following equation is established:

$5{,}000 \times 10^3$ kWh/year $\times$ 0.02 = 100×10^3 kWh/year

100×10^3 kWh/year $\times$ 1.45 Bt/kWh = 145,000 Bt/year

It is desired that the company confirm the power consumption and the temperature fluctuation of the electric motors after 5% drop of service voltage.

8.4 Others

8.4.1 Power Consumption Rate

Making the power consumption rate for 1979 four years ago 100%, it is increased approx. 50% to 150% as of July, 1983. The conceivable major causes are as follows:

(1) Increase in the load due to newly built silos.

(2) Increase in the load due to a new general office.

As to the general office, the load should be treated as outside the framework for power consumption rate of the factory. It is suggested that after installing a recording meter for enabling the determination of a power consumption in detail at the office, a power consumption rate be newly established and be controlled toward a set target.

8.4.2 Operation and Safety Control

We were not able to confirm data on troubles or accidents. However, common troubles which tend to occur at the powder-handling factories are as follows:

(1) Troubles attributable to the deterioration of insulation by moisture in the power board and the control board.

(2) Burning caused by the diminishing of cooling effect resulting from the clogging of an electric motor with powder.

It is important to clean the above-mentioned parts regularly. Specially a burning trouble with the electric motor is sometimes mistaken for an overloaded operation, so it is necessary to determine the cause with care. In addition, a small spark caused by the deterioration of insulation or a burning of the electric motor in powder is likely to lead to a large fire. We invite the employees' attention to operating safety and secure maintenance.

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 Burning in Boiler	2.3	0.5
Insulation of Steam Line	6.9	0.8
Recovery of Condensate	1.3	0.2
Drop of Steam Pressure	22.5	2.6
Continuous Operation	29.2	3.4
Total	62.2	7.3

	10^3 kWh/year	%
Improvement of Power Factor	9.9	0.1
Reduction of Service Voltage of Electric Motor	10.0	1.7
Total	109.9	1.8

ATTACHED DATA

Study Team Members

Part	Name	Present Post
Team Leader	Mitsuo Iguchi	Managing Director, ECC
Chemical Group		
Heat	Hiroo Igarashi	General Manager, International Cooperation Department, ECC
〃	Hiroshi Murata	Registered Diagnoser, ECC
Power	Kenichi Kurita	〃 〃
Food Group		
Heat	Akira Koizumi	General Manager, Hokkaido Branch, ECC
〃	Shiroo Honda	Registered Diagnoser, ECC
Power	Yuuji Kaneko	〃 〃

Counterparts Names

Part		Name	Organization
Chemical	Heat	Danai Egkamol	NEA
		Pinyo Tonthumas	〃
		Pichai Nitinon	〃
		Boonyong Juengthanawiwat	〃
		Nattavut Suanin	〃
		Derake Wuthichok	MOI
	Power	Thumasak Suwanadhep	NEA
		Wicha Thongsuk	〃
		Somkid Aoluknua	〃
Food	Heat	Supachok Kusolsong	NEA
		Supon Khwankongrai	〃
		Somjet Junsawang	〃
		Sakon Bhutachart	〃
		Tawatchai Titivudtiwong	MOI
		Surapong Bhiraleus	〃
		Sirichai Savangmongkol	〃
	Power	Banphot Diskul	NEA
		Umporn Koonchonrat	〃
		Buranachai Cutchon	〃

Itinerary of Study

1983	June	26	Departed Narita, arrived Bangkok
		27	Visits to the JICA Bangkok Office, NEA and TPA
		28	Meeting with NEA Director General and Deputy Director General
			Report on summary of outcome of the secondary study
		29	Arrangements for diagnosis (Preparation of instruments and explanation of plans)
		30 ~	Factory diagnosis and data sorting
	July,	27	
		27	Visit to JICA Office, Japanese Embassy Report on summary of outcome of the third study
		28	Meeting with NEA Director General, Report on summary of outcome of third study
			Delivery of instruments to NEA
		29	Visit to JICA Office, TPA, NEA
		30	Departed Bangkok, arrived Narita

Energy Conservation Survey
省エネルギー調査表

1 Name of Factory
工場名 ______________________

2 Location
所在地 ______________________ Tel. __________

3 Name of Company Officials
会社役員名 ______________________

President
社長 ______________________

Factory Manager
工場長 ______________________

Energy Manager
エネルギー担当者 ______________________

4 Segment of Industry
業種 ______________________

5 Capital
資本金 ______________________ bahts

6 Annual Turnover
年間売上高 ______________________ bahts

7 Number of Employees
従業員数 ______________________

8 Number of Engineers
技術者数 ______________________

Electricity
電気 ______________________

Heat
熱 ______________________

9 Major Products
主要生産物 ______________________

____

10 Production Capacity of Major Products
主要生産物の生産能力 ______________________

Nominal
公称 ______________________

Present Condition
現状 ______________________

11 Fuel Consumption
燃料消費高

☐ Fuel oil 重油	kl/y	bahts/y
☐ Diesel oil 軽油	kl/y	bahts/y
☐ Kerosene 灯油	kl/y	bahts/y
☐ Gasoline ガソリン	kl/y	bahts/y
☐ LPG 液化石油ガス	t/y	bahts/y
☐ Natural gas 天然ガス	m³/y	bahts/y
☐ Lignite or Brown Coal 亜炭又は褐炭	t/y	bahts/y
☐ Bagasse バガス	t(m³)/y	bahts/y
☐ Charcoal 木炭	t/y	bahts/y
☐ Firewood 薪	t(m³)/y	bahts/y
☐ Others ( ) その他	/y	bahts/y

12 Electric Power, 電力

Electricity Consumption 電力消費高	KWh/y		bahts/y
Contract Demand 契約電力	KW.	Receiving Voltage 受電電圧	V
Power Factor 力率	%		
Power Plant 発電設備	Have or Not.	Capacity 能力	KW or KVA.

13 Water Consumption, 水消費量

Sea Water 海水	m³ or t/y	River Water 河水	m³ or t/y
Underground Water 地下水	m³ or t/y	City Water 水道水	m³ or t/y

14 Boiler, ボイラ

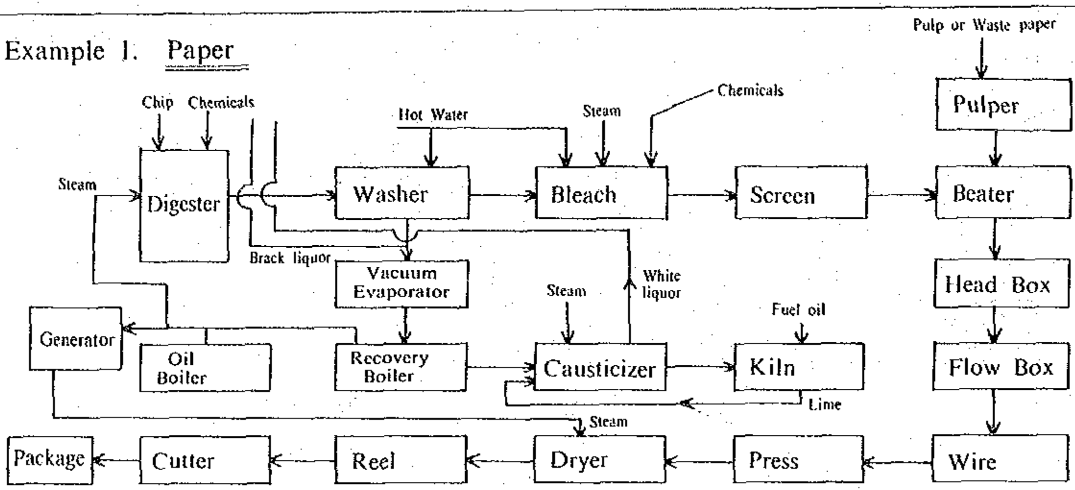
Built(A.D.) 設置(西暦)	Type 型式	Nominal Capacity 公称能力		Kind of Fuel 燃料の種類	Operating period 運転時間	
		Steam Press. kg/cm²G	Evaporating Volume t/h		hrs/day	days/y

15 Major Facilities Using Energy, エネルギー使用の主要設備

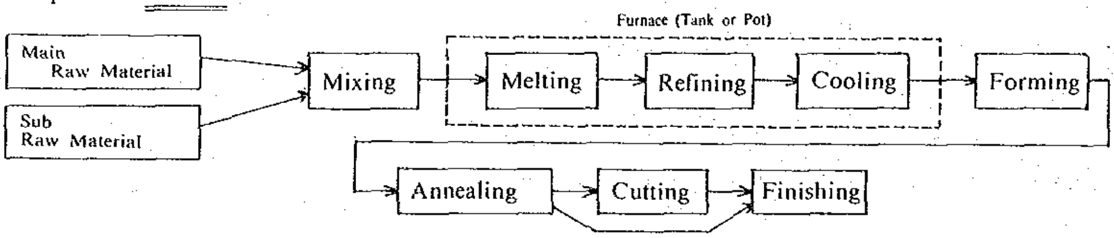
Built(A.D.) 設置(西暦)	Name of Facility 設備名	Products 生産物	Output 生産高		Kind of Energy used 使用エネルギーの種類	Operating period 運転時間	
			Nominal 公称	Present Condition 現状		hrs/day	days/y

16 Flow-chart of Producing Process of Major Products, 主要生産物の生産工程図

Example 1. Paper

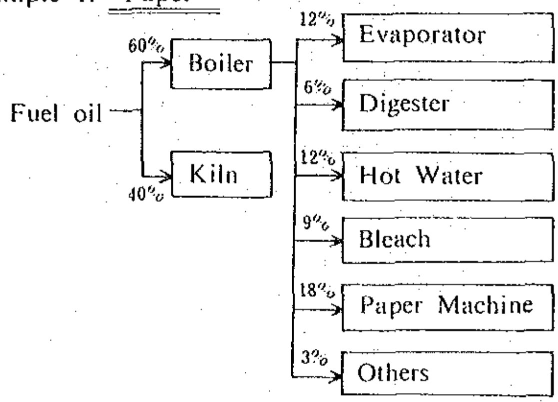


Example 2. Glass

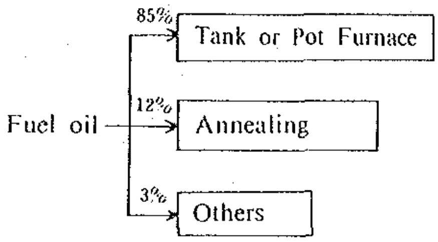


17 Energy Flow-chart, エネルギー流れ図

Example 1. Paper

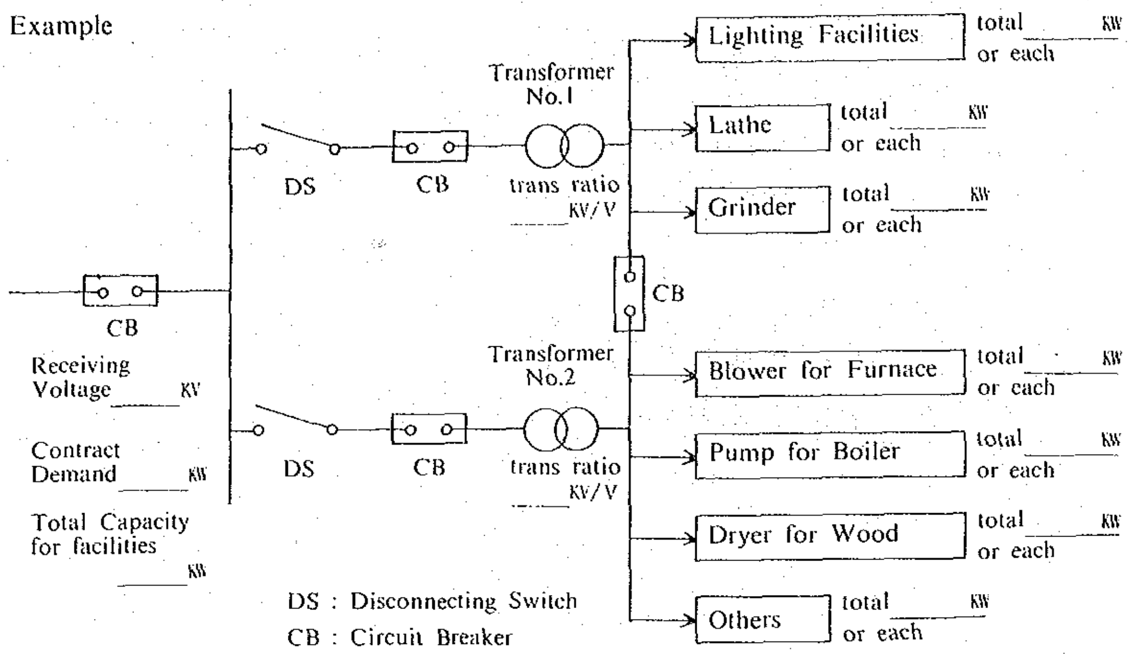


Example 2. Glass



18 Skeleton Diagram, 単線結線図

Example



19 Plant Layout, 工場配置図

20 In case you have any problem(s) in your course of promotion of energy conservation, please circle the no(s). of applicable item(s) among the following: (Maximum 5 items)

省エネルギー推進上の問題点があれば，下記の該当する項目に丸印を付して下さい。(但し，最高5項目まで)

(1) Prospect of energy price is not clear.
エネルギー価格の見通しが不明。

(2) The proportion of energy cost in the whole cost of enterprise is small.
企業におけるエネルギー費用の割合が小さい。

(3) Increase of energy cost can be covered by raising the prices of products.
エネルギー費用の上昇は製品値上げでカバーできる。

(4) Instability of energy supply. (power stoppage, etc.)
エネルギー供給が不安定（停電など)。

(5) Shortage of engineers.
技術者が不足。

(6) Difficulty in obtaining good energy conservation equipments.
省エネルギー機器のよいものが手に入り難い。

(7) Information such as active cases is not easy to obtain.
実施例のような情報が入りにくい。

(8) System of research and development is not sufficient.
研究開発体制が不十分。

(9) Shortage of fund for facility improvement.
設備改善の資金が不足。

(10) The facilities are superannuated.
設備が老朽化している。

(11) Employees' consciousness is low.
従業員の意識が低い。

(12) No personnel is available who can educate the employees.
従業員教育をできる人がいない。

(13) Shortage of measuring equipments.
計量設備が不足している。

(14) No time to analyze energy consumption rate.
原単位解析を行う時間がない。

(15) Shortage of information on government's measures.
政府施策の情報が不足。

(16) Shortage of government's subsidiary measures.
政府の助成策が不足。

(17) Others
その他。

1 Energy Management

1 Energy Management （エネルギー管理）

No.	Item	項目	Status			
1	Company's Energy Conservation Policy	企業の省エネルギー方針				
	Setting up Target	目標設定	Set up		not set up	
	Numerical Value of Target	目標値	______% improve to ______base			
	Completion Deadline	達成期限	by______			
	Investment for Energy Conservation	省エネルギー投資				
	Investment Scale	投資額	1981 ______ Bts			
			1982 ______ Bts			
			1983 Plan ______ Bts			
	Judgement for Investment	投資基準	Pay Back Time, within ______Yrs			
2	Check on Energy Consumption	エネルギー消費量管理				
	Measurement of Consumption	消費量計測	Electric Power		Fuel	
			Times/		Times/	
	Factory Total	工場計	done	not done	done	not done
	By Major Process	主要工程別	done	not done	done	not done
	By Major Facility	主要設備別	done	not done	done	not done
	Data Analysis	データ解析				
	Grasp of Energy Consumpt's. rate	原単位把握	done		not done	
	Preparation of Control Chart	管理図作成	done		not done	
	Analysis of Variance	変動要因分析	done		not done	
	Cost Control	原価管理				
	Energy Cost Accounting	エネルギー原価計算	Monthly,	Times/y,		not done
	Energy Cost Distribution by Process	工程別配分	done		not done	
	Accounting of Heat Balance	熱勘定	done		not done	

Diagnoser	

Date		Factory	

3	Organization	組　織			
	Planning and Promotion	企画・推進	Section		Person in Charge
	Committee	委員会	held		not held
	Frequency of Holding	開催頻度	______	Times/y	
	Committee Chairman	委員長	______		
	Project Team	プロジェクトチーム	made		not made
	Consultant Contract	コンサルタント契約	made		not made
4	System	制　度			
	Improvement Proposition System	改善提案制度	is		isn't
	Achievement Commendation System	実績表彰制度	is		isn't
	Inspection, Audit	視察，診断	done		not done
5	Education of Employees	従業員教育			
	Seminar	研修会	held	Times/y	not held
	Observation Meeting	見学会	held	Times/y	not held
6	Campaign to Employees	従業員への呼びかけ			
	Appeal from Factory Manager	工場長の呼びかけ	done		not done
	Poster, etc.	ポスター　等	done		not done
7	Activities in the Business Circles	業界の活動	Practised		not practised

2 Heat

2-1 Furnace, Kiln, Dryer

2-2 Steam Consuming Equipment

2-3 Boiler

2-4 Steam Piping, Condensate Recovery

2-1 Furnace, Kiln, Dryer

1	Part	工　　程				
2	Name of Equipment	設 備 名				
3	Use	用　　途				
4	Charge	被加熱物				
5	No. of Furnace	番　　号				
6	Type	型　　式				
7	Maker	メーカー				
8	Time built	設置時期				
9	Outer Dimension Length or Dia. Width Height	外法寸法 長さ・径 巾 高				
10	Design Capacity	設備能力				
11	Usage Continuous Batch h/Day h/month	使用状況 連　続 非連続				
12	Induced Draft Fan Forced Draft Fan	吸込み送風機 押込み送風機	____ m^3/h ____ mmAq ____ kW ____ ____ ____			
13	Improvement done	改造実績				

Diagnoser			Date		Factory

14	Fuel	燃　料						
	Name	名前						
	Lower Heating Value	発熱量（低位）	Kcal/kg. ℓ.m3N					
	Specific Gravity	比重						
	Moisture	水分						
15	Average Consumption	燃料使用量（平均）	/h					
16	Oil Storage	油貯蔵						
	Tank	Contents	タンク　油種					
		Volume	容量	m^3				
		Temp.	温度	°C				
		Insulation	保温	mm				
17	Fuel Receiving	受入れ						
	Measuring Volume	計量	done	not done				
	Temp.	温度測定	done	not done				
	Sp.grav.	比重 〃	done	not done				
	Analysis	分析	done	not done				
18	Oil Leak	油洩れ	good	not good				
19	Steam	スチーム						
	Pressure	圧力	kg/cm^2G					
	Temp.	温度	°C					
20	Electricity	電力						
	Elect. Heater	電熱	______ kW ______ V					
	Infra Red Lamp	赤外ランプ	______ kW ______ V					

	No. of Equipment	設　備　名	
21	Combustion		
	Burner	バーナー	Pressure jet, Low pr.air atomizing, Steam or air atomizing, Rotary, Intermixing, Interior atomizing, Semi mixing ____ ____ ____ ____ ____ ____ ____
	Burner Tile	バーナータイル	Good　　not good
	Cleaning of Burner tip	バーナー手入	times/y
	Flame Color	火焔　色	good　　not good
	Length	長　さ	good　　not good
	Sparks	花　火	good　　not good
	Blow off	吹きとび	good　　not good
	Color of Smoke	煙の色	good　　not good
	Air/fuel ratio	空気比	Factory Data ____　　Measured ____　　$m = \frac{0.21}{0.21 - (O_2)}$
	Automatic Controller	制御装置	exist　　not exist
	Fuel Consumption	燃料量	____ kg.ℓ.m3/h
	Fuel Temp.	油　温	____ °C (at Burner, after Heater)
	Air Temp.	燃焼空気温度	
	Primary Air flow	一次空気量	
	Secondary Air flow	二次空気量	
	Atomizing press.	噴霧圧	

	Quantity of Burners					
Zone	Preheating		Heating		Soaking	
Burner Type	axial	Side	axial	Side	axial	Side
Upper Zone						
Lower Zone						

	No. of Equipment	設備番号	
22	Furnace Pressure	炉圧	______ mmAq (Measuring Point ______ mmH)
	Pressure Control	炉圧制御	done　　not done
	Movement of Damper	ダンパー作動	good　　not good
	Air Sucking	空気吸込	
	from Wall	炉壁	good　　not good
	Burner Side	バーナーまわり	good　　not good
	Door	出入口	good　　not good
	Truck	台車シール	good　　not good
	State of Stack, Gas duct	煙突，煙道の状態	good　　not good
	Cooling Air	冷却空気	______ m3/min.
23	Heating	加熱	
	Furnace Temp.	炉温	______ °C
	Charging Temp.	装入温度	______ °C
	Extracting Temp.	抽出温度	______ °C

	Preheating Zone	Heating Zone	Soaking Zone
Set	°C	°C	°C
Actual	°C	°C	°C

	No. of Equipment	設備番号	
	Temp. measurement	温度測定	Thermocouple( ), Resistance Thermometer, Optical Pyrometer, Radiation thermometer, Seger cone
	Temp. Controller	温度制御装置	exist　　not exist
	Burner Setting	バーナー取付	good　　not good
	Arrangement of Charge (Furnace Load Factor)	装入方法	good　　not good,　　Truck Speed ______
	Seal		
24	Size of Charge	材料寸法	
	Heat Utilization of previous process, Hot Charge	ホットチャージ	done　　not done

	No. of Equipment	設備番号				
25	Drying	乾燥				
	Air Temp.	風温	________ °C			
	Air Flow	風量	________ m^3/h			
	Moisture of Charge	装入物水分				
	Inlet	入口	________ %			
	Outlet	出口	________ %			
26	Insulation	断熱	Preheating Zone	Heating Zone	Soaking Zone	
	Structure of Wall	壁面構成				
	Refractory Brick	耐火材				
	Insulating Zone	断熱材				
	Outer Wall	外壁				
	Color of Wall Surface	壁の色				
	Temp. of Wall Surface	壁面温度				
	Side Wall	側面	°C	°C	°C	
	Roof, Crown	上面	°C	°C	°C	
	Heat Flux		$kcal/m^2h$			
	Insulation of Skid	スキッド断熱	good	not good		
	Weight Reduction of truck, conveyor, etc.	台車・コンベア等の軽量化	done	not done		

	No. of Equipment	設備番号				
27	Waste Heat Recovery	廃熱回収				
	Name of Recovery Equipment	回収設備名				
	Type	型式				
	High Temp. Fluid	高温流体				
	Low Temp. Fluid	低温流体				
	Heat Recovered	回収熱量				
	Flow	流量				
	Temp. Rising (Falling)	温度上昇(低下)				
	Specific Heat	比熱				
	Temp. of Waste gas	排ガス温度				
	Furnace Outlet	炉出口	________°C			
	After Heat Recovery	廃熱回収後	________°C			
	Clearing of Heating Surface	伝熱面掃除	________Times/y			
	Preheating Zone in Furnace	炉の予熱帯	exist　not exist			
	Air Leak in Heat Recovery Equip.	廃熱回収設備の空気洩れ	found　not found			
	Cooling Water flow	冷却水量				
	Water Inlet temp.	〃 入口温度				
	Water Outlet temp.	〃 出口温度				

	No. of Equipment	設備番号	
28	Operational Management	操業管理	
	Operation Standard	作業標準	made not made
	Heating Curve	昇温曲線	exist not exist
	Recording	記録	good not good
	Maintenance	保全整備	good not good
	Period	周期	______ly
	Record	記録	good not good
29	Current Performance	実績	
	Output (or Input)	処理量	______ t/h
	Fuel Consumption	燃料量	______ ℓ.kg.m³/h
	Heat Efficiency	熱効率	______ %
	Loss with Waste Gas	排ガス損失	______ Kcal/h ______ %
	Loss with Coolant	冷却水損失	______ Kcal/h ______ %
	Loss through Wall	放熱損失	______ Kcal/h ______ %

2-2 Steam Consuming Equipment （蒸気使用設備）

1	Part	工程	
2	Use	用途	
3	Name of Equipment	設備名	
4	No. of Equip.	番号	
5	Type	型式	
6	Maker	メーカー	
7	Time built	設置時期	
8	Dimension	寸法	ℓ ____ mm x w ____ mm x h ____ mm, d ____ mm x h ____ mm
9	Heating surface area	伝熱面積	m^2
10	Volume	容量	
11	Capacity	能力	
12	Subject of heating	被加熱体	
13	Heat source	熱源	Steam: kg/cm^2G, °C t/h, Hot water °C, t/h
14	Quantity of Treatment	処理量	
15	Operating condition Temp. Press.	操業条件 温度 圧力	 °C kg/cm^2G
16	Insulation Surface Temp.	断熱 表面温度	mm good, not good °C heat flux $Kcal/m^2h$

Diagnoser	

Date		Factory	

17	Cleaning for heating surface	伝熱面の掃除	done　　not done
18	Instruments	計装	Temp.　Press.　Flow.　Other:
19	Auxiliary Equip.	附属設備	
	Heat Recovery	熱回収	exist　　not exist　　type
	High Temp. Fluid	高温流体	specific heat
	Low Temp. Fluid	低温流体	specific heat
	Temp. rising (falling)	温度上昇（降下）	
	Flow	流量	m^3/h
	Condensate recovery	ドレン回収	done　　not done,　　open system,　　closed system
	Rate of Recovery	回収率	%

2-3 Boiler （ボイラ）

1	Part	工程	
2	Use	用途	
3	No. of Boiler	番号	
4	Type	型式	Water tube boiler（水管） Flue tube boiler（炉筒） Once-through boiler（貫流） Hot-water boiler（温水） Other（その他）
5	Rated evaporation	定格蒸気量	t/h
6	Manufacture date	製造年月日	
7	Steam pressure	圧力	Rated（定格） kg/cm^2G, Normal（常用） kg/cm^2G
8	Heating surface area	伝熱面積	m^2
9	Auxiliary Equip.	附属設備	Superheater（過熱器） m^2, Reheater（再熱器） m^2 Economizer（節炭器） m^2, Air heater（空気予熱器） m^2
10	Fuel Name Lower Calorific Value Specific gravity	燃料 名前 発熱量（低位） 比重	 Kcal/kg, ℓ, m^3N
11	Usage Continuous Batch	使用状況 連続 非連続	 h/d, d/m, h/y,

Diagnoser		Date		Factory	

	Item	項目	Unit 単位	Nominal 定格	Actual 実績	Remarks 備考
12	Oil Tank	油タンク	——			
	Volume	容量	m^3			
	Temp.	油温	°C			
	Insulation	保温	mm			
	Leak	洩れ	——			good, not good
13	Boiler	ボイラ	——			
	Steam Pressure	蒸気圧力	kg/cm^2G			
	Steam Temp.	蒸気温度	°C			
	Feed water flow rate	給水 給水量	m^3/h			
	" Temp.	温度	°C			
	" Meter	流量計				Type
	Blow off flow rate	ブロー量	m^3/d			Continuous, Intermittance, Heat recovery
	Boiler water	缶水	——			
	pH	ピィエッチ				
	Conductivity	電気伝導率	μS/cm			
14	Feed Water	給水	——			
	pH	ピィエッチ				
	Conductivity	電気伝導率	μS/cm			
	Preparation method	処理法	——			
	Testing time	検査頻度	——			
	Cl' content	クロール濃度	ppm			

	Item	項目	Unit 単位	Nominal 定格	Actual 実績	Remarks 備考
15	Combustion	燃焼	――			
	Fuel	燃料				
	Consumption	使用量	ℓ.kg.m^3/h			
	Temp.	温度	°C			
	Meter	計器	――			exist, not exist
	Burner	バーナー				Oil burner
	Type	型式	――			Low press, air atomizing (低圧噴霧式) Steam or air atomizing (高圧噴霧式) Press. jet type (油圧式) Rotary (回転式) Gas burner Intermixing type (内部混合式) Injector atomizer (外部混合式) Semi-mixing (半混合式)
	Capacity	容量	ℓ.kg.m^3/h			
	Burner tile	バーナータイル	――			good, not good
	Clinker	クリンカー	――			found, not found
	Air ratio	空気比	――			Measuring point (場処)
	Insulation	断熱	mm			good, not good surface temp. heat flux.
	Sucking air	侵入空気	――			good, not good
16	Color of smoke	煙の色	――			good, not good
17	Air heater	空気予熱器	――			exist, not exist
	Air temp.	空気温度	――			
	Inlet	入口	°C			
	Outlet	出口	°C			

	Item	項目	Unit 単位	Nominal 定格	Actual 実績	Remarks 備考
	O_2 % Inlet	入口	%			
	Outlet	出口	%			
	Waste gas temp.	排ガス温度	———			
	Inlet	入口	°C			
	Outlet	出口	°C			
18	Economizer	エコノマイザー	———			exist, not exist
	Waste gas temp.	排ガス温度	———			
	Inlet	入口	°C			
	Outlet	出口	°C			
	Feed water temp.	給水温度	———			
	Inlet	入口	°C			
	Outlet	出口	°C			
19	Automatic Controller	自動制御	———			exist, not exist
	Subject	対象	———			Steam press. air ratio
	System	方式	———			
	Operation	作動	———			good, not good
20	Steam accumulator	スチームアキュムレーター	———			exist, not exist
	Capacity	容量	m^3			
	Pressure	圧力	kg/cm^2G			
22	Evaporation ratio	蒸発倍数	Kg/kg,ℓ			
	Boiler efficiency	ボイラ効率	%			Hh base, Hl base
	Loss with waste gas	排ガス損失	Kcal/h			

	Item	項　目	Unit 項目	Nominal 定格	Actual 実績	Remarks 備
23	Soot blow	スートブロー	/d			
	Service a burner	バーナー手入	/m			
	Removal of scale	スケール除去	———			
	Air heater	空気予熱器	/y			
	Economizer	エコノマイザー	"			
	Gas duct	煙　道	"			
	Stack	煙　突	"			
	Cleaning burner tip	バーナチップ手入	/m			

2-4 Steam Piping, Condensate Recovery（蒸気管，ドレン回収）

Steam Piping Insulation Leakage	蒸気配管 保温 漏洩				
Recovery of Flashed Steam Cylinder Hood	フラッシュ蒸気の利用 シリンダー上のフード	exist, 有 not exist 無			
Condensate Recovery Flow Rate System	ドレン回収 発生量 回収率 回収方式	 m^3/h % open, closed			
Steam Trap Type No. of Unit Present Condition	スチームトラップ 形式 数量 作動状況	 good, not good			
Flow Sheet Steam Condensate	フローシート 蒸気 ドレン				

Diagnoser	

Date		Factory	

3 Electric Power

3-1 Electric Power Management

3-2 Transformer

3-3 Motor Driven Machine-Except Air Compressor

3-4 Operation of Motors

3-5 Air Compressor

3-6 House Power Plant

3-7 Air Conditioner

3-8 Lighting Fittings

3-1 Electric Power Management（電力管理）

1	General	一 般				
	(1) Record of used power for every month	毎月の使用電力量（KWH の記録	done			not done（理由）
	(2) Examination the cause for variance for used power	使用電力量が変化した理由の検討	done			not done
	(3) Stability of voltage and frequency of source	受電電圧、周波数の安定状況	stable			not stable
2	Electric power specific unit (EPSU)	電力原単位				
	(1) Calculation for major product's EPSU monthly	毎月の主要製品の電力原単位の算出	Yes			No
	(2) Preparation table on the right for every process and use	用途別・工程別に右表があるか	Output (A) 生産量(A)	Used power (B) 電力使用量(B)	EPSU (B/A) 原単位(B/A)	ratio of electric power fee per total cost 生産費に占める電力割合費
	(3) Numerical EPSU target	電力原単位の目標値	決めている	determined (value)		決めていない not determined
3	Load Factor	負 荷 率				
	(1) Record of hourly consumption of power	毎時間の消費電力の記録	記録している	done	(max. kWh) (min.)	記録していない not done
	(2) Daily load curve graph	日負荷曲線	グラフ化している	done		していない not done
	(3) Improvement of load curve	日負荷の最大値を抑える対策	行なっている	done		行なってない not done
4	Value of power factor contracted	電力料金算定上の力率				
	(1) Supplier	電力会社				
	(2) Penalty fee	ペナルティ				

Diagnoser	

Date		Factory	

5	Substation	受変電設備		
	(1) Meters at receiving panel and adequancy of indication	受電盤の計器の有無とその指針の良否		

Meter 計 器	Voltage 電 圧	Ampere 電 流	kW 電力	kWh 電力量	Power Factor 力 率	kVr 無効電力	kVrh 無効電力量
Primary 一次側							
Secondary 二次側							
Note 備 考	Good Not good						

	(2) Measurement of transformer load	変圧器の負荷測定	Yes	No
	(3) Transformer exclusively for lighting	電灯用専用変圧器	Yes	No
	(4) Turning off transformer when off load	不要時の変圧器遮断	Yes	No
	(5) Improvement of power factor by static condenser	コンデンサーによる力率改善	Yes	No
	(6) One-line diagram	配線系統図の有無	Have	No
6	Distribution system	配線設備		
	(1) Measurement of main circuit load	主回路別の負荷測定	Yes	No
	(2) Rate of voltage drop of main circuit	主回路別の電圧降下率		
	(3) Balance in three phases	相間のバランス	Voltage __________	, Current __________
7	Motor	電 動 機		
	(1) Measurement of load of motors over 15 kW	15kw以上の電動機の負荷測定	Yes	No
	(2) Periodically lubrication of gear and motor	ギヤや電動機の定期的な給油	Yes	No
	(3) Turning off motor when off load	無負荷時の電動機の停止	Yes	No

8	Motor driven machine	電動機応用設備		
	(1) Flow control of blower and pump	ブロワーやポンプの流量制御	Motor speed control 電動機の速度制御 Control of numbers of operating motor 台数制御 Damper or valve control ダンパー，バルブの開閉 Others その他	
	(2) Checking leakage of compressed air or water	圧縮空気や水のもれのチェック	Yes	No
	(3) Keeping adequate working pressure of compressed air	圧縮機の使用圧力は適正か	Yes	No
	(4) Keeping adequate discharge pressure of pump	ポンプの吐出圧は適正か	Yes	No
9	Lighting fittings	照明設備		
	(1) Cleaning lighting fittings	照明器具の清掃	Yes	No
	(2) Turning off unnecessary light	不要な照明の消灯	Yes	No
10	Electric welder	電気溶接機		
	(1) Static condenser exclusively for welder	専用の力率改善用コンデンサー	Yes	No
	(2) Transformer exclusively for welder	専用の変圧器	Yes	No
	(3) Keeping circuit balance of three phases	電源の各相のバランス	Yes	No
	(4) Cable length from welder to holder	溶接機の手元までの配線長さ	Yes	No
	(5) Primary cutout type voltage reducing device	一次切入式電撃防止器の有無	Yes	No
11	Classification of load 負荷の配分			

Machines 主機のモーター	Air Compressors コンプレッサ	Pumps ポンプ	Heaters ヒーター	Lighting 照明	Air Conditioner 空調	Total 合計
kW	kW	kW	kW	kW	kW	kW
%	%	%	%	%	%	100.0 %

3-2 Transformer for (変圧器)

1	Type of Transformer	型式	☐ Oil Immersed Self Cooling (油入自冷式) ☐ Dry Type (乾式) ☐ Air cooling Forced Oil (送油風冷式) ☐ Others (その他)
2	Number of Phase	相数	☐ 3 Phase (三相) ☐ Single Phase (単相)
3	Connection (Single Phase)	結線方法 (単相Tr)	☐ Δ - 人 ☐ 人 - Δ ☐ Δ - Δ ☐ V - V
4	Rated Output	定格出力	____ kVA, Number of Bank (バンク数) ____
5	Rated Voltage Rated Current	定格電圧 定格電流	Primary ____ V, ____ A Secondary ____ V, ____ A
6	Rated Frequency	定格周波数	____ Hz. | 7 | % Impedance | パーセントインピーダンス | ____ % At ____ kVA Base
8	Maker, Year Made	メーカと製造年	
9	Loss	損失	Iron Loss (鉄損) ____ kW, Copper Loss At Full Load (全負荷銅損) ____ kW,

Measurement Record (1)

Time 時間	Voltage 電圧	Current 電流	Apparent Power 皮相電力	Power 電力	Power Factor 力率	Oil temp. 油温	積算電力計 Watt hour meter			Remarks
							読み Reading	常数 Coefficient	kWh	
	V	A	kVA	kW	%	°C				

Diagnoser	

Date		Factory	

Measurement Record (2)

Branch / Time Measured												
	Volt	Ampere	kW or kWh	Volt	Ampere	kW or kWh	Volt	Ampere	kW or kWh	Volt	Ampere	kW or kWh
a.m. p.m.												

3-3 Motor Driven Machine except Air Compressor ~ Over 15 kW （電動力応用設備コンプレッサを除く～15kW以上）

1	Name of Equipment	設備名	Number of Similar Equipment 同種設備の数 ____
2	Kind of Motor	電動機の種類	☐ D.C.（直流） ☐ Inductor（誘導機）— ☐ Wound Rotor / ☐ Squirrel Cage ☐ Others ____ ☐ A.C.（交流） ☐ Syncronous（同期機）
3	Rating of Motor	電動機の定格	Output（出力）____ kW, Voltage（電圧）____ V, Current（電流）____ A Frequency（周波数）____ Hz, RPM（回転数）____ rpm, Magnetic Pole（極数）____
4	Starting Method	起動方法	☐ Full-Voltage（直入） ☐ Star-delta（人-Δ） ☐ Rotor-resistance（二次抵抗） ☐ Others ____
5	Coupling Apparatus	伝導装置	☐ Direct（直結） ☐ Belt（ベルト） ☐ Gear（歯車） ☐ Others ____ └ Material（材質） ☐ Natural（自然物）____, Tension（弛度）____ ☐ Synthetic（人工物）____, Number（本数）____
6	Equipment	設備機械	☐ Pump（ポンプ） ☐ Blower（ブロワー） ☐ Others ____
7	Kind of Flow and Density	流体名と密度	☐ Air（空気） ☐ Water（水） ☐ Others, ____ ☐ Density (or Specific Gravity)（密度又は比重）____ kg/m^3 (lb/m^3)
8	Flow Control	流量制御	☐ Automatic（自動） ☐ Manual（手動） { ☐ Valve（バルブ） ☐ Damper（ダンパー） ☐ Speed Control（速度制御） ☐ Others ____ }
9	Speed Control	速度制御	☐ Motor（モーター） { ☐ Pole Change（極数） ☐ Frequency（周波数） ☐ Voltage（電圧） ☐ Others ____ } ☐ Mechanical（機械式）
10	Automatic Cutting-off (When Off-Load)	空転時の自動停止装置	☐ Yes（有） ☐ No（無）
11	Frequency of Lubrication	給油頻度	____ times/year（回／年） | 12 | Frequency of filter cleaning | 取入フィルター清掃 | ____ times/Month

Diagnoser		Date		Factory	

Motor driven machine （電動機応用設備）

Name of machine ______________

Date	Used power 使用電力				Used power /rated power x 100% 使用電力/定格電力	Temp. of fluid °C 流体温度	Flow Q m^3/min 流量 Q' t/h		Fluid 液体		Valve Position バルブ開度 管径cm	Velocity of fluid m/s 流速	Estimated Load kW 推定負荷	Efficiency % 総合効率	Remarks (Sound Vibration Leakage Others) 備考
	Voltage V 電圧	Current A 電流	Power factor % 力率	Electric power kW 電力			Rated 機器の定格	Actual 測定値 max. min.	Pressure H'kg/cm^2 Hm 圧力	Pipe Inner Diameter					

1) Required electric power of blower 送風機所要電力

$$P = \frac{A \cdot Q \cdot PT}{1{,}000 \cdot \eta \cdot 6.12} \text{ (kW)}$$

PT: Total pressure (mmAq) 全圧, A: Allowance (1.1-1.3) 余裕率, η: efficiency of blower (0.72-0.78%) 送風機効率

2) Required electric power of pump

$$P = \frac{A \cdot \gamma \cdot Q \cdot H}{\eta \cdot 6.12} \text{ or } P = \frac{Q' \cdot H'}{\gamma \cdot \eta \cdot 36.7} \text{ (kW)}$$

A: allowance (1.05~1.2) 余裕率, η: efficiency of pump ポンプ効率 (0.8~0.85%)

3) Velocity of fluid 配管内流速

$$U = \frac{Q}{A} \text{ (m/sec)}$$

Q: flow (m^3/sec) 流量

A: sectional area of pipe (m^2) 管内断面積

Adequate velocity

	velocity (m/sec)	pressure (Kg/cm^2)
City water 水道水	0.6 ~ 1.5	1.8 ~ 3.0
River water 一般水	1.5 ~ 3.0	3.0 ~ 10
Air 空気	8 ~ 15	1 ~ 2

3-4 Operation of Motors

Process 工程	Used for 用途	Maker メーカー	Year built 製造年	Output 容量		Voltage 電圧		Current			Revolu-tions 回転数	Speed control 速度制御	Power factor 力率	Note 備考
				Rated	Actual	Rated	Actual	Rated 定格 Ⓐ	Actual 実測 Ⓑ	Ⓑ/Ⓐ				
				kW HP	kW HP	V	V	A	A	%	r.p.m.		%	

Diagnoser	

Date		Factory	

3-5 Air Compressor （エアコンプレッサー）

Process 工程	Use for 用途	Pressure 圧力	Volume 圧縮量	Input 入力	Type 型式		No. 台数	Installation 設置方式		On-off Operation 台数制御		Cooling Water Temp. 冷却水温度		Air leakage 漏気				
					Oil	Oil-less		Centra-lized	Sepa-rated	Yes 有	No 無	Inlet 入口	Outpet 出口	Ratio 率	Body 本体	Pipe パイプ	Valve バルブ	Joint 接手
					reci-pro. screw	reci-pro. screw												

Diagnoser	

Date		Factory	

3-6 House Power Plant （自家用発電設備）

1	Kind of Engine	エンジンの種類	☐ Diesel Engine ☐ Gas Turbine	☐ Steam Turbine ☐ Condensing turbine ☐ Back Pressure Turbine ☐ Extraction and Back Pressure Turbine			
2	Output of Engine	エンジン出力	______ PS(kW)	3	Fuel Consumption	燃料消費量	______ ℓ(Kg)/h
4	Kind of Fuel	燃料種別	☐ Coal ☐ Heavy Oil ☐ Diesel Oil ☐ Others				
5	Caloric Value of Fuel	同上の発熱量	______ Kcal/ℓ(Kg)				
6	Rated Output of Generator	発電機の定格出力	______ kVA(kW)	7	Rated Power Factor	定格力率	______ %
8	Rated Voltage, Rated Current	定格電圧 定格電流	______ V ______ A				
9	Daily Record	運転日誌	☐ Yes（有） ☐ No（無）				

Measurement Record （測定記録）

Time 時間	Generated Energy 発電量	Fuel Consumption 燃料消費量	Steam Temp. 蒸気温度	Steam Pressure 蒸気圧力	Voltage 電圧	Current 電流	Power Factor 力率	Remarks 備考
	kWh	Kg	In. °C Out	In kg/ Out	V	A	%	

Diagnoser	

Date		Factory	

3-7 Air Conditioner（空調設備）

1	Type of System	空調方式	☐ Air Duct Conditioning（集中方式） ☐ Fan Coil Unit（ファンコイル方式） ☐ Unit Air Conditioning（パッケージ方式）
2	Room Air Conditioned (1) Room Size	室の状況 室の大きさ	Floor Space（床面積）____ m^2, Room Volume（室容積）____ m^3
	(2) Number of person in the Room	室内人数	____ 人
	(3) Usage	用途	☐ Office（事務室） ☐ Works（工場） ☐ Others
	(4) Room Temp.	室温	Actual Temp.（実測温度）____ °C Set Temp.（設定温度）____ °C Measurement Method（測温方式） ☐ Manual ☐ Automatic Control Method（制御方式） ☐ Manual ☐ Automatic
	(5) Humidity	湿度	Actual（実測湿度）____ （設定湿度）____ Measurement Method（測定方式） ☐ Manual ☐ Automatic Control Method（制御方式） ☐ Manual ☐ Automatic
	(6) Air Flow	風量	Fresh Air Flow Induced（外気取入風量）____ m^3/min, Circulating Air Flow（室内循環風量）____ m^3/min.
3	Water Cooling Tower	クーリングタワー	Actual Temp.（実測温度）____ °C, Wet Bulb Temp.（湿球温度）____ °C, Flow（水量）____ ℓ/min., Delivery Press.（吐出圧）____ kg/cm^2G
4	Type of Refrigerating Machine	冷凍機の種類	☐ Compression Type（圧縮式） ☐ Absorption Type（吸収式）
5	Refrigerant	冷媒	☐ Ammonia（アンモニア） ☐ Freon（フロン） ☐ High Pressure（高圧） ☐ Low Pressure（低圧）

Diagnoser	

Date		Factory	

6	Cleanness of Air (1) Method for removement of flying cotton	清浄度 風綿除去方式	☐ Nozzle absorbing (ノズル吸込) ☐ Traveling absorber (巡回吸込) ☐ Floor duct (床面吸込) ☐ Air conditioner (空調機) ┬ ☐ Wiper (ワイパー式) └ ☐ Blowoff (ブローオフ式)	
	(2) Method for electrostatic shielding	静電防止方式	Humidifier (給湿機)	Electric (電気方式)
7	Insulation of roof and wall	屋根，壁の断熱	good	not good
8	Insulation of duct and pipe	ダクト，配管の断熱	good	not good
9	Tightness of window and door	窓，ドアの気密	good	not good
10	Separation heat generating equipment	発熱機器の分離	yes	no
11	Partial air conditioning in large room	大空間の中の空調を要する部分の隔離	yes	no
12	Heat recovery by total enthalpy heat exchanger	全熱交換器による熱回収	yes (Type)	no
13	Water spray on roof	屋根散水	done	not done
14	Starting and stopping time of air conditioner	装置の起動停止時刻	Starting time ______ Stopping time ______	
15	Stopping water pump when refrigerating machine stops	冷凍機停止時に冷却水ポンプの停止	stop (auto, manual)	not stop
16	Prevention over cooling and stopping when unnecessary	過冷防止，不要時の運転停止	yes	no

17	Setting most suitable temperature by climate	季節による設定温度の変更	yes	no
18	Control of induced fresh air	必要外気量の管理	yes	no
19	Checking temperatures of evaporation, condensation and pressure of refrigerating machine	冷凍機の蒸発温度，凝縮温度の管理，制御圧の管理	yes	no
20	Cleaning (Condenser)	清掃（冷凍用コンデンサー）	done (times/month)	not done
21	Cleaning (Air Conditioner Coil)	清掃（空調用コイル）	done (times/month)	not done
22	Cleaning (Air Filter)	清掃（エアフィルター）	done (times/month)	not done
23	Cleaning (Cooling Tower)	清掃（クーリングタワー）	done (times/year)	not done

Air Conditioner Measurement Record No.1 （空調測定記録 その1.）

	Inlet Fan	Circulating Fan	Cooling Tower		Refrigerating Machine（冷凍機）	
			Pump	Fan	Compression Type	Absorption Type
	（外気取入ファン）	（室内循環用ファン）	（ポンプ）	（ファン）	（圧縮式）	（吸収式）
Rated（定格）	kW	kW	kW	kW	kW	Kcal/h
Actual（実測）	kW	kW	kW	kW	kW	Kcal/h

Air Conditioner Measurement Record No.2 (空調測定記録 その2.)

Place (場所)										
Temperature 温 度	Set 設 定		°C							
	Actual 実 測		°C							
Humidity 湿 度	Set 設 定		%							
	Actual 実 測		%							
Cleanness of Air 清浄度										
Insulation 断 熱	Ceiling 天井	Material 材 質								
		Thickness 厚 み								
	Wall 壁	M. 材 質								
		T. 厚 み								
	Floor 床	M. 材 質								
		T. 厚 み								
	Window 窓	Double glass 二重ガラス								
		Heat-absorbing glass 熱線吸収ガラス								
		Blinds ブラインド								
Tightness of Room 密閉状況										
Heat source 熱負荷	Persons 人		人							
	Motor モーター		台							
	Lighting 照 明		kW							
	Steam or Fuel スチーム									
	Heater 電 熱		kW							

3-8 Lighting Fittings （照明設備）

1	Lighting System	工場照明方式	☐ General（全般照明） ☐ General and Local（全般照明と局部照明）
2	Method of Turning On and Off	点滅方法	☐ Automatic（自動点滅） ☐ Manual（手動点滅） ☐ Both Automatic and Manual
3	Circuit Separation (In case of General Lighting)	全般照明の場合の回路方式	☐ One Switch per Room（1ルーム、1スイッチ） ☐ Several Switches per Room（1ルーム 複数スイッチ） ☐ One Switch per Line (Turn, Line by Line from Window side)（ライン毎に点滅）
4	Kind of Lamp and Number	ランプの種類と取付数	☐ Incandescent Lamp（白熱灯） ☐ Fluorescent Lamp (daylight color) 昼光色蛍光灯 ☐ Fluorescent Lamp (White)（白熱蛍光灯） ☐ Fluorescent Mercury Lamp（蛍光水銀灯） ☐ Energy Conservation Type F.L.（省エネ型蛍光灯） ☐ Good-color High Pressure Sodium Lamp（高演色型高圧ナトリムウ灯） ☐ Others Number of Lamps（取付数）________
5	Cleaning Frequency of Lighting Fittings	照明器具の清掃頻度	________ Times/Year（回/年）
6	Utilization of Daylight	昼光利用	☐ Glass ガラス ☐ Vinyl chloride 塩化ビニール ☐ Polystyrene スチロール ☐ Acryl resin アクリライト ☐ Polycarbonate ポリカーボネート ☐ Others その他

Measurement Record（測定記録）　　Time at AM/PM ________（測定時刻）

Place（場所）									
Illuminance（照度）									
Distribution of Illuminance（照度分布）									
Kind of Lamp（ランプの種類）									
Wall Color（壁の色）									

Power Consumption for Lighting（照明用消費電力）　Day Time（昼間）　kWh/h　from daily record 日誌から
Night（夜間）　kWh/h

Diagnoser	

Date		Factory	

List of Information Material Collected

1. Energy Production and Consumption Restructing Program
2. Electrical Rate (MEA. PEA)
3. Price list of oil product

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