Report No. 13: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thai Special Wire Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Thai Special Wire Co., Ltd. —

I. Outline of the Factory

Address	39 Paholyothin Km. 39, Tambol Klong Nuéng, Amphur Kland Luang, Patumthani	
Capital	40 million Bt	
Type of industry	Metal	
Major products	PC wire, PC strand	
Annual product	12,000 t	
No. of employees	160	
Annual energy consumption	Electric Power	4,419,400 kWh/y
	Fuel	Industrial Diesel Oil 819,586 kℓ LPG 20,395 t
Interviewees	Administrative Manager, Jirote Sirimangkala Asst. Chief of Production, Pichet Pracharat Mr. Uthai, Mr. Chalard	
Date of diagnosis Diagnosers	an. 17 ~ 18, 1983 T. Nakagawa, T. Noda, K. Kurita	

This company was established in 1974 as a joint venture with Sumitomo Shoji, Ltd. and Suzuki Metal Industry Co., Ltd. of Japan.

Currently, two Japanese vice-presidents are always stationed at the company.

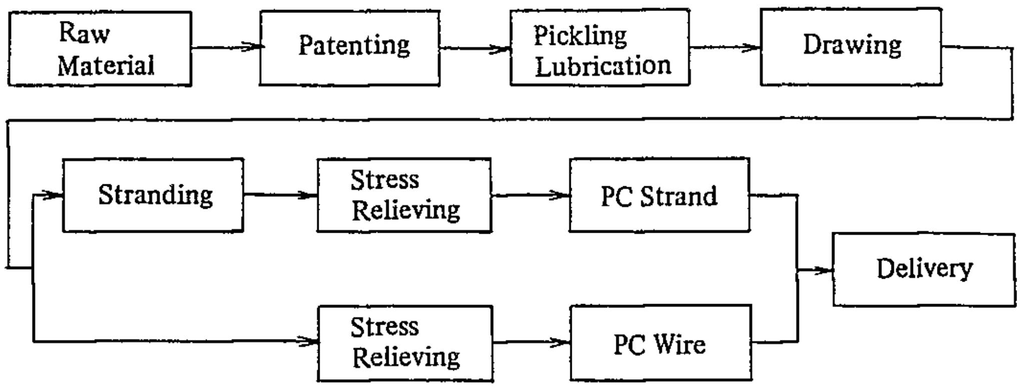
During its initial operation, it only produced PC-wire, but since then has diversified to PC-strand after increasing the facilities. It is the only factory that produces PC-strand and only one other company in Thailand, SISCO (Siam Iron & Steel Co., Ltd.), produces PC-wire.

Its production capacity is 21,600 t/year, but the factory is currently operating at 60% of capacity and produces 12,000 t/year. About 30% of the product is PC-strand. A two-shift system is used with operation of 16 hours per day and 300 days of operation per year. However, only the patenting furnace is required to continue operation over a 24-hour period. Drawing machine No. 1 was stopped.

There are 160 employees, including office clerks. They have many engineers such as five heat management engineers and five electricity management engineers.

The factory has an excellent layout and is well maintained.

2. Manufacturing Process

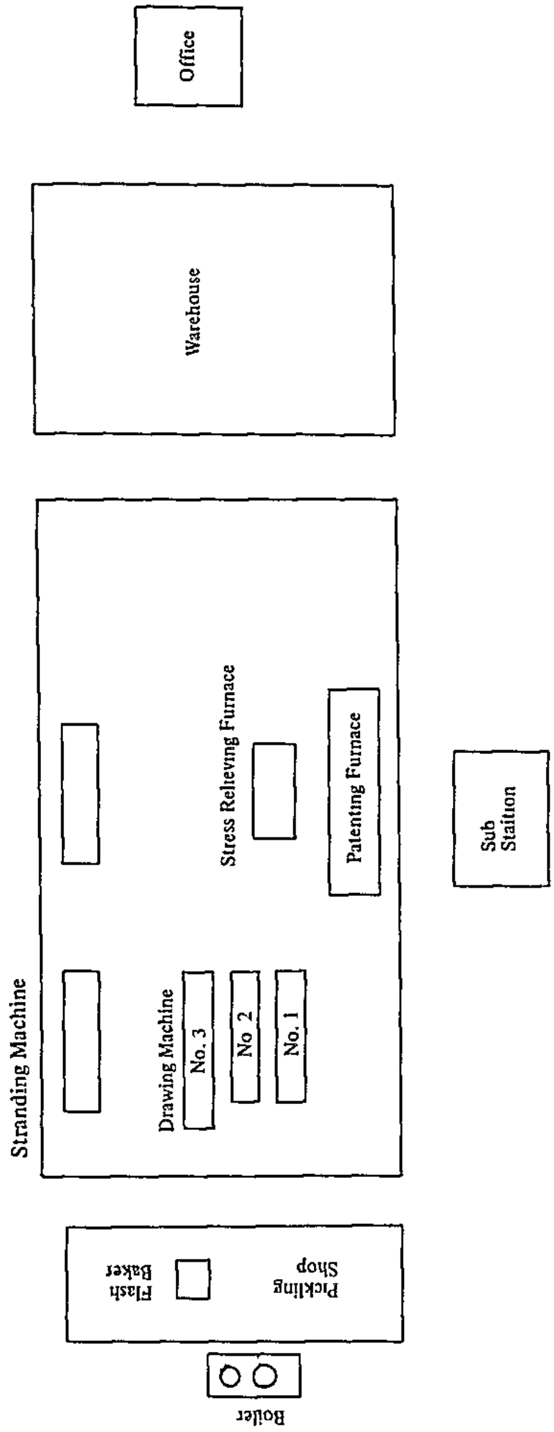


3. Major Equipment

3.1. Major Equipment

Name	No. of units installed	Type, etc.
Patenting furnace	1	Continuous 4 zone type with lead bath
Flash baker	1	Hot air circulation type for drying after pickling
Drawing machine	3	45 kW x 7 sets, 55 kW x 1 set 37 kW x 7 sets 55 kW x 7 sets, 55 kW x 1 set
Strand machine	1	75 kW
Hot air furnace	1	Continuous type
Lead bath	1	For PC wire stress relieving
Boiler	2	Evaporating volume 350 kg/h, once-through type
Pickling bath	1	

3.2. Layout


Office
Warehouse
Stress Relieving Furnace
Patenting Furnace
Sub Station
Stranding Machine
Drawing Machine
No. 3
No 2
No. 1
Flash Baker
Pickling Shop
Boiler

4. State of Energy Management

4.1. Investment in Energy Conservation and Cases of Improvement

The factory has just begun to deal with energy conservation and has not yet set a concrete target or made investments in energy conservation.

There is no plan for investment this year but employees are being instructed to efficiently operate the equipment. They want to recover investments within two years.

4.2. Grasp of Energy Consumption

A flowmeter to measure fuel consumption is provided.

A watt-hour meter is installed at each process.

Data is recorded daily for each process and shift, and electric power consumption rate is calculated, based on them.

In addition, a control chart ($\bar{x}$) and variation analysis are made and the data are very well controlled.

However, there was a spider's web in a panel in the receiving and transformer room and the indication of the power factor on an incoming panel was incorrect.

Production might be stopped and production efficiency be reduced due to unexpected accidents caused by improper maintenance of panels adversely effecting energy conservation.

Therefore, it is necessary that not only matters directly related to energy conservation, but also fundamental matters concerning overall factory control are promoted correctly. Thereby, Such a desirable tendency as to take action immediately.

4.3. Energy Conservation Committee and Suggestion System

A Cost Reduction Committee to promote energy conservation was started four months ago. The leader of this committee is the chief of manufacturing section. This committee is a multi-purpose organization to handle matters not only energy conservation. It consists of five members and meetings are held twice a month.

There has been no contract with consultants up to, now. There is neither suggestion system involving employees nor an award system.

QC circle activities started in 1981 with the assistance of the company. The company encourages employees to save energy through these activities.

These activities is refering to those in other industries.

4.4. Employee Training

The factory dispatched employees to training courses three times last year. In addition, employees were sent to Japan on factory observation-study tours.

Training is also conducted for new employees in a classroom for one week. They then receive on-the-job training for another week, and are finally employed after a probation period of four months.

4.5. Other

Totally, this factory has an enhanced sense of energy conservation and is well managed, as can be seen from the fact that an attendant always checks the quantity and quality of oil at its reception.

It was told that energy conservation will be promoted hereafter and the results can be expected.

It is very favorable in terms of quality control that a safety path is clearly indicated in the factory and that arrangement and maintenance are carried out properly.

5. State of Fuel Consumption

5.1. Actual Consumption of Fuel

Actual consumption and a breakdown for each process in FY1982 are as follows:

Light oil : 819.6 kl/year — Patenting 59%
— Pickling 20%
— Stress relief 21%

LPG : 20.4 t/year — for pilot burner of stress relief furnace

5.2. Rate of Fuel Consumption for Each Process

(1) Patenting : 47.8 l/t
(2) Pickling : 17.2 l/t (including boiler)
(3) PC-strand stress relief : Light oil 2.2 l/t + LPG 34.0 kg/t
(4) PC-wire stress relief : 22.0 l/t

5.3. Heat Balance

5.3.1. Simple Heat Balance of Patenting Furnace

(1) Heat Balance Table

Input			Output		
Item	10^3 Kcal/h	%	Item	10^3 Kcal/h	%
(1) Heat of fuel combustion	289.4	100.0	(2) Heat of wire	137.8	47.6
			(3) Heat loss in exhaust gas	81.1	28.0
			(4) Other heat loss	70.5	24.4
Total	289.4	100.0	Total (2)+(3)+(4)	289.4	100.0

Note: For one ton of wire heating weight at surrounding temperature 35°C

(2) Data Given for Calculation the Heat Balance

Amount of light oil	: 87 l/h
Specific gravity of light oil	: 0.82
Heat content of light oil (low level)	: Hl = 10,300 kcal/kg
Theoretical amount of air	: $Ao = \frac{0.85\ Hl}{1,000} + 2.0 = 10.76\ Nm^3/kg$
Theoretical amount of exhaust gas	: $Go = \frac{1.11\ Hl}{1,000} = 11.43\ Nm^3/kg$
Weight of Heated Wire	: 2,539 kg/h

(Note) Wire diameter: 8mmϕ, wire speed: 6m/min, and number of wire paths: 18.

Fuel consumption rate:

Amount of light oil (87 l/h) x specific gravity (0.82) ÷ weight of wire (2,539 kg/h) = 28.1 kg/t

Extraction temperature and heat content of wire:

850°C and 141.9 kcal/kg

Charging temperature and heat content of wire:

35°C and 4.1 kcal/kg

Temperature of exhaust gas:

Charging side: 700°C Average: (T_E) 735°C
Extraction side: 770°C

Oxygen content in exhaust gas:

Charging side: 3.4% Average: (O_2): 1.9%
Extraction side: 0.4%

(3) Equations for Calculating the Heat Balance

Input

Heat of fuel combustion

Fuel consumption rate x Hl = 289,430 kcal/t

Output

Sensible heat of extracted steel material

1,000 kg x {heat content of wire at extraction temperature (141.9 kcal/kg) − heat content of wire at atmospheric temperature (4.1 kcal/kg)}

= 137,800 kcal/kg

Sensible heat of exhaust gas

Air ratio

m = 21/{21 − Oxygen content in exhaust gas (1.9)} = 1.10

Wet exhaust gas per kg of fuel: G Nm^3/kg

$G = G_O + A_O(m - 1)$

$= 11.43 + 10.76(1.10 - 1)$

$= 12.5$

Sensible heat of wet exhaust gas

Amount of fuel per ton of wire (28.1 kg/t) x wet exhaust gas per kg of fuel (12.5 Nm^3/kg) x average specific heat of exhaust gas (0.33 kcal/$Nm^{3\circ}C$) x temperature of exhaust gas (735°C − 35°C) = 81,139 kcal/t

Note: An average value of exhaust gas temperatures at the extraction side and charging side, (770 + 700)/2 = 735°C was used.

Other

Total input (289.4 x 10^3 kcal/t) − {Sensible heat of wire (137.8 x 10^3 kcal/t) + heat loss in exhaust gas (81.1 x 10^3 kcal/t)} = 70.5 x 10^3 kcal/t

Reference: Heat loss from furnace walls is estimated as 17.7 x 10^3 kcal/t. However, the surface temperature of each zone is represented by an average value of surface temperature of each side surface.

	Zone 1	Zone 2	Zone 3	Zone 4
Average surface temperature of furnace wall	75°C	83°C	76°C	73°C
Surface area of furnace wall	12.6 m^2	52.1 m^2	38.2 m^2	35.8 m^2

Coefficient of emissivity at furnace wall 0.3

Surrounding temperature 35°C

5.3.2. Stress Relief Furnace for PC-Strand

Since exhaust gas blows out of two stacks and the charging port, and its flow rate are unknown, the heat balance can not be caluclated.

Here, only the effective amount of heat and the efficiency are calculated.

(1) Efficiency

Sensible heat of extracted steel material : 40.6 x 10^3 kcal/t

Heat of fuel combustion : 119.2 x 10^3 kcal/t

Efficiency $= \frac{40.6}{119.2} \times 100 = 34.3\%$

As will be described later, the concentration of oxygen in exhaust gas is high and almost all its loss occurs in exhaust gas.

(2) Specifications for Calculation

Light oil	Quantity	: 3.45 l/h = 2.83 kg/h
	Specific gravity	: 0.82
	Heat content	: 10,300 kcal/kg
LPG	Quantity	: 4.85 kg/h = 1.87 Nm^3/h
	Density	: 2.59 kg/Nm^3
	Heat content	: 29,200 kcal/Nm^3

Strand	Quantity processed	:	702 kg/h
	Unit weight	:	0.406 kg/m
	Speed of processing	:	7.2 m/min
	Number of paths	:	4
	Extraction temperature and heat content	:	380° C and 44.7 kcal/kg
	Charging temperature and heat content	:	35° C and 4.1 kcal/kg

(3) Heat of Fuel Combustion

Quantity of light oil per ton of strand (4.0 kg/t) x heat content of light oil (10,300 kcal/kg) + quantity of LPG per ton of strand (2.67 Nm^3/t) x heat content of LPG (29,200 kcal/Nm^3) = 119,164 kcal/t.

(4) Heat Content of Extracted Strand

1,000 kg x {heat content of strand at extraction temperature (44.7 kcal/kg) − heat content of strand at atmospheric temperature (4.1 kcal/kg)}
= 40,600 kcal/t.

6. Problems in Heat Control and Potential Solutions

6.1. Patenting Furnace

(1) Pattern of Temperature in Furnace

As indicated in the table below, the temperature pattern of this furnace is of quick heating type and more than half of the fuel used is thrown in zone 1.

	Furnace temperature °C	Opening position of burner control valve
Zone 1 (charging side)	940	70
Zone 2	920	25
Zone 3	910	10
Zone 4 (discharging side)	900	15

Although it seems that such pattern is adopted in consideration of quality, heating capacity and floor space within the factory, it is not desirable for energy conservation.

The temperature pattern of a continuous furnace should be changed to one where the temperature of the heating zone becomes higher than that of the preheating zone. The heat of the combustion gas should be effectively utilized by extending the preheating zone.

However, as initially mentioned, since it is closely related to quality, heating capacity, etc., it is recomended that the situation be dealt with adequately after consulting with Suzuki Metal Industries Co., Ltd. which is providing technical instruction.

(2) Stack

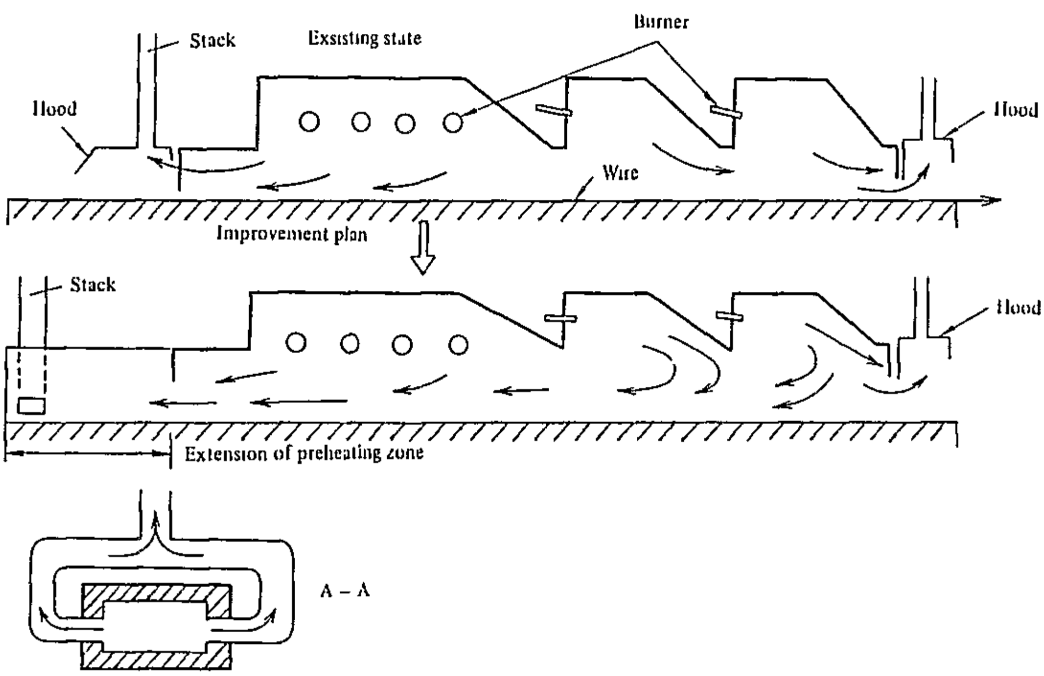
Although there are hoods for treating exhaust gas at the charging end and extraction end, any stack for forcibly treating the exhaust gas is not provided.

Because flow and discharge of gas in a furnace can not be controlled by hoods mounted at both ends, an exhaust outlet directly connected to a stack is necessarily provided at the charging inlet. As shown in the following drawing, an improvement in which most of the combustion gas flows to the charging end should be made.

All or most of the burners in the preheating zone can be eliminated by extending the preheating zone, improving the heat pattern and providing an outlet for exhaust gas at the charging end.

If a saving of 10% is achieved in the amount of fuel burnt in the furnace, the annual saving will become as follows:

$819.6 \times 0.59 \times 0.1 = 48.4$ kl/year



(3) State of Burner Combustion

Since burners in zone 3 and zone 4 are operated near the lowest limit of fuel quantity, control of the air-fuel ratio is extremely poor and exhaust gas including black smoke is forced out of an extraction outlet. In zone 2, balance on the right and left is uneven, making short flame on one side and long flame-on the other side, and adjustment of the burner is poor.

(4) Installation of CO Analyzer and O_2 Analyzer

Although the composition of combustion gas should be controlled well to prevent decarbonization, the presence of CO and soot as a result of the excessive control to reducing atmosphere will cause a waste of fuel. For this control, a CO analyzer should be installed near the nose portion in a boundary of zone 4 and zone 3, and control of the air-fuel ratio within an allowable CO range should be carried out.

In addition, it is recommended that the concentration of O_2 in exhaust gas at the tail portion of the furnace is checked by an O_2 analyzer. And the air-fuel ratio of burners in zones 2 and 3 be controlled so that the concentration of O_2 becomes as small as about 2 – 4% in order to reduce losses of exhaust gas.

(5) Ceramic Fiber Insualtion of Furnace

Since heat loss from the furnace occupies a small portion of the heat output, it is not necessary to insulate furnace with ceramic fiber immediately.

However, when the furnace is repaired, the adoption of a furnace wall with a a ceramic fiber lining should be investigated. Improvement of the insulation reduces heat loss from the furnace but moreover it shortens the time and reduces the amount of fuel oil for heat-up in furnaces that are operated intermittently (16 hours in operation and 8 hours stopped).

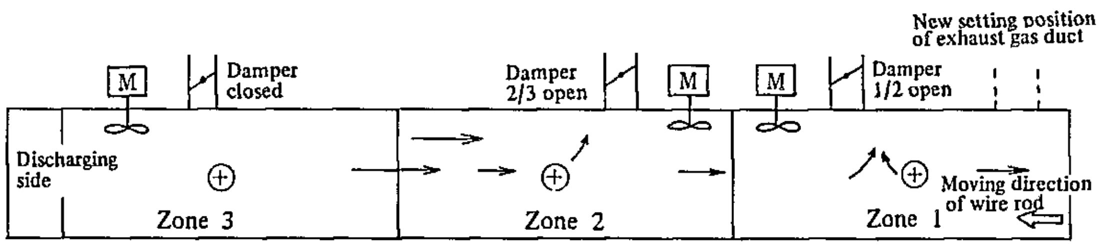
(6) Energy conservation by improvement of the heat transfer coefficient should be investigated by providing a preheating zone in front of zone 1.

(7) An air preheater is considered as a recovery method for heat lost in exhaust gas, but since this requires considerable investment, its feasibility should be discussed after such countermeasures for energy conservation as improvements in heat pattern, combustion and type of furnace have been executed.

6.2. PC-strand Stress Relief Furnace (Hot-air Furnace)

(1) Processing of Exhaust Gas

The position of an exhaust gas port and the opening of its damper are shown in the figure below.



Since opening of the exhaust damper located in zone 2 in the middle of furnace is 2/3 and the exhaust gas generated in zones 3 and 2 is discharged from here, there is a possibility that exhaust gas does not serve to transfer heat in zone 1.

A change should be made in which a damper in the exhaust duct in the intermediate zone is fully closed and combustion gas generated in the furnace is discharged from an exhaust duct in zone 1.

If possible, it may be preferable to change the position of the exhaust duct in zone 1 to the charging end side.

The opening of the damper of the exhaust duct in zone 1 should be adjusted so that a small amount of combustion gas is blown out from an open outlet at the extraction end without sucking of the outside air. (Pressure at the hearth of furnace near the extraction end should be adjusted within a range of 0.1 − 0.2 mmH_2O.)

(2) State of gas ejection and suction of gas at the charging and extraction ends of the furnace.

It was observed that combustion gas blew out from the charging end and that suction of a considerable amount of air occurred at the extraction end.

Since it is considered that the phenomenon of outside air suction from the extraciton port is affected by the fan, the change in this condition by stopping the operation of the fan should be observed.

(3) State of Burner Combusiton

	Condition of combustion	Openning position of burner control valve
Zone 1	Bad	15%
Zone 2	Very bad	10%
Zone 3	Good	50%

Insufficient combustion in zones 2 and 3 may be caused by using the burner in the low flow area.

The flow of combustion gas and temperature distribution in the furnace is improved by stopping the fan in zone 3 and fully closing the gas exhaust duct in zone 2. The quantity of fuel oil of the burner in zone 1 tends to decrease.

The burner in zone 1 is currently in a low flow area and combustion is not acceptable. The situation will become more unfavorable, so it should be discussed whether this burner should be shut off. Heat compensation in zone 1 will be made by a burner in zone 2.

A temperature controller in zone 3 is positioned upstream of the burner as viewed from the flow of combustion gas. It may disrupt control which is subjected to a cooling effect due to suction air.

(4) Content of Oxygen in Combustion Gas

The content of oxygen in combustion gas in the furnace at an intermediate position of each zone is as follows:

Zone 1	17.9%
Zone 2	18.3%
Zone 3	19.1%

The content of oxygen in zone 3 verifies the existence of negative pressure at the extraction end.

6.3. Lead Bath Furnace

(1) State of combustion of burner is poor. In addition, black smoke is ejected from chimney and peeping hole in the front wall.

By adjusting the opening of the damper as well as preventing air from coming in from the cleaning port at the base of the chimney, excessively positive pressure of the combustion chamber should be reduced so that combustion gas cannot be ejected from the peeping hole.

(2) Only half of the lead bath was covered while the remaining portion was exposed.

6.4. Boiler

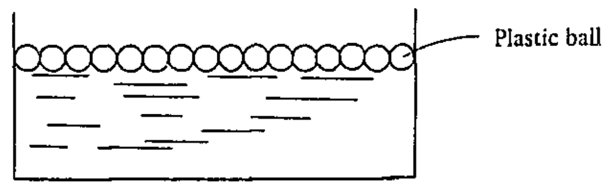
Since a part of the steam pipe is bare, it should be insulated.

Although heat radiated from the steam pipe with a diameter of 50 mm is 180 kcal/m.h, it will be reduced to 40 kcal/m.h by applying 25 mm thick insulation. (1 kg/cm^2g of saturated steam)

6.5. Pickling

The temperature of the bonderizing bath is 70 ~ 80° C and radiated heat form the liquid surface is 3,500 $kcal/m^2h$ (about 5.5 kg/h in terms of steam volume).

Although a cover lined with insulation material can be used to prevent heat radiation, this causes inconvenience for handling the wire coil. So, it is recommended that plastic balls be used.



Assuming the area of the bonderizing bath is 10 m^2 and the insulation effect is 50%, the fuel which can be saved is expressed as follows:

$$\frac{3{,}500\ kcal/m^2h \times 10\ m^2 \times 16\ h/day \times 300\ day/year \times 0.5}{0.8 \times 10{,}300\ kcal/kg \times 0.82 \times 1{,}000} = 12.4\ kl/year$$

7. State of Electric Power Consumption

Three lines in the wire drawing consume most of the power required by this factory. The No. 1 wire drawing line is operated by seven 55 kW DC motors and one 75 kW DC motor. The No. 2 wire drawing line is operated by a 37 kW induction motor and one 500 kgm torque motor. The No. 3 wire drawing line is operated by seven 45 kW induction motors and one 55 kW induction motor.

Although the No. 1 line was not operating on the day of that particular factory visit, it was reported that power factor was degraded when this line was operating.

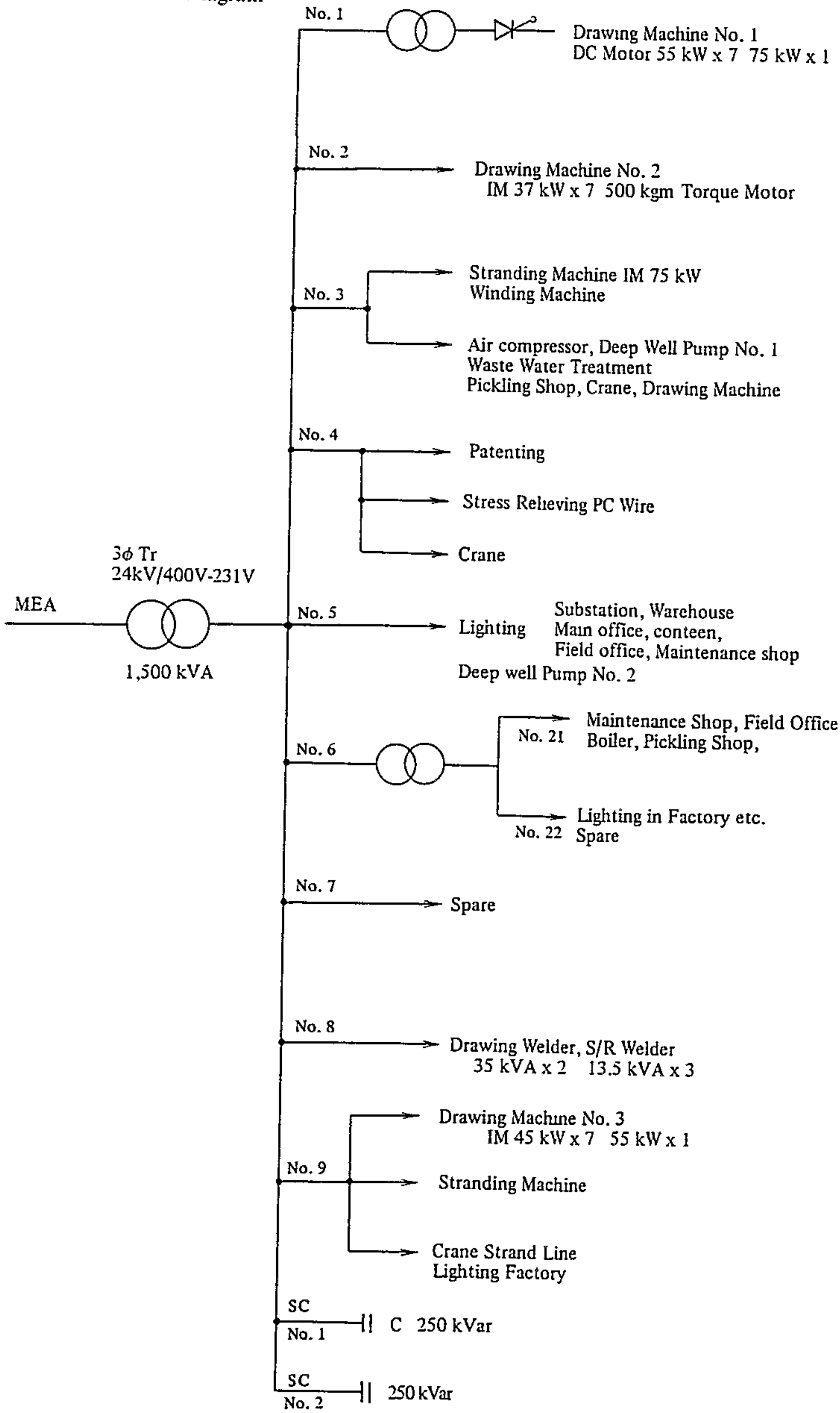
Regarding the electric power supply, service interruptions frequently occur during the rainy season (June to October) and produciton is adversely affected.

About ten service interruptions lasting about 30 minutes occur on average every month.

7.1. The Principal Data Relating to Power Consumption

• Power company	:	MEA
• Peak demand	:	1,300 kW
• Power consumption	:	4,419,400 kWh/year
• Load factor	:	920.7 kW of average electric power with annual operating time of 4,800 hours. Load factor: 70.8%
• Penalty	:	4,000 to 7,000 Bt is paid every month when the No. 1 wire drawing line is operating.
• Power factor	:	66.3 to 73.2% This is 85% when the No. 1 wire drawing line is not operating.
• Transformer	:	1,500 kVA, 24 kV/400-231
• Electricity energy consumption rate	:	Production is 12,000 t/year and total electricity energy consumption rate is 368 kWh/t.

7.2. One line Diagram



8. Problems in electric Power Control and Potential Solutions

8.1. Improvement of Power Factor

Assuming that the penalty when the No. 1 wire drawing line is operating is 4,500 Bt/month minimum and 7,500 Bt/month maximum, the corresponding reactive power is 300 kVar minimum and 500 KVar maximum.

Since the annual average of peak demand for every month is 1,000 kW, the reactive power is as follows:

1,000 x 0.63 + (300 to 500) = 930 to 1,130 kVar

Currently, there are two banks of 250 kVar condensers for improving the power factor, and normally the No. 1 condensers is connected but when the No. 1 wire drawing line is operating, the No. 2 condensers is also connected.

The DC motor is used in the wire drawing line to properly control speed but in this case, since constant torque is required, voltage is controlled by means of the thyristor Leonard system.

Because DC output voltage is proportional to cos α of the control angle, a value of cos α becomes small when speed control is enhanced and a power factor becomes small viewed from the AC side.

Two countermeasures are considered for this purpose.

(1) Addition of a Condensers

Assuming the reactive power is 1,130 kVar when the annual average peak demand is 1,000 kW, the apparent power becomes as follows:

$$\text{Apparent power} = \sqrt{1{,}000^2 + 1{,}130^2} = 1{,}509 \text{ kVA}$$

$$\text{Power factor} = \frac{1{,}000}{1{,}509} = 0.663$$

When two condensers of 250 kVar are inserted, the following improvement can be obtained.

$$\text{Apparent power} = \sqrt{1{,}000^2 + (1{,}130 - 500)^2} = 1{,}182 \text{ kVA}$$

$$\text{Power factor} = \frac{1{,}000}{1{,}182} = 0.846$$

Assuming the average reduciton in penalty fees due to this countermeasure is 5,500 Bt/month, the following savings can be achieved:

5,500 x 12 = 66,000 Bt/year

Copper loss of the transformer is also reduced.

Assuming that the No. 1 wire drawing line operates 15 days per month and copper loss at transformer rating of 1,500 kVA is 18 kW, a reduction in copper loss at 1,000 kW becomes as follows:

$$18 \text{ kW} \times \{(\frac{1{,}509}{1{,}500})^2 - (\frac{1{,}182}{1{,}500})^2\} \times 15 \text{ days} \times 12 \text{ months} \times 16 \text{ hours}$$

= 20,274 kWh/year

It amounts to 29,397 Bt/year.

The required expense is about 200,000 Bt. It can be recovered in two years because of these two merits.

When the No. 1 wire drawing line is stopped, a condensers line must be closed.

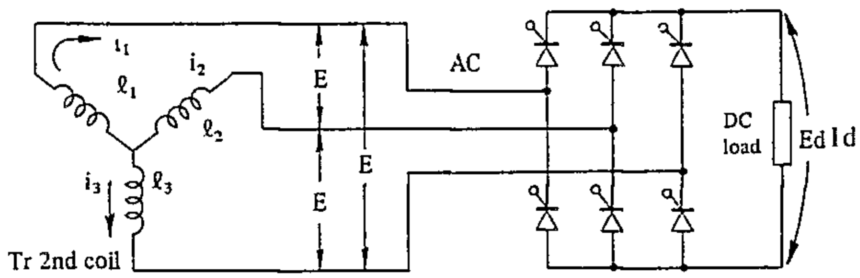
(2) Change of Gear Ratio

Although it did not appear that speed changed during operation, it is recomended that a wheel at the output end is replaced or the gear ratio of the bevel gear is changed if operation is controlled under constant speed for each product.

In this case, the power factor is not worsened. We cannot recommend replacement of the motor because of the large expense.

(Reference) Calculation of reactive power which increases at the time of speed change:

The three-phase bridge circuit is used for almost all circuits where a three-phase AC is converted to DC by a thyristor.



In this circuit, apparent power Pa on the AC side can be expressed as follows:

$$Pa = \frac{1.05\ EdId}{\cos\alpha}$$

Reactive power becomes Pa sin α.

The change when line speed is decreased to half is shown below.

Line speed	motor input EdId	α	Cos α	sin α	Reactive power
60 m/s	75 kW/0.895 + 55 kW/0.88 x 7 units = 521.3 kW	15°	0.966	0.259	146 kVar
30 m/s	37.5 kW/0.865 + 27.5 kW/ 0.85 x 7 units = 269.8	61°	0.485	0.875	510 kVar

Namely, reactive power increases 3.5 times.

8.2. Secondary Resistance Loss of Induction Motor

The external resistance of the induction motor in the No. 3 wire drawing line is left as it is, secondary resistance loss is large.

The No. 3 wire drawing line has seven 45 kW induction motors and one 55 kW induction motor but since there is no motor test table, the specifications are estimated as follows:

Rated output	45kW	55kW
Rated voltage	380V	380V
Rated primary current	86A	105A
Frequency	50Hz	50Hz
Number of poles	4	4
Rated rotation speed	1,440rpm	1,440rpm
No-load loss	1,800W	2,080W
Primary winding resistance	0.0776Ω	0.0828Ω
Secondary winding resistance	0.846Ω	0.883Ω

The external resistance for 45 kW is 3.2 Ω per one phase. The slip when the external resistance is short-circuited is as follows:

$$S_1 = \frac{1,500 - 1,440}{1,500} \times 100 = 4\%$$

Therefore, the slip when the external resistance is connected to 3.2 Ω becomes as follows:

$$\frac{0.846 + 3.2}{S_2} = \frac{0.846}{4} \qquad S_2 = \frac{4 \times 4.046}{0.846} = 19.13\%$$

Rotation speed $N = 1,500\,(1 - 0.1913) = 1,213$ rpm

Secondary input $P_2 =$ (Primary input) − (No-load loss) − (primary copper loss)

$= 47.2 - 1.8 - 3 \times 80.1^2 \times 0.0776 \times 10^{-3} = 43.9$ kW

Secondary loss $P = S_2P_2 = 0.19 \times 43.9 = 8.3$ kW

When similarly calculated, secondary input and secondary loss of the first to fifth motors are as follows:

45 kW motor	Secondary input	Secondary loss
1st	43.9 kW	8.3 kW
2nd	46.5 kW	8.8 kW
3nd	42.9 kW	8.1 kW
4th	43.4 kW	8.2 kW
5th	45.5 kW	8.6 kW
Total		42.0 kW

When the external resistance is short-circuited and the motor is operated at a slip of 4%, output which is proportional to the rotation speed at constant torque becomes as follows:

$$(43.9 - 8.3) \times \frac{1,440}{1,213} = 42.3 \text{ kW}$$

When output is P_o, secondary input $P_2 = \frac{P}{1 - S_1}$ therefore, secondary loss is as follows:

$$S_1P_2 = \frac{S_1P_O}{1 - S} = \frac{0.04 \times 42.3}{1 - 0.04} = 1.76 \text{ kW}$$

When similarly calculated, output and secondary loss of the first to fifth motors when the external resistance is short-circuited are as follows:

45 kW motor	Output	Secondary loss
1st	42.3 kW	1.8 kW
2nd	44.8 kW	1.9 kW
3rd	41.3 kW	1.7 kW
4th	41.8 kW	1.7 kW
5th	43.8 kW	1.8 kW
Total		8.9 kW

Therefore, the increase in loss when the resistance is left as it is becomes as follows:

42.0 kW − 8.9 kW = 33.1 kW

Although the 55 kW motor was not operating when the factory was visited, there would be a secondary loss increase of 7.9 kW, if it was operating.

By considering the time for the adjustment of equipment and preparation of material, the actual operating hours are assumed to be 4,800 x 0.7 = 3,360 h/year.

The increase in annual loss becomes as follows:

(33.1 + 7.9) kW x 3.360 h = 137,760 kWh/year

As an improvement, the number of teeth of the gear on the load side could be increased.

The table below indicates the state of operation of major motors during the visit.

8.3. Lighting

(1) In the area of the patenting furnace and stress relieving furnace, there are flourescent mercury lamps installed at the rate of 5 lamps per span.

Since the inlet side of the patenting furnace and the wire drawing side of the stress relieving furnace are vacant, one span consisting of four fluorescent lamps a span would suffice.

Further all of these lamps are of narrow angle spot luminous intensity distribution curve type, (a mercury-arc lamp usually has a spot type distribution curve), and four lamps per span will suffice if they are replaced with wide-angle type ones as the ceiling is only 7 m high.

Thereby 19 lamps in the 19 spans can be reduced. Since a fluorescent mercury lamp is 400 W, the following energy can be saved:

Usage	Capacity	Rated voltage	Ampere			Rated revolution speed	Power factor	Remarks
			Rated A	Actual B	B / A			
Wire drawing No.2	kW 37	V 380	A 77	A 63 R 68 B	% 81.9	r.p.m. 960	% 84.5	Cage rotor Actual voltage 378V
Wire drawing No.2	37	380	77	59.7 W 60.3 B	77.5	960	84	Cage rotor Actual voltage 377V
Wire drawing No.2	37	380	77	68 6 72 68	89.1	960	86.9	Cage rotor Actual voltage 373V
Wire drawing No 2	37	380	77	55.9 R 59 W 54 B	72.6	960	84.2	Cage rotor Actual voltage 374V
Wire drawing No.2	37	380	77	60.9 R 64 W 60 B	79.1	960	87	Cage rotor Actual voltage 375V
Wire drawing No.2	37	380	77	68 R 72 W 70 B	90.9	960	80.7	Cage rotor Actual voltage 379V
Wire drawing No 2	37	380	77	55.5 R 56 W 54 B	72.1	960	80.7	Cago rotor Actual voltage 378V
Wire drawing No.3	45	380	86	80.1 R 85.8 W 79.1 B	93.1	1,440	90	Wound rotor Actual voltage 378V
Wire drawing No.3	45	380	86	82.9 R 88 W 82.6 B	96.4	1,440	92.4	Wound rotor Actual voltage 376V
Wire drawing No 3	45	380	86	80.2 R	93.3	1,440	89.4	Wound rotor Actual voltage 372V
Wire drawing No.3	45	380	86	76 R	88.4	1,440	93.7	Wound rotor Actual voltage 377V
Wire drawing No.3	45	380	86	82.2 R	95.6	1,440	90.9	Wound rotor Actual voltage 378V
Strand-ing PC Wire	75	380	142	69.6 R 72.7 W 70.8 B	49.9	970	57.3	Wound rotor Actual voltage 377V

$19 \times 400 \times 300$ days $\times 5$ h $\times 10^{-3}$ = 11,400 kWh/year

16,530 Bt/year

(2) Daylight fluorescent lamps are used in places other than the factory and pickling shop but since they are poor in luminous efficiency, improvement can be realized by changing them with energy-saving type white fluorescent lamps.

There are 252 daylight fluorescent lamps of 40 W and assuming that they are used ten hours per day on an average, the electric energy savings becomes as follows:

$5 \times 252 \times 10 \times 300 \times 10^{-3}$ = 3,780 kWh/year

5,481 Bt/year

9. Summary

The abovementioned remedial measures, if actually taken, will bring about energy conservation effects as shown below.

	kl/year	%
Improvement in flue of patenting furnace	48.4	5.9
Cover of bonderizing bath	12.4	1.5
Subtotal	60.8	7.4

	10^3 kWh/year	%
Addition of 500 kVar condenser	20.3	0.5
Replacement of gear in No.3 wire drawing line	137.8	3.6
Change of mercury-arc lamp	11.4	0.3
Replacement with energy-saving type fluorescent lamps	3.8	0.1
Subtotal	173.3	4.4

Report No. 14: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Sinthani Industry Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Sinthani Industry Co., Ltd. —

1. Outline of the Factory

Address	21 Mutee 14 Samrong Tai Prapradang Samutprakarn	
Capital	5 million Bt	
Type of industry	Metal	
Major products	Iron wire, Annealed wire, Galvanized iron wire, Barbed wire, Spring wire, Galvanized spring wire	
Annual Product	13,290 t	
No. of employees	147	
Annual energy consumption	Electric Power	2,399,600 kWh
	Fuel	Heavy Oil 504 kℓ Diesel Oil 84 kℓ
Interviewees	Chairman, Kan Kantanantha; Managing Director, Kovit Kantanantha; Director & Factory Manager, Sumate Kantanantha; Asst. Factory Manager, Santi Trakankool; Deputy Managing Director, Junji Kikuta	
Date of diagnosis	Jan. 24 ~ 25, 1983	
Diagnosers	T. Nakagawa, T. Noda, K. Kurita	

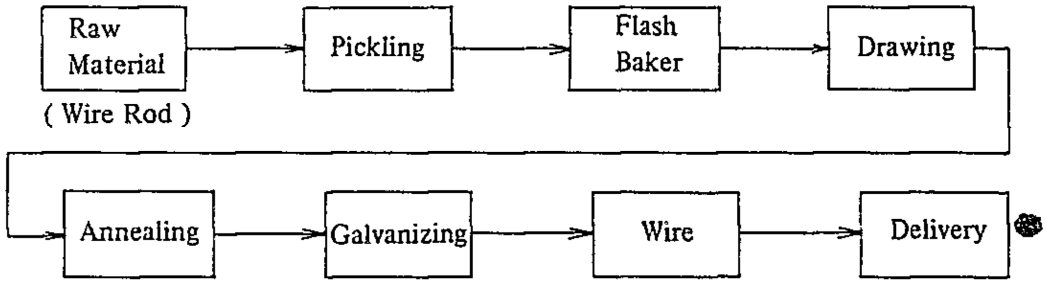
The company started in 1968 as a joint venture company using Thai and Japanese capital. The Sinthani Company of Thailand owns 60% of the total while Mitsui & Co., Kasuga Industries, and Kobe Steel of Japan own the remaining 40%.

Using wire imported from Taiwan, Japan, and other countries, as well as that manufactured in Thailand, as raw materials, the factory manufactures plated wire, barbed wire, spring wire, and other products.

In Thailand's wire industry, there are two large high-carbon manufacturers and six low-carbon wire manufacturers. In an effort to manufacture high-carbon wire in addition to low-carbon wire, the factory is trying to master spring manufacturing technology by inviting advisors from Kobe Steel.

In 1980, the production capacity of the factory was increased to 18,000 t/year, and the factory was operating at about 74% capacity.

2. Manufacturing Process

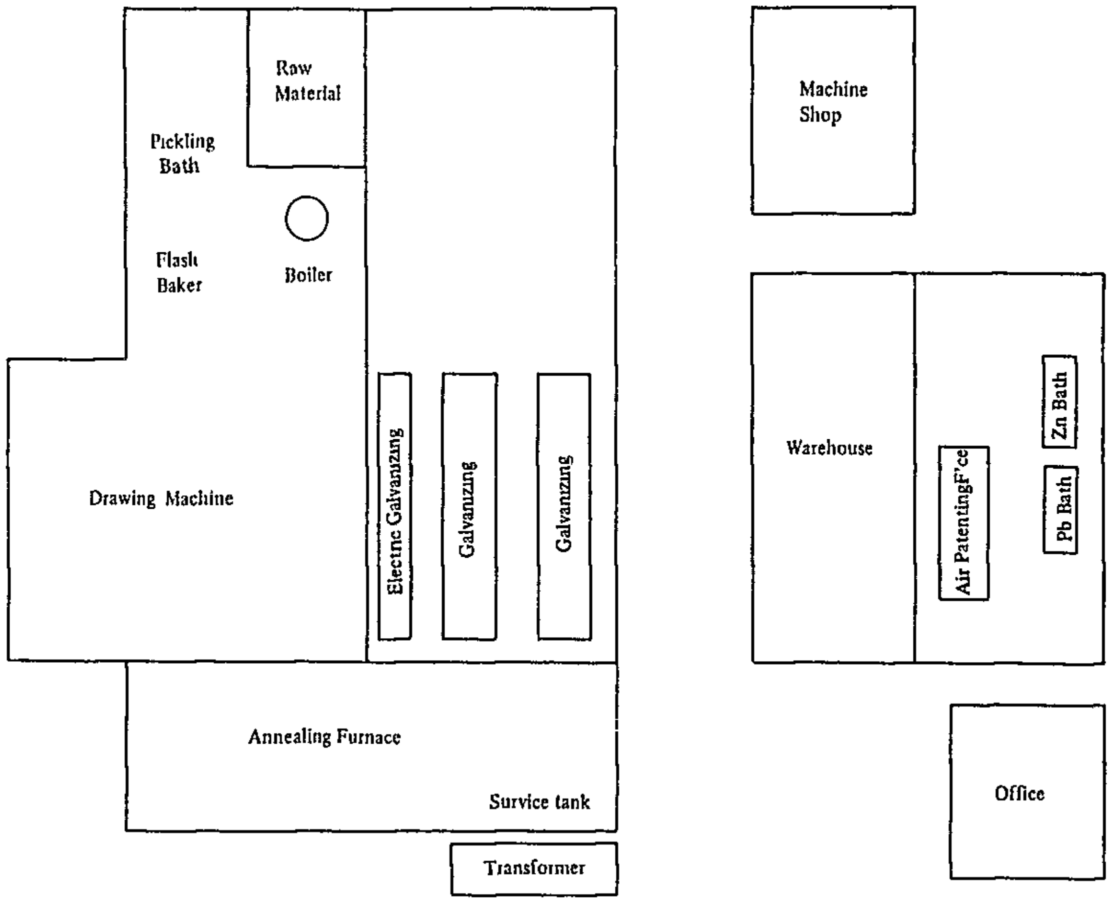


3. Major Equipment

3.1. Major Equipment

Name	No. of units installed	Type, etc.
Pickling bath	1	Direct firing type
Flash baker	1	Hot air circulation type For drying after pickling
Boiler	1	Evaporating volume 250 kg/h
Annealing furnace	8 pits	1,200 kg/Batch
Galvanizing line	3	Hot dip type
	1	Electric galvanizing line
Air patenting furnace	1	Continuous type
Drawing machine	# 1 line	30 kW x 2 sets
	# 2 line	30 kW x 3 sets
	# 4 line	30 kW x 2 sets
	# 5 line	30 kW x 2 sets
	# 6 line	30 kW x 3 sets
	# 7 line	30 kW x 4 sets
	#13 line	15 kW x 2 sets
	#28 line	15 kW x 1 set

3.2. Layout



4. Energy Management

4.1. Investment in Energy Conservation and Cases of Improvement

As part of its efforts to save energy, the factory began to improve its operating methods in 1982.

Its goal for energy conservation is to reduce its fuel oil consumption by 10%. The factory expects to save 30% in two years.

The factory plans to invest 50,000 Bt to install air preheaters for its galvanizing furnaces and another 50,000 Bt to install transformer capacitors. The investment for air preheating is expected to be recovered in 3 years, and that for the capacitors, in 4 years.

In the past, the factory installed air preheating equipment and water heaters to utilize the waste heat of its additionally installed galvanizing furnaces, expressing a strong interest in conserving energy.

4.2. Grasp of Energy Consumption

The factory recorded fuel consumption data every month and calculated fuel consumption rates.

The factory also recorded its power consumption every month. However, hourly power consumption data was not recorded, and the factory could not prepare daily load curves, thus failing to improve its load factor.

Energy consumption and other data is sent to the Japanese shareholders who check the sales and manufacturing of the factory. An analysis of causes for variations in consumption is not made.

4.3. Energy Conservation Committee and Suggestion System

The factory has no special organizations for energy conservation. However, in the middle of last year, QC circles were formed, and seminars are sponsored by the factory about three times a year to discuss how QC activities should be conducted.

The factory has sent employees of the level of group leader or higher to seminars held out of campany (e.g. TPA seminars).

The factory has neither an improvement suggestion system nor a prize-awarding system.

Appeal for energy conservation by the factory superintendent are made through posters and by other means.

4.4. Other

In general, the equipment was installed 15 years ago (e.g. boilers) and consists of old models. Their efficiency no longer matches the requirements of the times.

The furnace now being used as an air patenting furnace was originally intended for an entirely different application and is thus operated at a low efficiency.

5. State of Heat Consumption

5.1. State of Fuel Consumption

The state of fuel consumption, fuel-consuming equipment and the proportion of use are shown in the following.

Fuel oil A 504 kl/year
- Patenting furnaces
- boiler
- Annealing furnaces
- Galvanizing furnace

Diesel oil 84 kl/year
- 95% Flash baking furnace, pickling bath (80 kl/year)
- 5% Forklifts

5.2. Simple Heat Balance of Patenting Furnaces

5.2.1. Heat Balance Table

Input			Output		
Item	10^3 Kcal/h	%	Item	10^3 Kcal/h	%
(1) Heat of fuel combustion	1,076.1	100	(2) Heat of extracted wire	151.7	14.1
			(3) Heat loss in exhaust gas	476.3	44.3
			(4) Heat release from furnace body	262.7	24.4
			(5) Other heat loss	185.4	17.2
Total	1,076.1	100	Total (2)+(3)+(4)+(5)	1,076.1	100

Note: For one ton of wire weight, reference temperature 35°C

5.2.2. Data Given for Calculation of the Heat Balance

Consumption of fuel oil A — 26 l/h

Specific gravity of fuel oil A — 0.86

Low heat content of fuel oil A — 10,200 kcal/kg

Theoretical amount of air $A_o = \frac{0.85\ Hl}{1,000} + 2.0 = 10.67\ Nm^3/kg$

Theoretical amount of wet exhaust gas $G_o = \frac{1.11\ Hl}{1,000} = 11.32\ Nm^3/kg$

Heated wire weight 212 kg/h

NOTES: Wire diameter 2.1 mm

Wire speed 13.08 m/min.

Number of wires 10

Consumption of fuel oil A per ton of wire

(26 l/h x 0.86 kg/l)/0.212 t/h = 105.5 kg/t

Wire extraction temperature and heat content

950°C (Value obtained during interview) 155.8 kcal/kg

Wire charging temperature and heat content

35°C 4.1 kcal/kg

Exhaust gas temperature

Charging side 890°C

Extraction side 935°C

O_2 content in exhaust gas

Charging side 9.2%

Extraction side 2.8%

Specific heat of exhaust gas — 0.33 kcal/Nm^3°C

Surface temperature of furnace

Average temperature 114°C

Surface area of furnace 77.9 m^2

Furnace surface emissivity 0.3

5.2.3. Equation for Calculating the Heat Balance

Input

Heat of Fuel Combustion

Fuel oil consumption per ton of wire (105.5 kg/t) x Heating value of fuel oil (10,200 kcal/kg) = 1,076,100 kcal/t

Output

Sensible Heat of Extracted Wire

1,000 kg x {Heat content at wire extraction temperature (155.8 kcal/kg) — Heat content at room temperature (4.1 kcal/kg)} = 151,700 kcal/t

Sensible Heat of Exhaust Gas

- Air ratio = 21/{21 — O_2 content in exhaust gas (6)} = 1.40

NOTE: Amounts of exhaust emitted from the opening on the charging side and from the extraction side were not available, and the O_2 content in exhaust gases were based on an arithmetic mean value of the two, (9.2 + 2.8)/2 = 6%.

- Wet exhaust gas amount per kg of fuel oil A Theoretical amount of wet exhaust gas (11.32 Nm^3/kg) + {Air ratio (1.40) — 1} x Theoretical amount of air (10.67 Nm^3/kg) = 15.59 Nm^3/kg
- Sensible heat of exhaust gases = Fuel oil consumption per ton of wire (105.5 kg/t) x Wet exhaust gas amount per kg of fuel oil (15.6 Nm^3/kg) x Average specific heat of exhaust gases (0.33 kcal/Nm^3°C) x {Exhaust gas temperature (912°C) — Atmospheric temperature (35°C)} = 476,311 kcal/t

NOTE: Mean value of (890 + 935)/2 = 912°C between exhaust gas temperatures on the charging and extraction sides was used.

Loss of Heat Through Radiation from Furnace Outer Walls

- Heat release per m^2 of furnace surface area

$$\{(\frac{114+273}{100})_4 - (\frac{35+273}{100})^4\} \times 4.88 \times 0.3 + 2.2\sqrt[4]{114-35}$$

$\times (114 - 35) = 715$ kcal/m^2h

- Heat loss through furnace outer walls

{Heat loss per m^2 of furnace surface areas (715 kcal/m^2h x Surface area of furnace (77.9 m^2)} ÷ Heated wire weight (0.212 t/h) = 262,729 kcal/t

Other Heat Loss

Total heat input (1,076,100 kcal/t) — (151,700 kcal/t + 476,311 kcal/t + 262,729 kcal/t) = 185,360 kcal/t

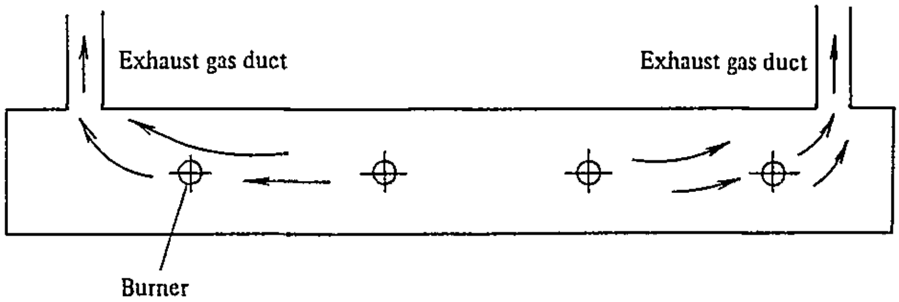
6. Problems in Heat Control and Potential Solutions

6.1. Patenting Furnace

(1) The portion which wire occupies per meter of furnace width is 2.1 mm x 10 pieces = 21 mm, and the proportion is only 2%.

The proportion of the wire projection area on the hearth should be enlarged by increasing the number of wires passed through or by narrowing the width inside the furnace.

(2) The furnace temperature profile throughout the entire furnace length is a high 920 ~ 1,030°C. The furnace is intended to be a high-efficiency, high-speed heating furnace. However, exhaust gas outlets are installed on the charging and extraction sides, and the heat of the combustion gas is not utilized effectively.



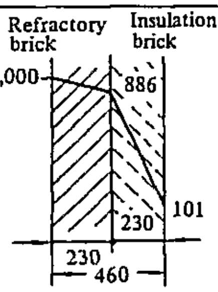
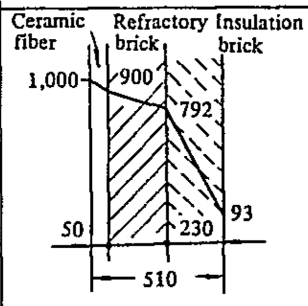
Close the outlets for exhaust gases on the extraction side and use the outlet on the charging side only to increase the heat transmission efficiency of combustion gases to the wire.

The chimney should be exposed to the outside from the side wall at an adequate height in order to obtain sufficient draft and to improve the indoor environment. The burner closest to the charging end is located almost directly in front of the exhaust outlet, and the furnace heat transmission effect is very ambiguous. Whether or not this burner should be used needs be studied. The fundamental problem is that the furnace length is short.

(3) As shown in the heat balance table, heat loss through the furnace wall accounts for approximately 1/4 of the heat input.

The furnace should be insulated to reduce heat loss from the furnace surfaces. It will be difficult to insulate the exterior surfaces because of the frame metals, therefore insulation of the interior surfaces using ceramic fiber is recommended. Ceramic fiber insulation is also effective to reduce the accumulated heat of the furnace and shortened the heating time of furnace itself, thereby saving fuel.

The diagram in the following shows reduced heat loss from the furnace surface when the internal walls are lined with ceramic fiber to 50 mm.

	Existing state	Improvement plan
Composition of furnace wall		
Heat release	572 Kcal/m²h	487 Kcal/m²h
Compared with existing state	100	85
Accumulated heat	144,690 Kcal/m²	132,170 Kcal/m²
Compared with existing state	100	91

Condition for calcuration

1) At steady condition
2) Emissivity 0.3
3) Reference temperature 35°C

Assuming that the upper and side walls of the furnace will be insulated and that the surface area will be 50 m², the following amount of heat can be conserved.

$(572 - 487) \times 50 = 4{,}250$ kcal/h

This results therefore, in the following amount of fuel conserving per year.

$$\frac{4{,}250}{10{,}200 \times 0.86 \times 1{,}000} \times 22.5 \text{ h} \times 300 \text{ d} = 3.3 \text{ kl/year}$$

The cost for the lining of ceramic fiber is approximately 31,000 Bt and can be recovered in approximately two years.

(4) The burner capacity is 16.5 l/h (model PLB-3, pneumatic pressure 800 mmH_2O), and the combustion quantity per burner will be 26 l/h/7 burners ≒ 3.7 l/h burner, which is about 20% of the rated capacity. For this reason the fuel oil atomizing condition has been downgraded. Oil nozzles should be changed to suit the normal flow rate.

(5) The furnace pressure is a high 0.9 ~ 2.0 mmH_2O. For this reason, combustion gases escape from the openings around nearly half of the burners.

Open the chimney damper and adjust the furnace pressure to 0.2 ~ 0.4 mmH_2O. Remodeling of the chimney is desirable. (See Paragraph (2))

(6) The fuel oil pressure of each burner is high 1.5 ~ 2.3 kg/cm^2G. Adjust this level to 0.4 kg/cm^2.

(7) Oil leaks in large quantities from the burners. Retighten the burner pipe joints and replace packings to repair this condition.

(8) The temperature for zones 1 and 2 is set higher than the temperature scale of the furnace temperature indicator.

Change the range to a scale (0 ~ 1,200°C) matching the operating temperature.

6.2. Lead and Zinc Bath Furnaces

Common problems observed with both new and old furnaces are described in the following:

(1) Burner combustion was bad, and combustion gases were flowing back and were escaping from the burner openings.

The damper of the new furnaces should be opened to increase draft and to lower furnace pressure to prevent the escape of combustion gases.

The heat exchanger installed in the flue of the new lead bath furnace to heat scrubbing water after pickling is a good example of waste heat recovery. However, the drafting force is weakened by an increase in ventilation resistance, lowering of the exhaust gas temperature, and other reasons. Full attention is needed to control the furnace pressure.

Adequate flow of ventilation must be secured for the old furnace wihtout a damper by such means as cleaning the flue and repairing leakage. Then, a damper to adjust furnace pressure should be installed.

(2) Heat loss from the lead and zinc bath surfaces is great.

Prevent heat loss by covering the bath surfaces with insulation covers.

The melting point of lead is 327.4° C. Assuming the surface area of the bath to be approximately 2 m^2, heat loss will be as follows.

$$4.88 \times 0.27 \{(\frac{273+327}{100})^4 - (\frac{273+35}{100})^4\} + 2.8\,(327-35)^{1.25}$$

$$= 4{,}969 \text{ kcal/m}^2\text{h}$$

Assuming 70% of heat loss can be avoided by installing insulation covers, fuel conservations in one year can be calculated as follows.

$$\frac{4{,}969 \times 0.7}{10{,}200 \times 1{,}000 \times 0.86} \times 16 \times 300 \times 4 \text{ units} = 7.6 \text{ kl/year}$$

(3) A large quantity of oil leaks from the burners. Repair pipe joints to prevent oil leakage to conserve fuel and prevent danger.

(4) Oil pressures before some burners were high 0.8 and 1.9 kg/cm^2G. The pressure level should be adjusted to the standard 0.4 kg/cm^2G and the burners should be cleaned. High oil pressure before the burner disrupts proper combustion and deteriorates the atomizing condition. Operate at the standard

oil pressure.

(5) Carbon deposits were seen on the burner tiles, and center misalignment of the burners is suspected. Realignment of the burner centers is urgently required.

6.3. Pit Type Annealing Furnace

(1) The pot weight is 500 kg accounting for 40% of the annealing wire weight of 1,200 kg. The required heat can be lowered by reducing the pot weight. The matter of service life is related, so, the shape, material, plate thickness, etc. should be studied to conserve energy.

(2) Oil was leaking from a number of burners.
Repair pipe joints to conserve fuel and avoid danger.

(3) The burner atomizing condition was bad, and oil was dripping on the hearth. Flames were striking the burner tiles. The burners should be adjusted and repaired, and the burner mounts should be corrected to maintian complete combustion.

$$\frac{180 - 40}{0.86 \times 10{,}200 \times 0.8 \times 1{,}000} \times 100 \times 16 \times 300 = 9.6 \text{ kl/year}$$

(4) Oil pressure before the burner is high 1.1 kg/cm^2G. Adjust to the standard level of 0.4 kg/cm^2G.

(5) Insulate the furnace inner walls by lining with ceramic fiber to reduce heat loss and accumulated heat in the walls to shorten the heating time and conserve fuel.

6.4. Boiler

(1) Burner combustion is extremely bad. The nozzles require urgent repair to operate the boiler properly.

(2) The inspection hole above the burner has no door and is open. Put a door prevent inflow of air.

(3) Steam pipes are not at all insulated. The heat loss of a bare 2" pipe and a pipe of the same diameter with 25 mm insulation using saturated steam at a pressure of 1 kg/cm^2G will be as follows.

Bare pipe	180 kcal/mh
Pipe with 25 mm insulation	40 kcal/mh

About 100 m of 2" steam pipes in the factory are bare. By insulating to a thickness of 25 mm, the following energy conservation will be possible.

$$\frac{(180 - 40) \text{ kcal/mh}}{10{,}200 \times 0.86 \times 0.8 \times 1{,}000} \times 100 \text{ m} \times 16 \text{ h} \times 300 \text{ days} = 9.6 \text{ kl/year}$$

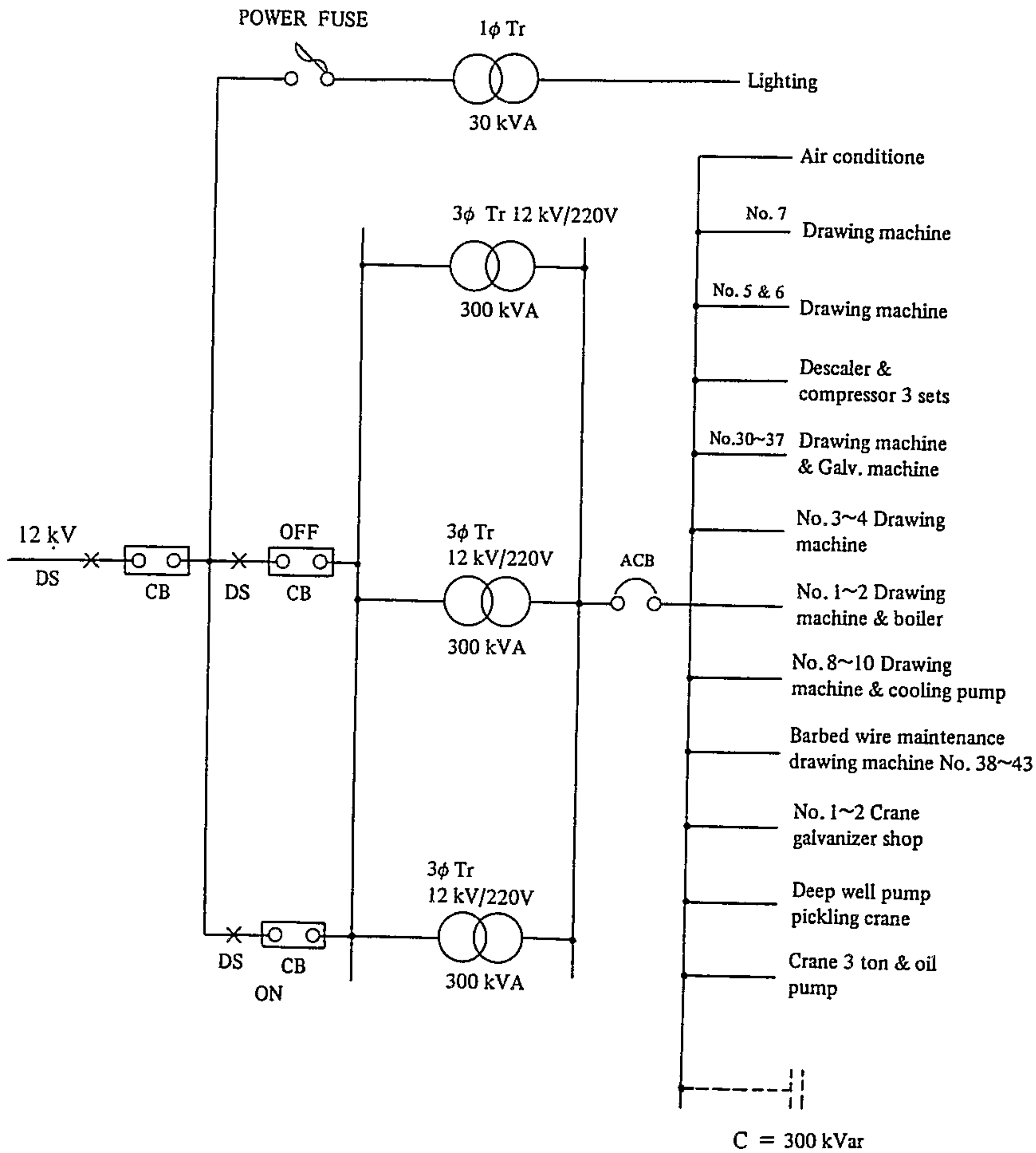
7. State of Electric Power Consumption

Viewing the factory facilities from the standpoint of power consumption, the bulk of the power is consumed by wire drawing motors. The capacities of most of the motors are less than 15 kW. The smaller the motor capacity is, the lower the power factor. Consequently, the power factor of the factory on the whole is low.

7.1. Principal data regarding power consumption is given in the following:

- Power company : MEA
- Peak demand : 720 kW
- Power consumption : 2,399,600 kWh/year
- Load factor : Annual working hours: 6,992 hour
  Average power: 343 kW
  Load factor: 47.6%
- Penalty : Paid monthly
  3,000 to 4,000 Bt/month
- Power factor : 67.9 ~74.5%. No improvement in power factor
- Transformers : 12 kV/220 V, 300 kVA 3 units in parallel
  12 kV/220 V, 30 kVA 1ϕ 1 unit for lighting
- Power consumption rate : 180.6 kWh/t

7.2. One line Diagram



8. Problems in Electric Power Control and Potential Solutions

8.1. Maintenance of Meters

Power is received at 12 kV and is distributed to the factory to operate a transformer for lighting and three 300-kVA motive power transformers in parallel. An open type monitoring panel for 12 kV is contained in an independent substation building with a transformer, switchgear, low voltage open-type switchboard, voltmeters, ammeters, wattmeters, and power factor meters installed to facilitate power control. Nevertheless, the ammeters, wattmeters power factor meters, etc. were not correctly indicating, and it was difficult to determine the utilization states of power from the 12-kV side. The indicators should be adjusted and the current rate of consumption should always be grasped in order to promote energy conservation programs in the future.

The following is the measurement data of an example of incorrect indication of meters mounted on the substation panel.

Because the voltage and current on the 12 kV side were 11,300 V and 30 A, respectively, the apparent power should be 587 kVA. If the power factor is 70%, the level should be 410 kW and can never be 50 kW. The main load is wire drawing motors, and a power factor higher than 90% cannot be expected. All of motors can not necessarily do not have appropriate loads, and the average power factor of the factory will be also approximately 70%. Capacitors to improve the power factor are not installed, and the power factor cannot be 99.5%. These exmaples show that the indications of the wattmeters and power factor meters on the 12-kV side are incorrect.

Time	Volt	Amp.	Apparent power	Power	Power factor	Remarks
1–24 2:50 PM	11,300V 220V	30A 1,100A	 419 kVA	*50 kW	99.5%	← Instrument in 12 kV side ← Instrument in 200V side
1–25 10:7 AM	 215V	 1,550A	Calcurated 577.2 kVA	 410 kW	Calculated 71	We measured ampere and kW by clip on Ammeter.
1–25 11.7 AM	 220V	 1,690A	 644.4 kVA	 480 kW	 74.5	kW and kVar was measured by MEA meter 430 kVar.

8.2. Load Factor

The peak demand is a large 720 kW and the load factor is a low 47.6%. By suppressing the peak demand, the capacities of the equipment, such as receiving transformers, can be lowered and power distribution losses minimized.

The time of day when maximum load occurs can be determined by repairing meters, by logging data every hour, and by preparing daily load curves. An interlocking system should be provided to prevent large loads at the same time and suppress the peak demand to increase the load factor.

The demand can be suppressed by shutting off loads in a predetermined sequence when the demand forecast value exceeds the set value by introducing demand controller. As a result of lowering the peak demand 60 kW by adjusting the wire drawing operation, the conservation will amount to 68,400 Bt/year, with the cost of demand controller recovered in 2.5 years.

$$9.5 \text{ Bt} \times 60 \times 12 = 68{,}400 \text{ Bt/year}$$

8.3. Power Factor

Because the power factor is low, the factory has to pay a penalty every month.

The power factor of the factory was calculated based on available data.

November	Peak demand	680 kW	64,600 Bt
	Penalty	162 kVar	2,430 Bt

Based on this data, the reactive power will be

$0.63 \times 680 + 162 = 590.4$ kVar

The power factor will be:

$$\text{Cos } \varphi = \frac{680}{\sqrt{680^2 + 590^2}} = 0.756$$

August	Peak demand	620 kW	58,900 Bt
	Penalty	279 kVar	4,185 Bt

Based on the above, the reactive power will be:

$0.63 \times 620 + 279 = 670$ kVar

$$\text{Cos } \varphi = \frac{620}{\sqrt{620^2 + 670^2}} = 0.679$$

Then, the power factor is calculated based on the following measurement of the MEA meter between 10:07 and 11:07 a.m. on January 25.

Electric power 480 kWh/h

Reactive power 430 kVarh/h

$$\frac{480}{\sqrt{480^2 + 430^2}} = 0.745$$

An instantaneous value was measured using a clip-on power meter. The voltage was 210 V, current, 1,414 A: and power 410 kW resulting in a power factor of 79.7% thus:

$$\text{Cos } \varphi = \frac{410}{\sqrt{3} \times 210 \times 1{,}414 \times 10^{-3}} = 0.797$$

Connecting a 300 kVar capacitor to the secondary side of the transformer (shown by a dotted line in the one line diagram), the following power factor results even under the August conditions, requiring no penalty to be paid.

Reactive power $= 670 - 300 = 370$ kVar

Peak demand 620 kW

Apparent power $= \sqrt{620^2 + 370^2} = 722$ kVA

$$\text{Cos } \varphi = \frac{620}{722} = 0.859$$

Similarly, under the conditions of October 1982, the power factor can be improved to 92%.

On an annual average, the power is 343 kW and the power factor, 0.718.

Therefore,

$$\text{Average apparent power} = \frac{343}{0.718} = 478 \text{ kVA}$$

$$\text{Mean reactive power} = \sqrt{478^2 - 343^2} = 333 \text{ kVar}$$

Connecting a 300-kVar capacitor, the power factor can be increased to 99.4% and the apparent power to 345 kVA.

$$\text{Apparent power} = \sqrt{343^2 + (333 - 300)^2} = 345 \text{ kVA}$$

$$\text{Cos } \varphi = \frac{343}{345} = 0.994$$

The factory pays an average 3,500 Bt as a monthly penalty. Implementing these improvements. 42,000 Bt can be saved each year. The cost for purchasing a capacitor relay and switchgear is estimated at about 100,000 Bt. and can be recovered in about two years. Adding the conservations gained by reducing power losses of the transformers as described in the next paragraph the period for capital recovery can be further shortened to about 1.5 years.

8.4. Transformers

Three 300-kVA transformers are operated in paralle. The mean apparent power after improving the power factor will be lowered to 345 kVA and the number of transformers can be reduced.

Excessively large transformers have had to be used for the following two reasons:

(1) Apparent power is large because the power factor is low.

(2) Peak demand is large, reaching an approximate maximum of 900 kVA.

The following is a study of the transformer load calculated when the load factor is increased 20% by demand control by suppressing the maximum power to 500 kW and by increasing the power factor to 99.4% after a 300-kVar capacitor is installed.

Assuming that the power factor for 500-kW power before improvement was 68%.

$$\text{Reactive power} = 500 \times \frac{\sqrt{1 - 0.68^2}}{0.68} = 539 \text{ kVar}$$

Inserting a 300-kVar condenser the reactive power lowers to 239 kVar and the apparent power to 554 kVA.

$$\text{Apparent power} = \sqrt{500^2 + 239^2} = 554 \text{ kVA}$$

Therefore, by suppressing the peak demand to about 500 kW and by inserting a 300-kVar condenser one transformer can be disconnected.

Power losses of the transformers can be reduced as shown in the following by disconnecting one transformer and by improving the power factor.

Lighter no-load losses

1.8 kW x 6,992 h = 12,586 kWh/year

Lighter copper losses

Current copper losses $3.2\ kW \times \left(\frac{\frac{478}{3}}{300}\right)^2 \times 3 = 2.71\ kW$

Copper losses after improvement $3.2\ kW \times \left(\frac{\frac{345}{2}}{300}\right)^2 \times 2 = 2.12\ kW$

Lighter copper losses $(2.71 - 2.12)kW \times 6{,}992\ h = 4{,}125\ kWh/year$

Total loss reduction

$12{,}586 + 4{,}125 = 16{,}711\ kWh/year$

Conservations by loss reduction will amount to 24,400 Bt/year.

It is commendable that a special transformer for lighting is installed from the standpoint of energy conservation. On holidays when no motive power is required, only the transformer for lighting should be used. By releasing the primary sides of the main transformers, their no-load losses can be reduced.

8.5. Motor

The operating conditions of motors are shown in the attached sheet. The following motors have light loads: one 30-kW motor for the No. 1 drawing machine one 30-kW motor for the No. 7 drawing machine, one 15-kW motor for the No. 13 drawing machine one 15-kW motor for the No. 28 drawing machine, two 15-kW motors for the galvanizing line among others. The load trends of these motors should be continually studied in the future. When the same trends continue, 30-kW motors should be replaced with 22-kW motors, and 15-kW motors with 7.5-kW motors. This measurements are made by measuring instantaneous values. When watching future trends data should be recorded at least on hourly basis. Accurate records of measurements can be obtained by measuring a recording wattmeter and recording ammeter. This data is for input and it should be noted that a further margin is for output.

The power factor abruptly decreases when a motor load lowers below 50% of the rate output and motors should be selected so that their load factors are higher than 80%. Nevertheless, purchases of new motors are not economical and replacement should be made utilizing existing motors.

Variations in the voltage applied to motors are large and should be matched to the rated voltage as much as possible. No-load losses will increase because of overexcitation when the voltage is too high. Load losses will increase by an increase in current when voltage is too low. When purchasing motors those with the same rated voltage should be purchased.

Imbalances in current could be observed. This situation causes braking resulting in increased motor losses and overheating. Current imbalances are caused by voltage imbalances. The factory has no large imbalanced loads, and this can be attributed to the power supply side. Adjustments may be made by connecting a single-phase load such as lighting to a high-voltage line.

	Process	Used for	manufacture	Year built	Output	No.	Voltage	Current			Revolutions	Speed control	Power factor	Note
								Rated (A)	Actual (B)	(B)/(A)				
					kW		V	A	A	%	r p m		%	
In	No 1	Drawing machine	Hitachi	1969	M1 30	1	220 (R) 216 (A)	100	R 68 S 67 5 T 69 9	68 5	960 (6P) Rated	No	76 1	19 36 kW (Actual cage rotor)
	"	"	"	"	M2 30	1	220 (R) 216 (A)	100	R 49 S 51 3 T 52.5	50 9	960 (6P) Rated	No	61 5	11 8 kW(A)
Out	"	"	"	"	M3 7 5	1	220 (R) 216 (A)	26	11 6 11 7 12.03	45 3	1,450 (4P) Rated	"	73.1	3 2 kW (A)
	No 2	"	"	"	M2 30	1	220 (R) 209 (A)	100	R 97 5 S 108 2 T 101.1	102.3	960 (6P)	"	85.3	31 2 kW (A)
	"	"	"	"	M3 30	1	220 (R) 208 (A)	100	R 92 8 S 95 T 93 6	93 8	"	"	87 5	29 5 kW (A)
	"	"	"	"	M4 30	1	220 (R) 210 (A)	100	R 73 7 S 79 7 T 70.6	74 7	"	"	79 8	21 4 kW (A)
	No 4	"	"	"	30	1	220 (R) 216 (A)	100	R 60 9 62.9 58 5	60 8	"	"	72.4	No 3 No working M2 working 16 5 kW (A)
	"	"	"	"	M4 30	1	220 (R) 216 (A)	100	R 72.4 75 3 73 7	73 8	"	"	78 5	–
Cage	No 5	Wire drawing	Hitachi	1969	M3 30 cage	1	220 (R) 216 (A)	105	R 63 5 S 69 3 T 65 4	62.9	965 (6P)		77.5	20 1 kW (A)
	"	"	"	"	M4 30	1	220 (R) 219 (A)	105	R 75 3 S 81 2 T 74 7	73 4	"		77 4	22.1 kW (A)
	No. 6	"	"		M2 30	1	220 (R) 207 (A)	105	R 64 4 S 63 3 T 62.2	60 3	"		76 5	–
	"	"	"		M3 30	1	220 (R) Darty	105	R 76 9 S 70 6 T 72.9	70 0	"		82.0	–
	"	"	"		M4 30	1	220 (R) Darty	105	R 74 7 S 74 T 74	70 7	"		82.0	–
Wound type	No. 7	"	"		M1 30	1	– 108 (A)	111	R 54 8 S 51 4 T 53 5	47 6		Secondary resistance	56 6	10.9 kW (A)
"	"	"	"		M2 30	1	200 (R) 204 (A(A)	111	R 83 6 84 6 85 1	76 1	1,455 (4P)	"	83 7	25 kW (A)
"	"	"	"		M3 30	1	200 (R) 208 (A)	111	R 82.2 78 5 79 3	72.1	"	"	82 3	23 5 kW (A)
No 8, 9 10, 11 below 11 kW	No 7	Wire drawing	Hitachi		30	1	200 (R) 208 (A)	111	R 79 9 S 77 6 T 79	71 0	1,455 (4P)	"	81.5	23 2 kW (A)
Wound type	No 13	"	"		M1 15	1	200 (R)	55 5	R 20 3 19 4 19 6	50 4	1,430 (4P)	"	57	–
"	"	"	"		M2 15	1	200 (R)	52	R					–
Cage	Galvanizing No. 1	Driving	Mitsubishi		15	1	211 (A)	–	17.18 18.23 18 76	–			44	6 24 kW (A)
"	" No 3	"	"		15	1	210 (R) 200 (A)	62	R 31 8 31 30 5	50 2	970 (6P)		60	
	Wire drawing M/C No 28	"	"		15	1	200 (R) 200 (A)	62	R 34 4 32 33 1	53 5	970 (6P)		61	–

8.6. Heating of Secondary Resistor of 30-kW Motor for No. 7 Wire Drawing Machine

Compared with the squirrel-cage motors for the other wire drawing machines, the motor for the No. 7 drawing machine is of a winding type. The motor is overheated because it is operated without shorting its secondary resistor to retain resistance. Its pulley should be exchanged to attain an optimal speed and the secondary resistor should be shorted. The heating value of the secondary resistor is roughly calculated based on a test report of the motors by the motor manufacturer prior to shipment.

Winding-type induction motor 30 kW 4P 50Hz 220V 10A 1465 r.p.m.

Rated continuous type B insulation

Stator resistance 0.042Ω

Rotor resistance	0.458Ω			
No-load test	220 V	36.3 A	1,150 W	
Lock test	40 V	100 A	2,300 W	635 V (Secondary)
Load characteristic (by a circle diagram)	100% load current 98.1 A			

Efficiency: 91% power factor 87.2% slip 3.38%

Maximum output 244%, maximum torque 295%.

The level of a secondary resistor is 4.5Ω per phase. Assuming that 1Ω remains, by proportional transition, the slip will be:

$$\frac{0.458}{3.38} = \frac{0.458 + 1}{S} \qquad S = 10.76\%$$

Assuming input P_1 = 23.5 kW and current, 79.3 A, based on the data, the secondary input will be:

$$P_2 = \underset{\text{Primary input}}{23.5} - \underset{\text{Primary copper loss}}{3 \times 79.3^2 \times 0.042 \times 10^{-3}} - \underset{\text{No-load loss}}{1.15}$$

$$= 21.6 \text{ kW}$$

The secondary resistance losses will be:

$$SP_2 = 0.1076 \times 21.6 = 2.3 \text{ kW}$$

The loss inside the secondary resistor will be:

$$2.3 \times \frac{1}{1.458} = 1.578 \text{ kW}$$

Assuming actual operating time to be 6,998 hours.

1.578 x 6,998 = 11,039 kWh/year (16,070 Bt/year)

Shorting the secondary resistor, the speed becomes faster and this can be adjusted by changing the pulley diameter

8.7. Lighting

The factory primarily uses mercury lamp. A total 62 fluorescent lamps are used in some sections of the factory as shown in the following.

Store	40 W x 4 lamps	Laboratory	40 W x 6 lamps
Offices	40 W x 18 lamps	Conference rooms	40 W x 2 lamps
Factory	40 W x 6 lamps	Canteen	40 W x 12 lamps
Workshop	40 W x 14 lamps		

All of these lamps have daylight fluorescent lamps. Replacing them with energy conservation white fluorescent lamps, which are now being manufactured in Thailand, energy conservation of 5 W per lamps will be possible. Therefore, used 10 hours a day.

5 W x 62 lamps x 10 h x 312 days x 10^{-3} = 96.7 kWh/year

1,407 Bt/year

9. Summary

The abovementioned remedial measures, if actually taken, will bring about energy conservation effects as shown below.

	kl/year	%
Additional insulation of the patenting furnace	3.3	0.6
Lids on lead and zinc baths	7.6	1.5
Insulation of steam pipes	9.6	1.9
Subtotal	20.5	4.0

	10^3 kWh/year	%
Lighter transformer load losses	16.7	0.7
Exchange of No. 7 wire drawing pulleys to reduce external secondary copper losses	11.0	0.5
Change daylight fluorescent lamps to energy conservation white lamps	1.0	—
Subtotal	28.7	1.2

Report No. 15: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thai Malleable Iron and Steel Co., Ltd. —

June. 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Thai Malleable Iron & Steel Co., Ltd. —

1. Outline of the Factory

Address	Paholyotin (K.M. 37) Klong-Lhuang Patumtani	
Capital	18 million Bt	
Type of industry	Foundry	
Major products	Water pipe joints	
Annual product	2,400 t/year	
No. of employees	250	
Annual energy consumption	Electric Power	6,280,440 kWh/year
	Fuel	Heavy B Oil 519 kℓ/year LPG 294 t/year
Interviewees	Managing Director, Mr. Kampol Srethakdi Chief, Finance & Dispatch Control Mr. Visit Lerdbunnapong	
Date of diagnosis	Jan. 27 ~ 28, 1983	
Diagnosers	T. Nakagawa, T. Noda, K. Kurita	

This company started in 1970. Initially, it entered into a two-year technical licensing agreement with Awaji Industries Co., Ltd. of Japan.

Facilities were enlarged twice in 1974 and 1981.

It produces a small cast part and, in particular, its major product is a joint for water pipes. It also produces a cover for motors.

When the facility was extended machines were automated and rationalization was promoted gradually.

The production capacity is 3,600 t/year but current production is 2,400 t/year under one working shift.

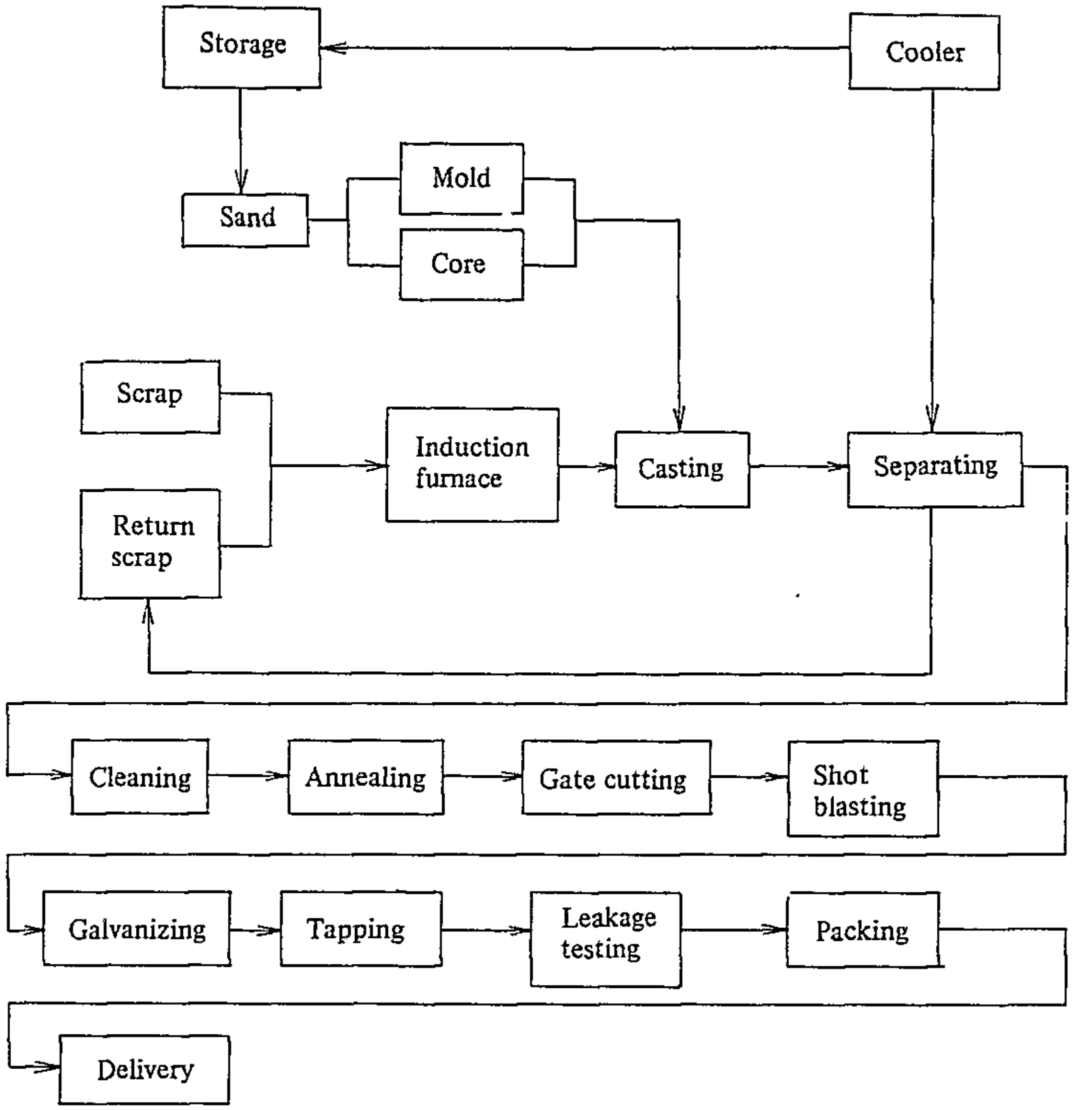
Although it operates 300 days/year, the annealing furnace operates 360 days annually and 24 hours a day because it must be operated continuously.

The plating process is operated on two shifts (16 hours a day).

The factory was well maintained and the working shop was in good order.

In addition, a space for future extension has already been prepared.

2. Manufacturing Process

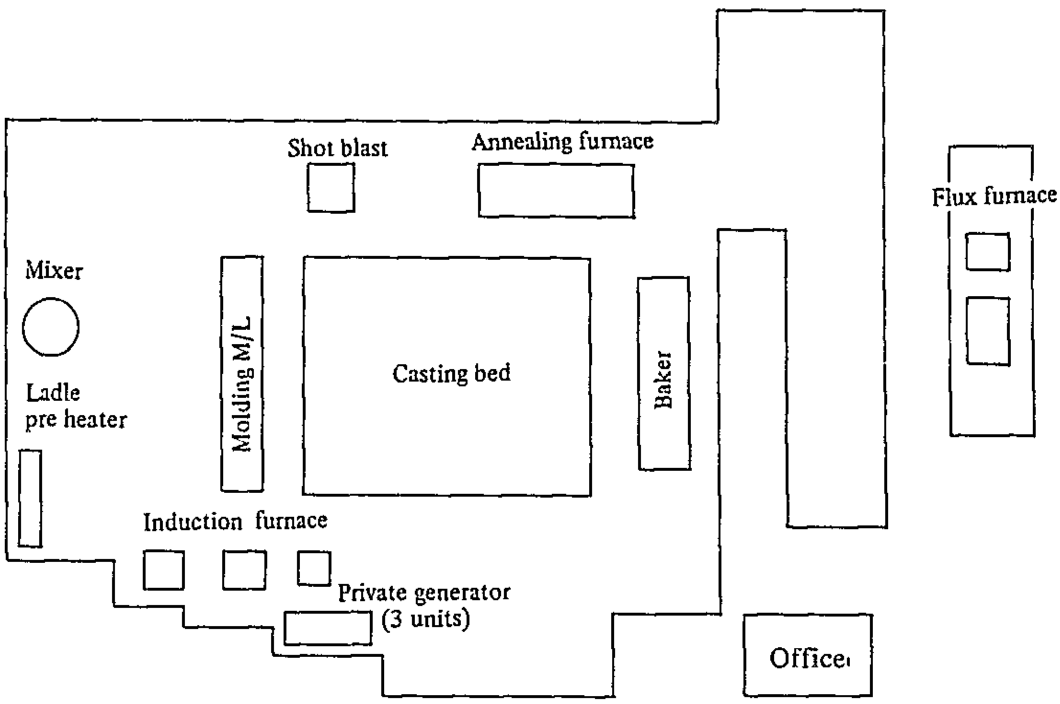


3. Major Equipment

3.1 Major Equipment

Equipment	Number of unit	Specification
Induction furnace	2	Crucible type, 1000 kW 4 t/charge
Induction furnace	1	Channel type, 350 kW 10 t/charge
Annealing furnace	1	Tunnel type, car type
Molding baker	1	LPG firing
Ladle preheater	1	LPG firing
Compressor	7	55 kW 3 units 30 kW 1 unit 22 kW 2 units 15 kW 1 unit
Mixer	2	45 kW, 30 kW
Shotblast	1	22 kW
Private Diesel-engine generator	3	75 kW 2 units 50 kW 1 unit
Galvanizing furnace	1	Hot bath, LPG firing

3.2 Layout



4. State of Energy Management

4.1 Investment in Energy Conservation and Cases of Improvement

The company has not set any particular energy-conservation targets.

Mr. Kompol says that they expect to reduce electric power consumption by 10% because of an increase in the power charges.

Last year, about 50mm of ceramic fiber was placed on the wall of the annealing furnace reducing fuel consumption by about 5%. This required 250,000 Bt of investment. Recovery of investment is planned to be within two years.

This factory has a special contract for its energy charges. This contract is such that the power charge at out of the peak demand times (6:30 PM to 8:30 PM) can be discounted.

Although this does not allow for overtime, it is one means of achieving cost reduction. We are told that this method contributed to a five percent reduction in cost.

4.2 Grasp of Energy Consumption

Electric power used every month is recorded but the fluctuations are not investigated.

There is no record of electric power used every hour or a daily load curve.

In addition, transformers are installed separately and are difficult to control totally.

Consumption of fuel was measured every hour previously but since the flowmeter is out of order now, only the quantity received every week by means of a tank rolley is known.

The energy consumption rate for each application and process is not calculated.

There is a one line diagram for the induction furnace and transformer for 500 kVA but there is no one line diagram for the entire factory.

4.3 Energy-Conservation Committe and Suggestion System

There is no specific energy-conservation organization but problems of energy-conservation are discussed at general meetings held six times a year.

There was a consultant contract ever when the inside wall of the annealing furnace was lined with ceramic fiber.

There is not suggestion system, training of employees or plant tours.

The company does not encourage its employee to save energy.

However, it was observed that various countermeasures are being taken for the annealing furnace such as a study of the operation, stopping one burner in the firing zone and stopping the supply of cooling air.

A channel type induction furnace was under repair and it was discussed whether it was better to be used as a holding furnance or not.

This factory has continued to enlarge its facility since the start of operation and new equipment has been introduced. They are extremely enthusiastic about improvements in the energy-conservation area.

5. State of Fuel Consumption

5.1 Actual State of Fuel Consumption

Actual state of fuel consumption and the values for 1982 are as follows:

Fuel oil B	519 kl/year	Annealing furnace
LPG	294 kl/year	75% (220 kl/year) Glavanizing
		25% (74 kl/year) Core drying
		ladle preheating

5.2 Fuel Consumption Rate

The fuel consumption rate for the annealing furnace is as follows based on production amount and the actual use of fuel oil B in the last year:

Fuel consumption rate= 519 x 10^3 l/year/(200t/month x 12 months/year)
= 216 l/t

Even though two-stage annealing is considered, this value is considerably high and strict execution of energy-conservation should be undertaken.

5.3 Approximate Heat Balance of Annealing Furnace

For the two-stage annealing furnace, the heat balance should be caluculated by dividing the furnace into the 1st stage annealing zone and 2nd stage annealing zone but since distribution of fuel used in each zone was unknown and measurement values required for heat balance in each zone can not be obtained, the heat balance was calculated by assuming the temperature of the heated zone as 720°C for the 2nd stage annealing temperature. Therefore, although it lacks accuracy, it will help in understanding approximate heat balance of the annealing furnace.

5.4 Heat Balance Table

Heat input			Heat output		
Item	10^3 Kcal/t	%	Item	10^3 Kcal/t	%
(1) Heat of fuel combustion	2,054.2	100	(1) Sensible heat of annealed casting	157.6	7.7
			(2) Sensible heat of pot	315.1	15.3
			(3) Sensible heat of waste gas	697.3	33.9
			(4) Heat loss from furnace body	232.3	11.3
			(5) Miscellaneous	651.9	31.7
Total	2,054.2	100	(2) + (3) + (4) + (5) + (6)	2,054.2	100.0

Remark . Calculation is on basis of 1 ton weight of annealed casting and room temperature.

5.5 Data Given for Determination of the Heat Balance

Consumption of fuel oil B	: 57 l/h
Specific gravity of fuel oil B	: 0.91
Low heat content of fuel oil B	: 9,900 Kcal/kg
Theoretical amount of air	: 10.42 Nm^3/kg
Theoretical amount of wet exhaust gas	: 10.99 Nm^3/kg
Weight for one carriage	Casting: 1 ton Pot (container for casting): 2 ton
Charging rate for carriage	: 4 unit/each 4h

Consumption of fuel oil B per 1 ton of casting:

Consumption of fuel oil B (57 l/h) x specific gravity of fuel oil (0.91 kg/l) ÷ weight of casting for one carriage (1 ton/unit) ÷ charging rate for carriage (4 unit/each 4h) = 207.5 kg/ton

Extraction temperature of casting	: 720°C
Average specific heat of casting	: 0.23 Kcal/kg°C
Temperature of exhaust gas	: 400°C
Oxygen content in exhaust gas	: 13%
Specific heat of wet exhaust gas	: 0.33 kcal/Nm^3°C
Average surface temperature of side wall	: 77°C
Surface area of furnace	: 120 m^2
Emissivity of furnace surface	: 0.85

5.6 Equations for Calculating the Heat Balance

Input

Heat of Fuel Combustion

Amount of fuel oil B per 1 ton of annealed casting (207.5 kg/t) x low heating value of fuel oil (9,900 kcal/kg) = 2,054,250 kcal/t

Output

Heat Content of Annealed Casting

1,000 kg x average specific heat of casting (0.23 kcal/kg°C) x {annealing temperature (720°C) − ambient temperature (35°C)}
= 157,550 kcal/t

Heat Content of Pot

2,000 kg x average specific heat of pot (0.23 kcal/kg°C)
x {temperature of pot (720°C) − ambient temperature (35°C)}
= 315,100 kcal/t

Note: Tempearture and average specific heat of pot are the same as those for annealed casting.

Sensible Heat of Exhaust Gas

- Air ratio = 21/{21 − oxygen content in exhaust gas (13)} = 2.62
- Wet exhaust gas flow per 1 kg of fuel oil

theoretical wet exhaust gas (10.99 Nm^2/kg) + {air ratio (2.62) − 1} x theoretical air (10.42 Nm^3/kg) = 27.9 Nm^3/kg

- Sensible heat of exhaust gas

Amount of fuel oil B per 1 ton of annealed casting (207.5 kg/t) x wet exhaust gas flow (27.9 Nm^3/kg) x average specific heat of exhaust gas (0.33 kcal/Nm^{3}°C) x {temperature of exhaust gas (400° C) − ambient temperature (35° C)}
= 697,315 kcal/t

Heat Loss from Furnace

- Heat loss per 1m^2 of furnace surface

[{surface temperature (77° C) + 273° C}/100° C]^4
− [{ambient temperature (35° C) + 273° C}/100° C]^4
x 4.88 kcal/m^2h°C x 0.85 + 2.2
x $\sqrt[4]{\text{Surface temperature (77° C)} - \text{ambient temperature (35° C)}}$
x {surface temperature (77° C) − ambient temperature (35° C)}
= 484 kcal/m^2h

- Heat loss from furnace

Heat loss per 1m^2 of furnace surface (484 kcal/m^2h) x surface area of furnace (120 m^2) ÷ weight of annealed casting per hour (0.25 t/h) = 232,320 kcal/t

6. Problems in Heat Control and Potential Solutions

6.1 Annealing Furnace

(1) Prevention of Air Inflow

(a) Pressure in the furnace (measurement point is about 0.6m above the upper surface the carriage) is a low 0.3 − 0.4 mm H_2O.

(b) Maintenance of the carriages were poor and there was considerable clearance between the connecting parts of cars.

(c) Amount of sand for sealing under the carriage is insufficient.

(d) Doors at the charging side and extraction side did not fall down onto the level of upper surfact of the carriage at its normal position, but left a gap.

By the reasons of a) to d), a considerable amount of cold air came into the furnace.

The fact that air content in the exhaust gas is 13% verifies this situation.

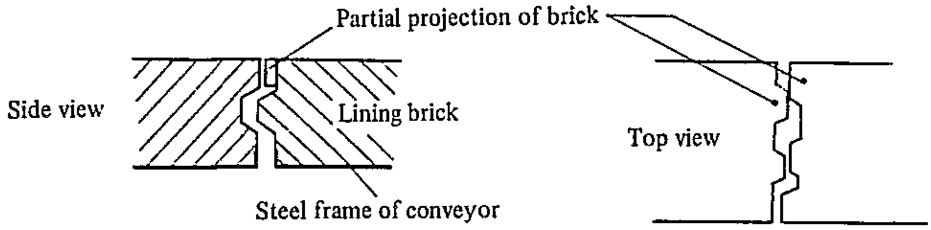
Cold air entering the furnace from under the carriage not only cools the lower portion of the pot, but also contributes to cause temperature differences in the furnace by pushing hot combustion gas up to the furnace ceiling.

Inflow of cold air increases the quantity of exhaust gas and results in greater heat losses by exhaust gas.

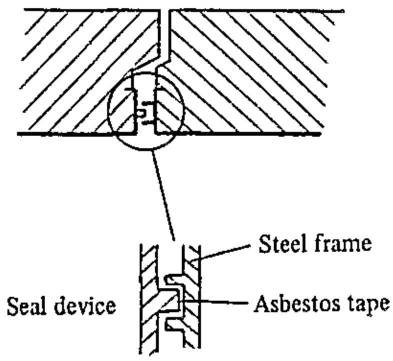
The following countermeasures should be considered:

(a) Face of metal frame of carriage brick should be maintained in smooth so that the carriages are able to contact closely each other.

(Actual comfiguration)

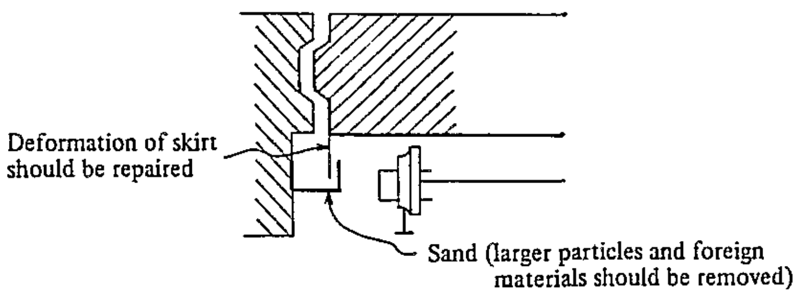


(Example of improvement)



(Leak proof at the contact faces of the conveyors should not be done by the brick faces but by seal devices of the steel frame)

(b) Sand for sand seal should always be supplemented.



(c) Doors at charge and extract ends should be completely closed.

It is difficult to completely seal the clearances of the carriages themselves and those between the carriages and the furnace.

Therefore, it is very important to prevent air under the carriage from coming into the furnace by adjusting the opening of the chimney damper to a positive pressure in the furnace.

In this case, the pressure in the furnace must be between 0.2 to 0.4 mm H_2O

at the upper surface of the carriage.

If a measuring hole for pressure in the furnace is located at a height of H (m) from the surface of the carriage, pressure in the furnace P mm H_2O may be set as follows taking into account the effect of the buoyancy of the high temperature gas.

$$P = (0.2 \text{ to } 0.4) + H\ (m)$$
$$= (0.2 \text{ to } 0.4) + 0.6 = 0.8 \text{ to } 1.0 \text{ mm } H_2O$$

By applying these countermeasures, air coming into the furnace is significantly reduced.

When the oxygen content in exhaust gas is reduced from 13% (air ratio: 2.62) to 4.8% (air ratio: 1.3), the amount of fuel oil X kg/t is as follows:

$$(2{,}054.2 - 697.3) + 14.11 \times 0.33\ (400 - 35) \times \frac{X}{1{,}000} = \frac{9{,}900}{1{,}000} X$$

$$X = 164.9 \text{ kg/t}$$

Therefore, the fuel oil saving rate is

$(207.5 - 164.9)/207.5 \times 100 = 20.5\%$.

Annual savings are 106.4 kl/year.

(2) Maintenance of Burner

The oil pressure before burner of certain burners showed a high value of 0.8 kg/cm^2G.

Although the burner combustion was good, there was considerable oil leakage, fouled burner chips and soot on the burner tile.

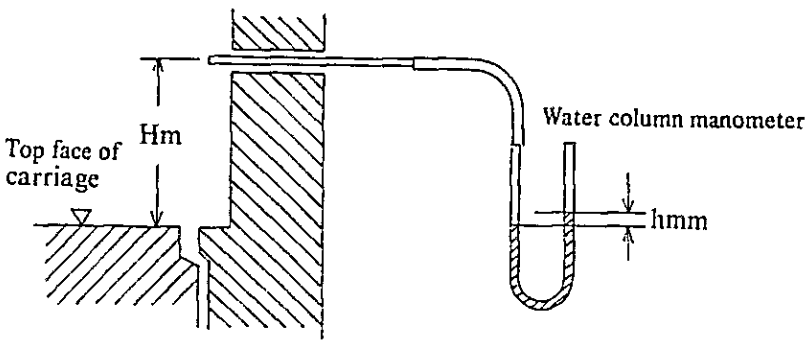
As countermeasures, oil burners and auxiliary equipment are given periodic maintenance which prevents fouling of the burner nozzle and carbon deposits on the burner tile. The oil pressure before burner is adjusted to a normal pressure of 0.4 kg/cm^2G.

(3) Lowering of Heat Capacity

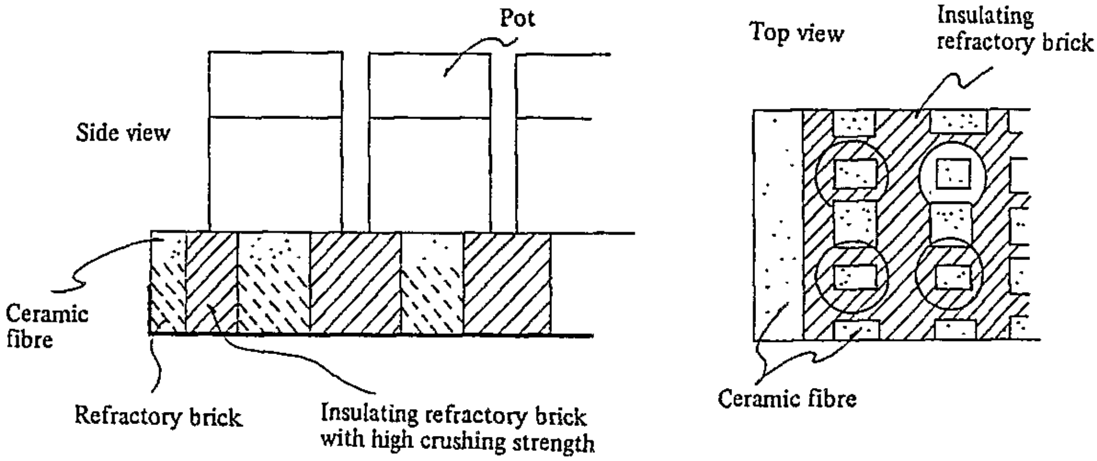
Insulation is not used for the carriage brick.

Therefore, the decrease in weight and insulation of the carriage should be examined referring the recommendation shown below.

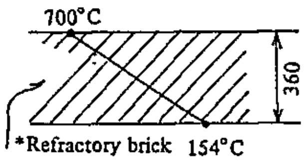
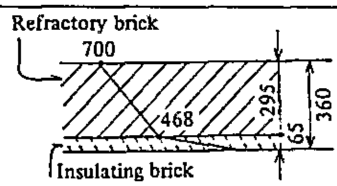
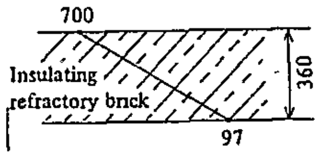
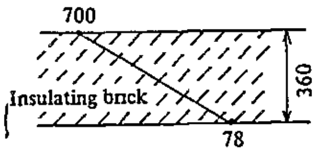
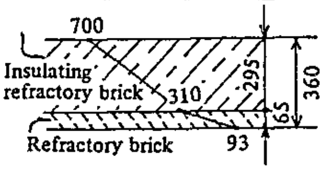
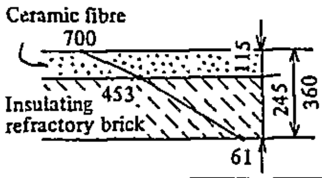
The weight of the pot should be reduced so that the heat capacity can be decreased by studying the material and configuration.



hmm = (0.2~0.4) – H(m)



Calculated values for heat loss from the undersurface of the carriage (under steady conditions) and accumulated heat of carriage brick at the extraction time when various insulating materials are used in the carriage are shown in the following table.

No.	Composition of refractory	Heat released		Sensible heat per unit area	
		Kcal/m²h	relative value	Kcal/m²	relative value
1		1,390	100	77,780	100
2		770	55	94,330	121
3		490	35	34,720	45
4		270	19	24,650	32
5		430	31	39,890	51
6		220	19	13,760	18

Data for Calculations

- Imissivity of undersurface of carriage: 0.8
- Ambient temperature at lower portion of carriage: 50°C

When the above-mentioned values are used and insulation proposed by the above-mentioned recommendation (combination of No.3 and No.6 of the table) is applied, there is an estimated annual savings of 65 kl of fuel oil.

- Current status

Heat loss: 1,390 kcal/m^{2}h x (2.56 m^2/set x 12 sets/unit) x 24 h/day x 0.85 = 871 x 10^3 kcal/day

Note 1) Surface area of carriage: 1.6 m x 1.6 m = 2.56 m^2

Note 2) twelve carriage are used at the annealing furnace.

Note 3) Heat loss shown in the table is when the carriage brick is in steady state. However, since it takes considerable time until the carriage brick reaches this steady condition, it can not be assumed that all carriages in the furnace are releasing heat under steady conditions.
Here, carriages similar to a steady condition corresponds to 85% {(time residing in furnace: 48 hrs. − temperature raising time: 8 hrs.)/time residing in furnace : 48 hrs ≒ 0.85)}.

Accumulated heat: 77,780 kcal/m^2 x 2.56 m^2/unit x 6 units/day
= 1,195 x 10^3 kcal/day

Total: 871 x 10^3 kcal/day + 1,195 x 10^3 kcal/day
= 2,066 x 10^3 kcal/day
= 743,760 x 10^3 kcal/year

Note: Operating time; 360 days/year

- After using insulation

When the ratio of the surface area of No.3 to No.6 of the insulation is 2 to 1, calculations made similar to the above-mentioned manner result in the following values:

Heat loss	251 x 10^3 kcal/day
Accumulated heat	187 x 10^3 kcal/day
Total	438 x 10^3 kcal/day = 157,680 x 10^3 kcal/year

- Savings

(743,760 x 10^3 kcal/year − 157,680 x 10^3 kcal/year) ÷ 9,900 x 10^3 kcal/t ÷ 0.91 t/kl = 65 kl/year

Saving rate: 65 kl/519 kl = 12%

7. State of Electric Power Consumption

The load of the two low-frequency induction furnaces with 4 t/charge takes up 75% of the total electric power consumption.

Although only one shift is operating, the starting block is thrown into the induction furnace at the end of the day 5 (PM). After about 250 kW is applied for about ten minutes, the power is cut off until 9 o'clock.

About 90 kW is applied starting from 9 o'clock for melting. Material is added at 3 o'clock in the morning and then the power is disconnected and operation is again started at 8 o'clock in the morning by connecting the power. Therefore, there is a special contract with the power company setting forth two types of charges for on-peak times (6:30 PM to 8:30 PM) and off-peak times.

7.1 The Principal Data Relating to Power Consumption

- Power company : MEA
- Peak demand :
  Maximum value during peak time: 204 kW
  Maximum value during off-peak time: 2,664 kW
- Power consumption 6,280,440 kWh
  On-peak times: 54,600 kWh
  Off-peak times: 6,625,840 kWh
- Load Factor

Assuming 2,700 annual operating hours, the maximum annual value of peak demand 2,664 kW and an average amount of electric power of 2,306 kW, the annual load factor will be 86.6%.

- Penalty None

Since the induction furnace occupies seventy-five percent of the load and the power factor of the induction furnace reaches one hundred percent as described elsewhere, the power factor throughout the factory is as good as ninety percent.

- Transformer

There are two 3ϕ 1200 kVA transformers for the two induction furnaces, two 3ϕ 500 kVA transformers for general use and lighting and one 1ϕ 500 kVA transformer for the channel type induction furnace which is currently idle. (Refer to the one line diagram.)

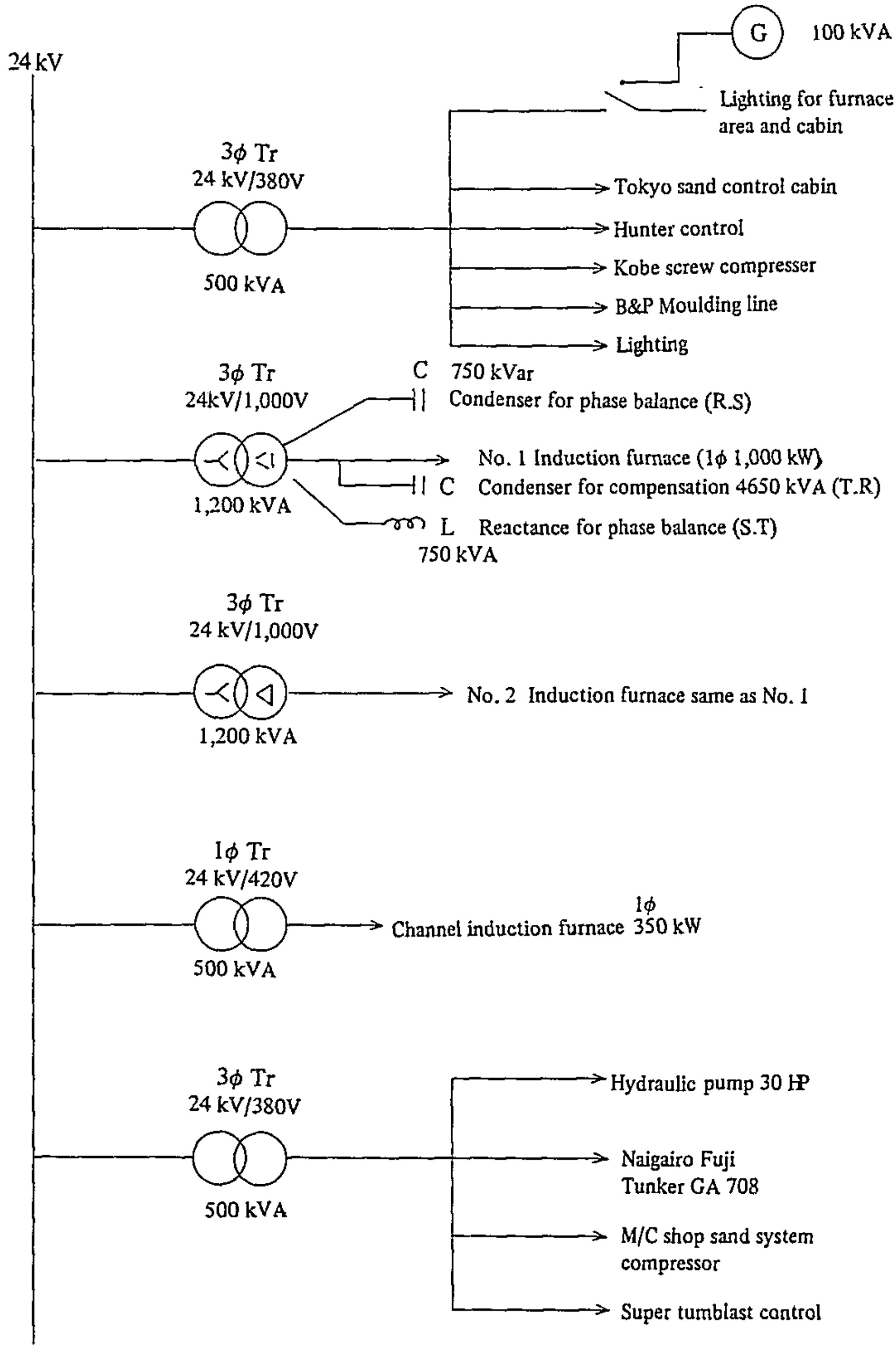
- Fuel consumption rate

Since the annual energy consumption is 6,280,440 kWh and annual output is 2,400 ton, the electric power consumption rate is 2,617 kWh/t.

Assuming yield to the charged material is thirty-five percent, and seventy-five percent of the electric energy used is consumed by the induction furnace, the consumption rate of the induction furnace is obtaained as follows:

$$\frac{6{,}280{,}444 \times 0.75 \times 0.35}{2{,}400} = 686.9 \text{ kWh/t}$$

7.2 One line Diagram



8. Problems in Electric Power Control and Potential Solutions

Total capacity of the three phase transformers is 3,400 kVA excepting a single phase 500 kVA transformer for the channel type furnace.

Among them, two transformers for the induction furnaces provide 1,200 kVA each and 70% of the total transformer capacity comes from these two transformers.

It is said that 75% of the total electric power is consumed by the induction furnace.

Since the transformer for the induction furnace is a three-phase type and the induction furnace is a single-phase type, a condenser is connected to one phase and a reactor is connected to another phase to balance the system.

There are drawings for each piece of equipment such as the induction furnace but there is no one line diagram for the factory.

Because the 24 kV side is connected to the distribution line at a separate location and because there is no cumulative voltmeter, ammeter or wattmeter, it is very difficult to observe the cumulative load.

Since two 500 kVA transformers for general use are located apart and the switch boards are also separated, it is difficult to have overall control.

Although the power factor for the induction furnace is low, it is improved by a condenser.

Since the power factor for the induction furnace which consumes seventy-five percent of the total electric power is improved to up to one hundred percent by condenser, the power factor as a whole is good even if the power factor of the remaining 25% of the electric power for general use, is low.

Although condensers are not connected to two transformers (500 kVA each) for the general electric power load and the power factor is low, a large reactive power for which a penalty must be paid does not result.

Voltage, current, electric power, apparent power and the power factor for each power switch board should be recorded every hour. By recording, especially, the time of one charge and the electric power of the induction furnace, the electric power consumption rate can be known and the system can be operated as to decrease the electric power consumption rate based on the data.

8.1 Transformer for the Induction Furnace

As shown in the attached table, the power factor is near 100%. The factory manager reported that a switch on the secondary side of the transformer is cut off when the factory is not operating but then, electricity flows through the transformer and no-load loss is generated.

Accordingly, it is recommended that a circuit breaker on the primary side of the transformer be cut off.

Energy saving due to this operation is calculated as follows:

Record of transformer performance

No. 1 Induction furnace 1200 kvA kvA and kW figures are calculated.

Time	Voltage	Current	Apparent power	Power	Power factor	Remarks
1–27 11:40 AM	V 950	A 470	kvA 773	kW 766	% 99.0	490A other 400A 2 lines
2:50 PM	940	580	944	943	99.9	570A 590A
3:45 PM	660	440	503	502	99.9	400A 450A
1–28 11:15 AM	530	330	303	303	100	330A 350A
11:45 AM	970	430	722	721	99.8	420A 470A

No. 2 Induction furnace 1200 kvA kvA and kW figures are calculated.

Time	Voltage	Current	Apparent power	Power	Power factor	Remarks
1–27 11:30 AM	V 950	A 600	kvA 987	kW 982	% 99.5	540A 620A
2:50 AM	500	350	303	297	98.0	320A 380A
3:45 PM	880	360	549	547	99.6	200A 480A
1–28 11:15 AM	900	500	779	776	99.5	470A 510A
11:45 AM	950	430	708	678	95.8	480A 390A

500 kvA New kvA and power factor figure are calculated.

Time	Voltage	Current	Apparent power	Power	Power factor	Remarks
1–27 3:00 PM	V 390	A 241	kvA 163	kW 131	% 80.3	Measured by AC Power meter
1–28 10:52 AM	387	231	155	120	77.4	

500 kvA Old

Time	Voltage	Current	Apparent power	Power	Power factor	Remarks
1–27 3:30 PM	V 374	A 547	kvA 354	kW 280	% 79.1	Measured by AC Power meter
1–28 10:30 AM	374	74.6	48	36.4	75.8	

Since the induction furnace is stopped for three hours and fifty minutes from 5:10 PM to 9:00 PM and five hours from 3:00 AM to 8:00 AM totalling eight hours and fifty minutes, power corresponding to no-load loss (4.2 kW) can be saved when the transformer is cut off on the primary side during this period as mentioned before.

4.2 kW x 2 units x (8 + 5/6)h x 300 = 22,260 kWh/year

When the transformer is cut off on holidays, energy savings are as follows:

4.2 kW x 2 x 24 x 65 = 13,104 kWh/year

Total power of 35,364 kWh/year can be saved.

This provides a savings of 45,713 Bt/year.

8.2 Operation of the 500 kVA Transformer at Night

Loads required at night such as for lighting, blower, water pump, etc. must be concentrated on either one of the two 500 kVA transformers. The other transformer should be released on the primary side at night.

On holidays, one transformer should not be operated and be cut off at its primary side.

In this case, since the load at night is currently small, power savings can be approximately calculated only as no-load loss.

2.5 kW x 14 h x 300 + 2.5 kW x 24 h x 65 = 14,400 kWh/year

Since the secondary voltage of one of these transformers is low, voltage adjustment by means of a transformer tap change is required.

8.3 Motor

Operating state of motors of more than 15 kW is described below.

Only actual measurements of current and input were entered for motors of which rated rotation speed and the number of poles could not be confirmed

Use for	Output kW	Number	Rated voltage/ load voltage	Load imput kW	Rated current A	Load current B	B/A	Rated revolution r.p.m.	Power factor %
Driving mixer Toshiba	kW 30	1	380V/375V	21	A 63	42A 49 49	% 74.1	965	66
Driving mixer Toshiba	45	1	380V/388V	48.2	90	85	94.4	1465	84.4
Driving super Tumblast Fuji	22	1	380V/365V	17.1	43	31.6 31.8 32.1	74.0	1460	85.1
BLP Hydraulic pump	HP 30	1	380V/381V	19	50.3	40 42 39.1	79.5	965	72.0
Compressor for sand mixer	kW 55	1	380V/382V	49.9	–	88.2 86 93.1	–	–	–
Compressor for sand mixer	15	1	– /375V	–	–	19	–	–	–
Compressor coring moulding	55	1	380V/371V	36.1	110A	56.8 58.6 58.0	52.5	965	77
Compressor moulding	55	1	380V/375V	50.5	107A	93.6 90.3 94.5	86.7	2925	83.1
Compressor Tapping	22	1	380V/366V	15.1	–	22.7	–	–	–
Compressor moulding	22	1	380V/368V	19.6	44.5	37.3	84.9	1440	82.4
Compressor hunter moulding	30	1	380V/374V	30.5	60	53.3 50.9 55.5	88.7	2925	88.3

It can be estimated that the power factor for transformer load in the general use is near the value indicated in the previously mentioned table. Since high-pressure air is also supplied for general work, power saving can be realized by supplying the air exclusively from the low pressure (about 1.5 kg/cm^2) compressor.

Five of seven compressors are in operation.

55 kW 1 unit Moulding 6 to 7 kg/cm^2
55 kW 1 unit Moulding 4 to 5 kg/cm^2
30 kW 1 unit Moulding 6 to 7 kg/cm^2
22 kW 1 unit Moulding 6 to 7 kg/cm^2
22 kW 1 unit Tapping 6 to 7 kg/cm^2
55 kW 1 unit Sand mixer 4 to 5 kg/cm^2
15 kW 1 unit Sand mixer 6 to 7 kg/cm^2

None of these compressors are operated continuously. When those with the same pressure are collectively used, and a compressor with 22 kW (for moulding) is used to supply air for the general work, power savings is as follows according to the record of motor operation:

$$19.6 \text{ kW} \times [1 - \frac{2.5^{\frac{1.4-1}{1.4}} - 1}{7.5^{\frac{1.4-1}{1.4}} - 1}] \times 3 \text{ h} \times 300 = 10{,}857 \text{ kWh/year, } 14{,}030 \text{ Bt/year}$$

8.4 Lighting

Because of natural lighting through roof panels was not sufficient, about twenty units of double 40 W fluorescent lamps were lit.

Assuming that these lamps can be turned off by taking in enough sunlight, energy savings become as follows:

$40 \text{ W} \times 2 \times 20 \times 10 \text{ h} \times 365 \times 10^{-3} = 5{,}840$ kWh/year

7,549 Bt/year

8.5 Pot type Induction Furnace

There is a large clearance of about 10 cm between the body and the cover of the no.2 induction furnace. It is reported that heat loss from this clearance is 300 kW/m^2.

Assuming that the outside diameter of the cover is 0.8m, the area of clearance becomes $0.8 \times \pi \times 0.1 = 0.25$ m^2.

The heat radiated from this clearance becomes $0.25 \times 300 = 75$ kW.

Therefore, when this clearance is completely closed, electric power savings become as follows:

75 kW x 2,700 h/year = 202,500 kWh/year

However, after work was completed, a tentative cover was installed to prevent heat loss.

Since this is very important, we recommend that a permanent cover be installed not only at the completion of work, but also during melting, in order to save energy.

Inlet and outlet temperatures of cooling water for the furnace are 34°C and 40°C. The temperature rise is 6°C and cooling is excellent.

When the induction furnace is further cooled, induction efficiency increases.

It was reported that a starting block prepared at the completion of work is 800 kg, but ordinarily about 2 tons of starting block will allow the melting speed at the start of the operation to become faster and the power factor to become larger.

Work subsequent to the transfer of molten metal into a ladle is carried out efficiently and it is notable that there is no cooling or waiting, either.

9. Summary

The abovementioned remedial measures, if actually taken, will bring about energy-conservation effects as shown below.

	kl/year	%
Prevention of air sucking to the annealing furnace	106.4	20.41
Supplement of insulation for carriage of annealing furnace	65.0	12.50
Subtotal	171.4	32.9

	10^3kWh/year	%
Cutting off the transformer of the induction furnace at night	35.4	0.6
Cutting off one 500 kVA transformer at night	14.4	0.2
Lowering the pressure of compressor	8.8	0.1
Utilizing sunlight	5.8	0.1
Improvement of induction furnace cover	202.5	3.2
Subtotal	266.9	4.2

Report No. 16: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thai Special Steel Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Thai Special Steel Co., Ltd. —

I. Outline of the Factory

Address	135 Soi Wadsuansom Poochaosamingprai Rd. Bangprong, Samutprakarn	
Capital	62 million Bt	
Type of industry	Metal	
Major products	Large size casting	
Annual product	600 t	
No. of employees	76	
Annual energy consumption	Electric Power	1,320,800 kWh
	Fuel	Heavy A Oil 144 kℓ
Interviewees	General Manager Pricha Sangwanich Plant Manager Prasert Marasubin	
Date of diagnosis	Feb. 9, 1983	
Diagnosers	T. Nakagawa, T. Noda, K. Kurita	

This company was established in 1974 as a joint venture with Japan Metal Co., Ltd. However, currently it is entirely Thai-owned and has no financial relationship with Japan Metal Co., Ltd., but they are still related in terms of technical assistance and procurement of materials.

This company manufactures large casting products such as crushers, chain sprocket wheels and mill gears.

The factory's production capacity is about 1,500 t/year, but it currently produces 600 t/year or about 40%.

There is a plan to increase the output to capacity in one year.

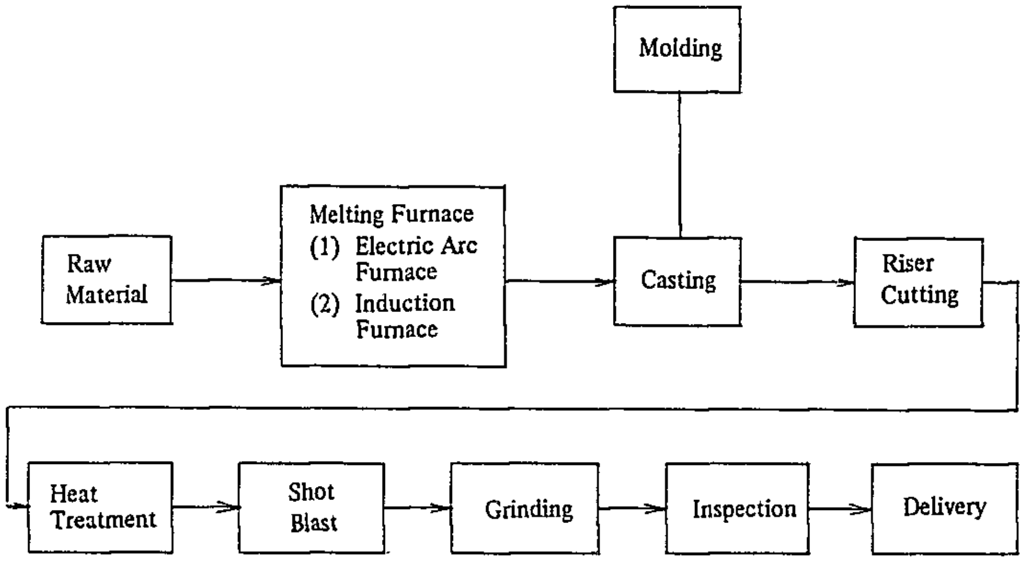
Operation is based on seven and half hours per day, at six days per week, with three hundred annual operation days.

The industry consists of about ten companies and among them this company is ranked second or third in the manufacture of ordinary casting, and is ranked first or second in the manufacture of special casting.

Besides the production facilities, a test room and analysis room are completely furnished and it is therefore concluded that enough attention is being paid to quality control.

It was reported that the product yield is 51%. An electric-arc furnace and a 300 kg induction furnace were not operated on the day of diagnosis.

2. Manufacturing Process

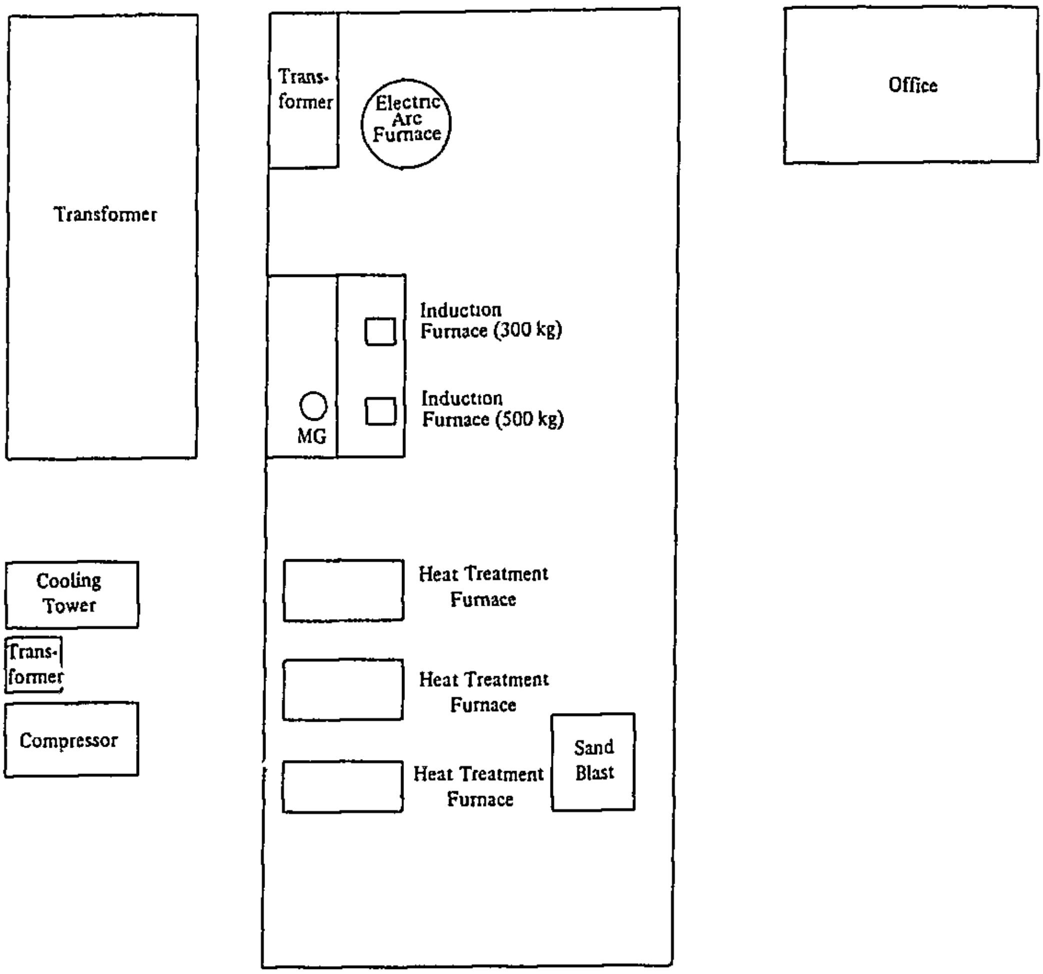


3. Major Equipment

3.1 Major Equipment

Name	No. of units installed	Type, etc.
Electric arc furnace	1	3 t/charge, 1,500 kVA
High frequency induction furnace	1	500 kg/charge, pot-type
	1	300 kg/charge, pot type
Heat treatment furnace (shuttle type)	1	4 t/charge
	1	1.5 t/charge
	1	2 t/charge
Air compressor	3	22 kW

3.2 Layout



4. State of Energy Management

4.1 Investment in Energy Conservation and Cases of Improvement

The company has no particular energy conservation target. Since the consumption of electric power occupies a large portion of energy consumption, various measures are undertaken, such as turning off lights during lunch, to reduce consumption as much as possible.

Investment related to energy conservation has not been made and there is no special plan for investment during the current fiscal year. The company is now investigating how to deal with energy conservation from now on.

Their standard for investment is that costs can be recovered in two or three years.

4.2 Grasp of Energy Consumption

A voltmeter, ammeter, wattmeter, watt-hour meter and power-factor meter are installed in a receiving and transforming room with adequate equipment.

A one-line diagram is maintained and the conditions for electric power control are well arranged.

Grasp of energy consumption is properly exercised. Since both an electric-arc furnace and an induction furnace are subjected to batch operation, a record is taken for each operation and the electrical power consumption rate is calculated and reported to managers of the factory.

In addition, the proportion of electric power used by three groups, such as an electric-arc furnace, induction furnace and motor and others is analyzed.

Fuel is measured for each batch operation by installing a flowmeter.

Cost of energy is calculated and shares about 20~30% of that of the product.

4.3 Energy Conservation Committee and Suggestion System

Although there is no organization to plan and promote energy conservation, this theme is discussed in general meetings within the company and problems are pointed out and actual results are investigated. Because they can be assisted by JMC, they do not currently require a technical consultant.

Information exchange within the industry is not so good and it is unofficially exchanged between two or three companies at management level.

There is no suggestion system.

4.4 Employee Training

Employees are chosen to attend a seminar and receive practical experience at King Mongkut Institute of Technology.

The company calls on employees twice a year to make sure that they properly operate the equipment and understand that benefits to both the company and themselves are interrelated.

5. State of Fuel Consumption

5.1 State of Fuel Consumption

Only fuel oil A is used and its annual amount is 144 kl. The distribution of fuel oil A consumption is as follows:

Quenching	:	70%
Annealing	:	20%
Tempering	:	10%

5.2 Fuel Consumption Rate

Because the total weight processed by each quenching, annealing and tempering process is not known, an average fuel consumption rate is obtained by using 50 t/month of product weight as follows:

$12{,}000\ l/50\ t = 240\ l/t = 2{,}105 \times 10^3\ kcal/t$

Even though the processed weight for each of quenching, tempering and annealing is ambiguous, this value is extremely poor if correct, and measures to decrease the fuel consumption rate are required.

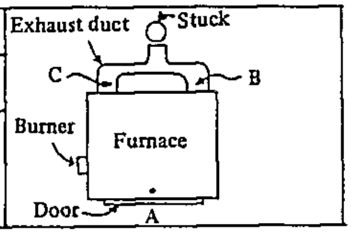
6. Problems in Heat Control and Potential Solutions

6.1 Sand Seal of Heat Treatment Furnace

Since the sand for seal between the carriage and furnace floor and for seal of the door is almost losted, we recommend that it be supplemented. When the seal conditions become poor, outside air is sucked in from under the carriage or front door thereby local cooling the heated material and causing an adverse effect on quality, as well as increasing heat loss in exhaust gas.

The analysis of exhaust gas in a flue duct which indicates a state of negative pressure is shown below.

Measure-ment point / Time	A		B		C	
	O_2%	Tempera-ture °C	O_2%	Tempera-ture °C	O_2%	Tempera-ture °C
15–0	9.6	400	14.9	100	15.3	150
15–20	9.5	400	14.8	110	15.3	150



Before adding sand for seal, it should be sieved to remove large particles of foreign matter.

When the sand seal is maintained in good condition, the oxygen content in the furnace can be reduced to about 5%.

Because the current oxygen content is an average 15%, when the low level heat content of fuel oil A is assumed to be 10,200 kcal/kg, the amount of wet exhaust gas with a 5% oxygen content becomes 14.7 Nm^3/kg oil. That with a 15% oxygen content becomes 38.0 Nm^3/kg oil and therefore, the amount of exhaust gas is reduced by about 60%.

Since the heat balance of this furnace has not been calculated and therefore, the rate of heat loss of exhaust gas is unknown, and the following formula can be obtained by assuming this rate of 30% and reducing the heat input from Q kcal/h to Q' kcal/h:

$$Q' = 0.3 \times (1 - 0.6)Q' + 0.7Q$$

$$\therefore \frac{Q'}{Q} = 0.80$$

That is, by making the sand seal complete, a 20% fuel conservation is possible.

Annual amount of conservation becomes as follows:

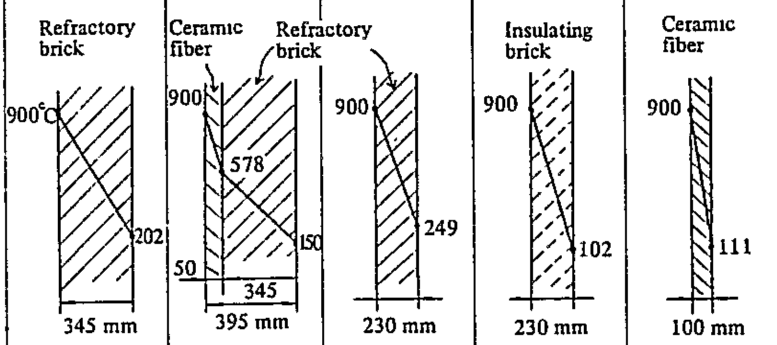
144 kl/year x 0.20 = 28.8 kl/year

6.2 Improvement of Insulation of Furnace Wall and Carriage

Because it is difficult to insulate the out side surface of the furnace as is, it is recommended that it be lined with ceramic fiber.

By improving the insulation, there is a possible reduction of heat loss from the furnace and a shortening time of the temperature rise due to a reduction of accumulated heat in the furnace wall, resulting in fuel conservation. An example is shown below.

Kind of refractory and dimension



	Side wall		Door		
Heat release	Kcal/m²h 1,952	Kcal/m²h 1,160	Kcal/m²h 2,758	Kcal/m²h 587	Kcal/m²h 691
Compared with existing state	100	59	100	21	25
Accumulated heat	Kcal/m² 100,560	Kcal/m² 65,390	Kcal/m² 69,900	Kcal/m² 21,200	Kcal/m² 2,430
Compared with existing state	100	65	100	30	3

Note: Reference temperature 35°C
Emissivity 0.3 (outside wall color: silver)

According to this table, when the furnace wall is lined with 50 mm of ceramic fiber, the amount of fuel conservation due to a reduction in heat loss becomes as follows:

$$\frac{(1{,}952 - 1{,}160) \times 8{,}5\ m^2}{10{,}200 \times 0.86 \times 1{,}000} \times 7.5\ h \times 300\ day = 1.73\ kl/year$$

The cost for lining the furnace will be approximately 5,500 Bt, which can be depreciated in approximately eight months.

Refractory brick is used for the carriage but it is better to replace it with insulation brick. However, since a large load is partially applied to bricks on the carriage because of the irregular shape of cast products, refractory insulation brick will be recommended when the strength of insulation brick is considered to be not sufficient by analysing the loads.

Thereby, the amount of accumulated heat and amount of heat loss of the carriage are reduced and an improvement is achieved, so that the temperature near the cast product contacting the brick approaches the furnace temperature.

Deviation of the carriage was great, with one side touching the wall and the other having a clearance of about 40 cm.

It is necessary to stack brick on the carriage again or properly maintain the wheel bearing.

An example of an achievement of 5—8% in energy conservation by improving the insulation was reported.

Assuming a 5% conservation of energy, the following amount of fuel conservation can be expected:

144 kl/year x 0.05 = 7.2 kl/year

6.3 Opening of Door at the Starting Time of Combustion

At the starting time of combustion, the door was partialy opened. This may be because of a possibility of incomplete combustion due to the shortage of air in the furnace when the furnace is cooled, and the draft in the stack is small.

However, this method results in a large heat loss from the door opening. It is recommended that an operating plan be established and the furnace be preheated by a burner of a small capacity two or three hours before charging with the door closed.

Control of combustion in this furnace may become easier when several burners of small capacity are used.

6.4 Fouling of Pump and Burner

The oil pump and burner leak oil and are badly fouled.

Oil leakage must be prevented by completely maintaining the piping joint and main body of the burner. The periphery of the pump station and burner must be cleaned.

A burner is misaligned with the center of a burner tile and the flame contacts the lower portion of the tile.

The flame was long and burned the front brick surface.

Considering the conditions described in the preceding paragraph, it appears that the capacity of the burner is too large.

7. State of Electric Power Consumption

The load of the factory can be approximately divided as follows:

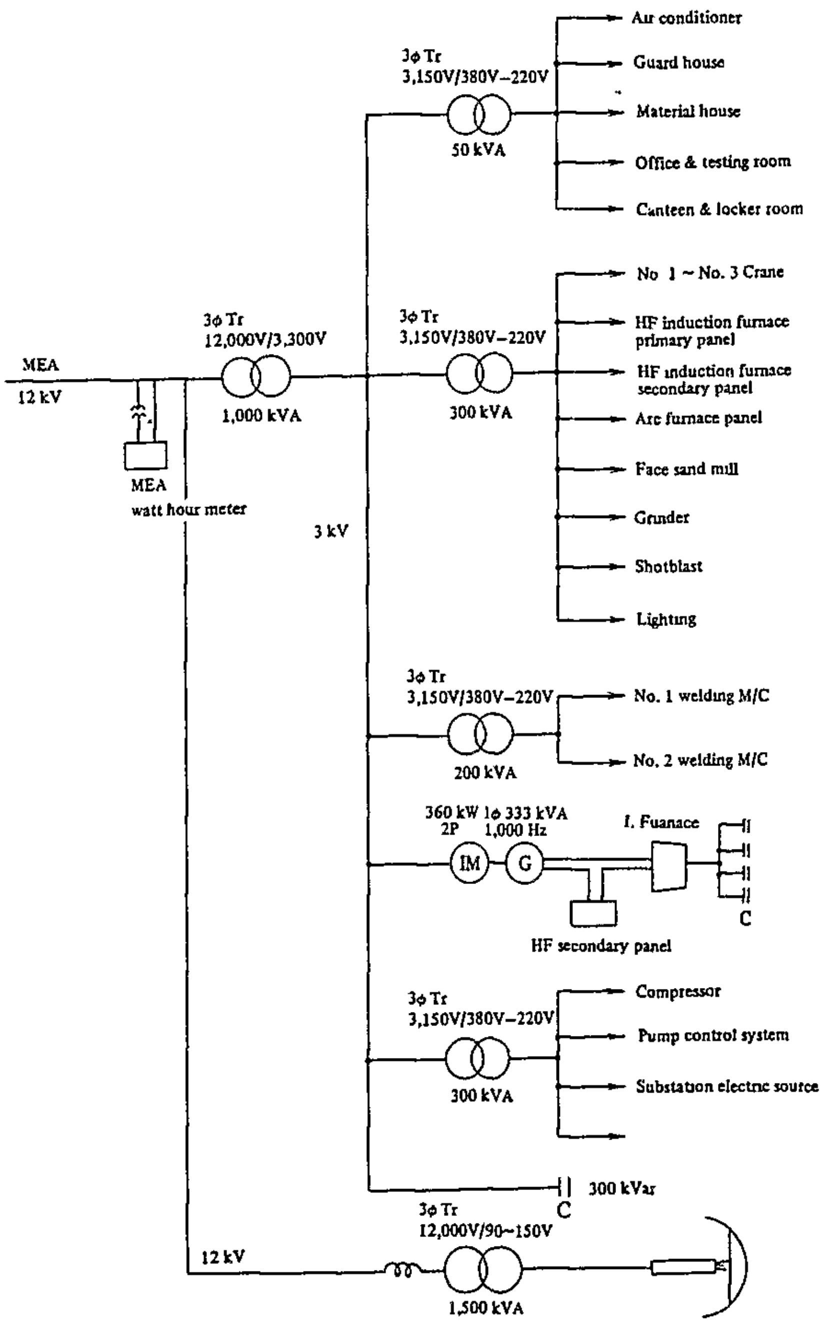
3 t electric-arc furnace	:	32 to 33%
1,000 kHz high-frequency induction furnace	:	9 to 14%
Motor, welding machine, gouging machine, other	:	53 to 58%

7.1 Principal data relating to power consumption

• Power company	:	MEA
• Peak demand	:	1,940 kW
• Power consumption	:	1,320,800 kWh
• Load factor	:	Operating time 2,550 h/year Average power 518 kWh Accordingly, 26.7%

- Penalty : Not paid
- Power factor : 95%
- Transformer : 1,500 kVA for electric-arc furnace
- Power consumption rate : 1,000 kVA for general electric power
  From the data of the previous year, 630 to 815 kWh/t for 3 t electric-arc furnace, and 901 to 1,098 kWh/t for high-frequency induction furnace

7.2 One-Line Diagram



8. Problems in Electric Power Control and Potential Solutions

8.1 Load Factor

The load factor is a low 26.7%. Peak demand of the previous year fluctuated between 1,380 and 1,940 kW, but if the maximum electric power is assumed to be 1,380 kW, the load factor is $\frac{518}{1,380} = 0.375$, or only 37.5%.

While 60% of the total capacity of the transformer is occupied by an electric-arc furnace, it only consumes 18—44% of electric power.

From this fact, it can be seen that the operating hours of the electric-arc furnace are shorter than other loads.

Therefore, the following countermeasures can be considered:

(1) Since the operating hours of the electric-arc furnace are short, other loads, which can be stopped or restricted, must be stopped to the extent possible during the melting period when a large amount of electric power is required by the electric-arc furnace. If the operating schedule is determined by this method, the peak demand can be restricted.

(2) A demand controller is installed to preset the peak demand at the value to be restricted, and when this value is likely to be exceeded, loads are cut off in a predetermined sequence. A simple diagram of the operating principle of the demand controller is shown below.

An watt-hour meter with a pulse oscillator is connected to the primary or secondary side of the transformer (primary side of diagram) and pulses from the watt-hour meter are counted at the demand controller.

When peak demand reaches the set value, a predetermined load is cut off so that the set value of peak demand is not exceeded.

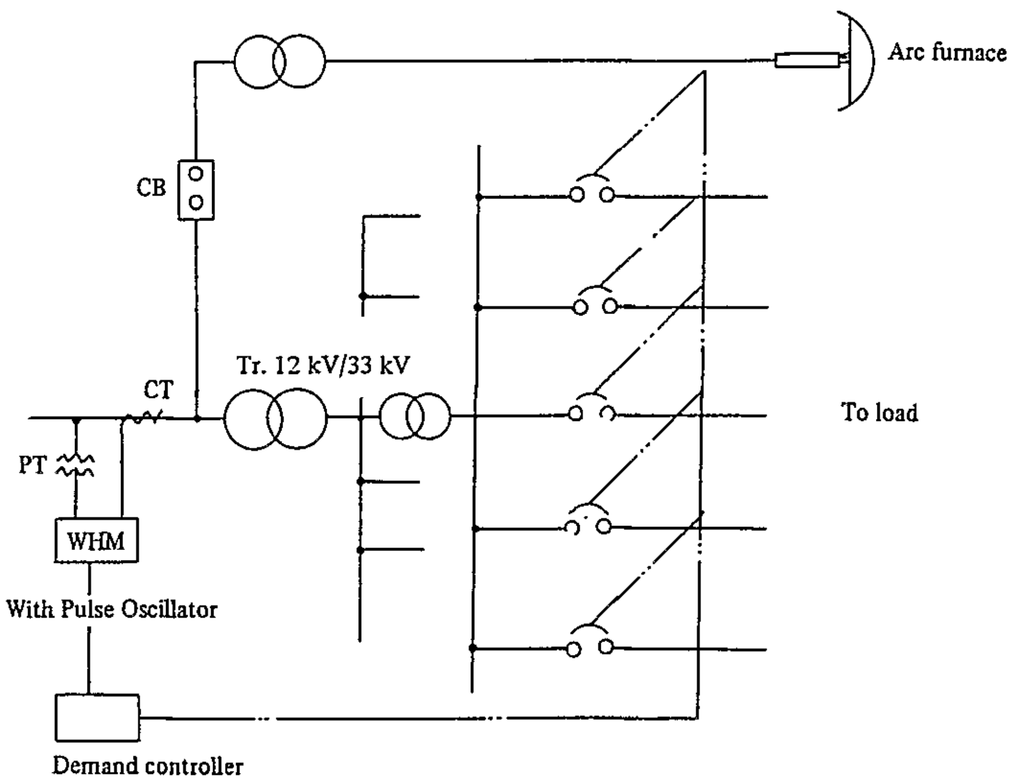
As the average value of peak demand at this factory during the previous year was 1,613 kW, the following saving calculated below can be obtained if set at 1,500 kW:

$(1,613 - 1,500) \times 95 \times 12 = 128,820$ Bt/year

Investment can be reasonably recovered in two years.

Melting Charge Weight & Electric Energy Consumption

	Total kwh	Peak demand	Arc Furnace		HF Induction Furnace		Motor & Other	
			Melting ton	kwh	Melting ton	kwh	kwh	%
		kw						
1	102,000	1,700	32.36	22,090	27.32	26,330	53,580	52.5
2	100,000	1,880	*54.683	37,020	16.153	17,422	45,558	45.6
3	156,800	1,580	*104.89	69,020	15.281	15,149	72,631	46.3
4	114,000	1,580	*56.31	39,630	19.85	20,540	53,830	47.2
5	112,000	1,940	40.688	28,760	26.413	25,180	58,060	51.8
6	132,000	1,700	*60.223	41,510	28.959	27,289	63,201	47.9
7	126,000	1,680	*66.283	44,400	23.903	23,675	57,925	46.0
8	104,000	1,600	28.904	18,640	24.584	24,006	61,354	59.0
9	100,000	1,440	39.088	26,600	20 991	18,927	54,473	54.5
10	98,000	1,440	38.857	31,680	13.245	13,550	52,770	53.8
11	90,000	1,440	42.488	29,560	7.598	8,013	52,427	58.2
12	86,000	1,380	37.889	28,370	6.711	7,367	50,263	58.4



System of Demand Controller

8.2 Cover of Induction Furnace

Charging of the high-frequency induction furnace is carried out successively and impurities in the materials to be charged are few and temperature control is carefully done. However, there is no cover for this melting furnace.

A cover must be provided to prevent heat loss from the surface of the melted metal.

When the amount of heat loss from the melted metal surface is 300 KW/m^2 in one example, the amount of electric power conserved by providing a cover becomes as follows:

Surface area of melted metal is assumed to be 0.2 m^2 and the annual operating hours at 2,250 h/year.

300 kW/m^2 x 0.2 m^2 x 2,250 h/year = 135,000 kWh/year

Since lower cooling water temperatures result in better efficiency of the induction furnace, the outlet temperature of the cooling water must be kept low by increasing the amount of cooling water.

Temperature of cooling water at the time of diagnosis was 30° C at the inlet and 43° C at the outlet.

8.3 Compressor

The pressure of the compressor outlet is 8.7 kg/cm^2 G as high and is reduced at service. By dropping this pressure to 7 kg/cm^2 G, the following conservation of energy can be obtained:

Since the required power for the compressor is a function of pressure and amount of air, the amount of energy conservation if the amount of air is constant, and when an actually measured value motor output is 20 kw, becomes as follows:

$$20 \text{ kW} \times \left\{1 - \frac{(8^{\frac{1.4-1}{1.4}} - 1)}{(9.7^{\frac{1.4-1}{1.4}} - 1)}\right\} \times 2{,}550 = 5{,}720 \text{ kWh/year}$$

(Although two 22 kW compressors were operated, it is assumed that only one compressor is continuously operated throughout the year.) Since the belt on the compressor is loosened, and may cause irregular rotation and shorten the life of belt, adjustment must be made.

Operating condition of motor (more than 15 kW).

Use	Capacity	Rated volt.	Rotation speed r.p.m.	Rated amp.	Measuring amp.	Power factor	Air pressure	Remarks
	kw				A	%		
Underground pump	Unknown	380	Unknown	Unknown	29.5 29.5 30.4	-		
Compressor	22	380	1,450	44.5	35.5 36.8 35.8	84	87 kg/cm^2	
Compressor	22	380	1,450	44.5	35.9 38.1 35.0	85	8.7 kg/cm^2	
Compressor	22	380	1,450	44.5	Out of operation			

8.4 Transformer

Actually measured values for each transformer other than that for the electric-arc furnace and the input of the factory are shown below.

Record of Receiving Point and 1,000 kVA
Transformer for General Electric Power

In come					Secondary for 1,000 kVA Tr				Remarks
Time	V	A	kW	cosφ	V	A	kW	cosφ	
1.50' PM	11.6 kV	22	420	0.95	3,300V	70	380	0.93	

In the following, a record of a transformer stepped down from 3,000V to 380V is shown below.

Trans.	Time	V	AR	AS	AT	Apparent power	kW	Cos. φ
kVA	PM	V	A	A		kVA		
50	1.45'	381	59.5	55.2	64.1	39.3	36.5	0.929
200	2.15'	391	23.9	28.3	23.4	16.2	7.6	0.469
300	2.20'	387	41	34	46	27.5	20.3	0.738
300	2.50'	383	137.3	146.7	143.8	95.4	76.4	0.801

Since the load of the 300 kVA transformer is small, it is possible to integrate it into one bank.

Because the no-load loss of one bank is reduced, electric energy conservation becomes as follows:

1.8 x 24 x 365 = 15,768 kWh/year

Then, the increase and decrease of the load loss are obtained

Since a 300 kVA transformer in the upper column has a repetitive load, this record is the minimum value and an average value is two times this value.

$20.3 \times 2 = 40.6$ kW

Transformer in upper column

$$40.6 + j40.6 \quad \frac{\sqrt{1 - 0.738^2}}{0.738} = 40.6 + j37.1 = 55$$

Transformer in lower column

$$76.4 + j76.4 \quad \frac{\sqrt{1 - 0.801^2}}{0.801} = 76.4 + j57.1 = 95.4$$

When composed: $116.7 + j94.2 = 149.5$

When a transformer in the upper column is removed, the load loss is reduced.

$$3.2 \times (\frac{55}{300})^2 \times 2{,}550 = 274 \text{ kWh/year}$$

Since the load of the transformer in the lower column is increased, load loss increases.

$$3.2 \times \{(\frac{149.5}{300})^2 - (\frac{95.4}{300})^2\} \times 2{,}550 = 1{,}201 \text{ kWh/year}$$

Therefore, increase of the load loss becomes as follows:

$1{,}201 - 274 = 927$ kWh/year

This is reduced from decrease of the no-load loss and the following conservation results:

$15{,}768 - 927 = 14{,}841$ kWh/year, 21,519 Bt/year

In this case, the secondary sides of two 300 kVA transformers must be connected by three CVV 1C/325 mm^2 cables.

8.5 Lighting

Sixty-six 40 W daylight fluorescent lamps are used in a canteen, test room and office.

By replacing these daylight fluorescent lamps with energy-conservation type white fluorescent lamps, 5W per lamp can be conserved.

$5 \text{ W} \times 66 \times 10 \text{ h} \times 300 \text{ day} \times 10^{-3} = 990$ kWh/year,

1,436 Bt/year

9. Summary

The abovementioned remedial measures, if actually taken, will bring about energy conservation effects as shown belows.

	(equivarent oil) kl/year	%
Sand sal of heat treatment furnace	28.8	20
Improvement of insulation of furnace wall	1.7	1.2
Improvement of insulation of carriage	7.2	5.0
Subtotal	37.7	26.2

	10^3 kWh/year	%
Cover of induction furnace	135.0	10.2
Change of pressure of compressor	5.7	0.4
Integration and abolishment of transformer	14.8	1.1
Improvement of lighting	1.0	0.1
Subtotal	156.5	11.8

Report No. 17: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— BIS Asia Equipment Industry Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— BIS Asia Equipment Industry Co., Ltd. —

1. Outline of the Factory

Address	No. 5 Viphavadee Rangsit Rd. Bangkhen, Bangkok	
Capital	40 million Bt	
Type of industry	Metal	
Major products	Truck chain (Link, Bush, Pin)	
Annual product	1,000 t	
No. of employees	150	
Annual energy consumption	Electric Power	848,000 kWh
Interviewees	Plant Manager Administ Manager Export Manager	Mr. Korsak Suphamanee Mr. Tuachai Daichareonsuk Mr. Prasert Lohabasai
Date of diagnosis	Jan. 14, 1983	
Diagnosers	T. Nakagawa, T. Noda, K. Kurita	

This factory belongs to the BIS group and began it's operation twelve years ago.

Imported raw steel materials are subjected to electric heating and mechanical processing to produce tractor parts such as link, pin and bush.

The factory's production capacity is 1,000 t/year, and since there are no domestic competitors, it is operated at full capacity.

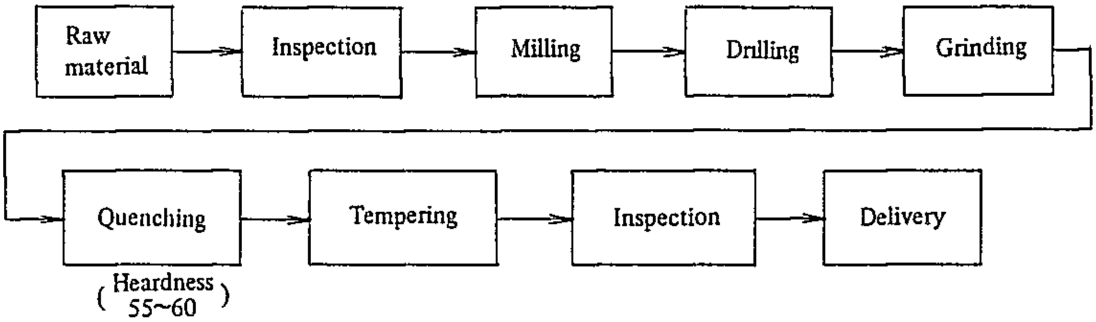
Products are sold not only in the domestic market, but are also exported to Malaysia, Singapore and Indonesia.

An exchange of technical information is conducted between Tokyo Iron Works.

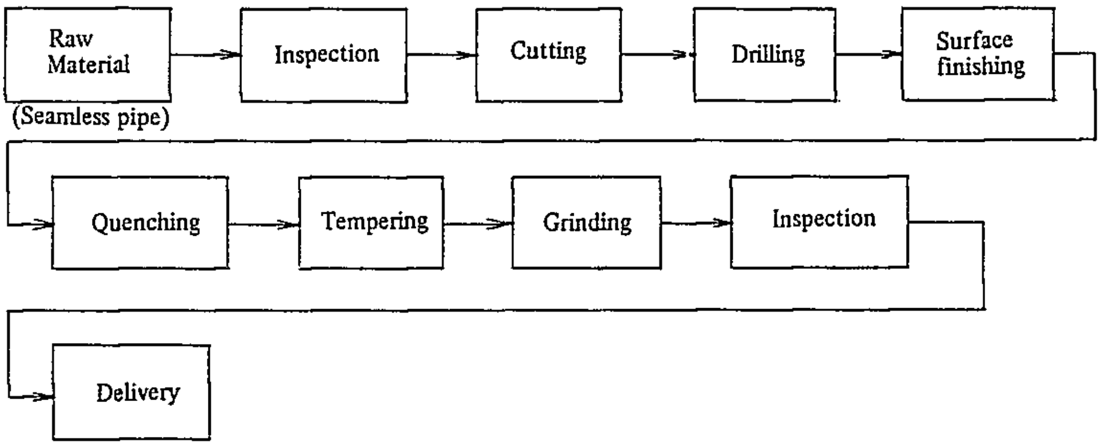
Inspection standards for raw materials, half-finished products and completed products have been established, and an emphasis on quality control has kept the proportion of defective products at less than 2%. Energy costs represent 3% of the product costs.

2. Manufacturing Process

(1) Link



(2) Pin, Bush

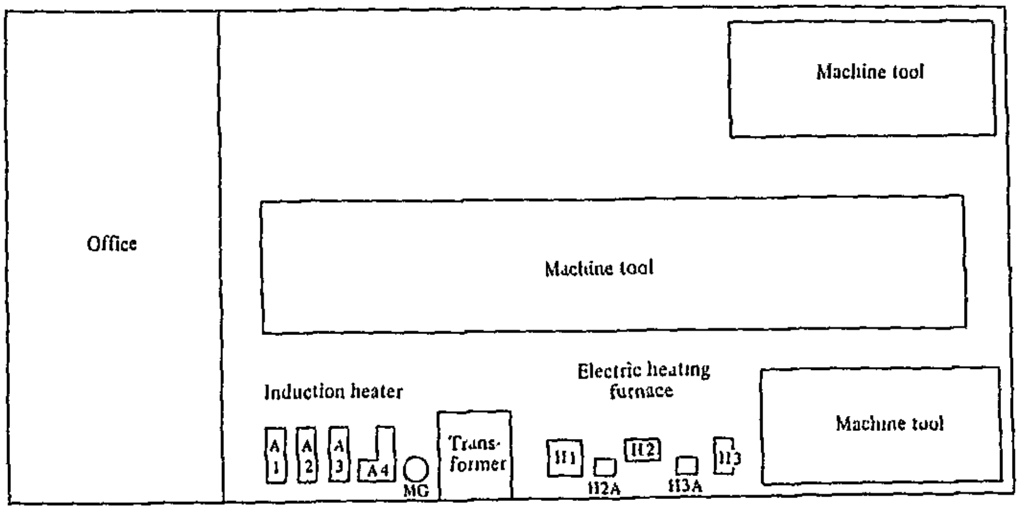


3. Major Equipment

3.1. Major Equipment

Name	No. of units installed	Type, etc.
Induction quenching heater	4	High frequency induction heater
Electric heating furnace	5	Quenching and tempering furnace
Machine tool	1 set	

3.2. Layout



4. State of Energy Management

4.1. Target for Energy Conservation and Investment

Currently, a target for energy conservation has not yet been set but efforts are in a planning stage.

Although energy conservation investment has not been made, the factory requires that any investment be fully recovered within five years.

4.2. Grasp of Energy Consumption

This company consumes only electric power, and there is no equipment requiring fuel.

Although the amount of electric power used is recorded every month, the fluctuation is not investigated.

Cost control for each product is carried out monthly, but energy consumption is not controlled because of slight variations.

An equipment list is prepared and the capacity of each machine is grasped.

There is no one-line diagram.

4.3. Energy Conservation Committee and Suggestion System

Although there is no special organization for energy conservation, problems are discussed in a monthly managers' meeting.

There is a plan to form a project team to promote energy conservation.

There is no contract with an outside consultant.

QC circle activities were established with the assistance of the company. Initially, they were conducted by staff members, but now foremen also participate.

Although there is no suggestion system, an improvement plan is now promoted through the QC circle activities. Results are reflected in bonuses and employees are well aware of this fact.

4.4. Employee Training

Employees attend training seminars and have been dispatched to Tokyo Iron Works on plant inspection tours.

4.5. Current Energy Conservation Activities

(1) The workweek was shortened from six to five days three months ago, and the hours per day increased from eight to nine hours.

As a result, losses due to starting and stopping equipment have decreased, resulting in improved operating efficiency, and in spite of the three hour decrease in the workweek, the same production output is maintained.

(2) Peak demand is controlled by starting equipment at different times every morning.

(3) Mechanical processing within the same group is carried out as much continuously as possible, and the charging of the heat treatment furnace has been increased from the previous 70 ~ 80% to 100%.

(4) An attempt is being made to turn off unnecessary lights and stop equipment that is running wihtout a load.

(5) There is a plan to change from batch operation of the induciton furnace for quenching to continuous operation to improve the operating efficiency.

A color standard for heating temperatures and a materials chart are posted on the side of the control panel of the heat treatment furnace, indicating that standardization of work is proceeding.

On the whole, this factory is well managed.

5. State of Electric Power Consumption

Most of the electric energy is consumed by one high-frequency induction furnace using an 8 kHz high-frequency motor-generator as a power source, three high-frequency induction furnaces powered by a 10 kHz high-frequency electronic tube, and five electric resistance furnaces (heating furnaces). On the day of diagnosis, only the 8 kHz high-frequency induction furnace and three electric resistance furnaces were in operation. The principal data relating to power consumption is as follows.

5.1. The Principal Data Relating to Power Consumption

- Power company : MEA
- Peak demand : 460 kW max.
- Power consumption : 848,000 kWh/year
- Load factor : Load factor is 74.5% with annual operating

time of 2,476 hours and average electric power of 342.5 kW.

- Power factor : 77%, penalty of 11,820 Bt/year, 2,070 Bt/month max.
- Transformer : There are two transformers 3ϕ 450 kVA and 400 kVA. In addition, there are three 1ϕ x 180 kVA transformers as a power source for the high-frequency induction heating device using an electronic tube.

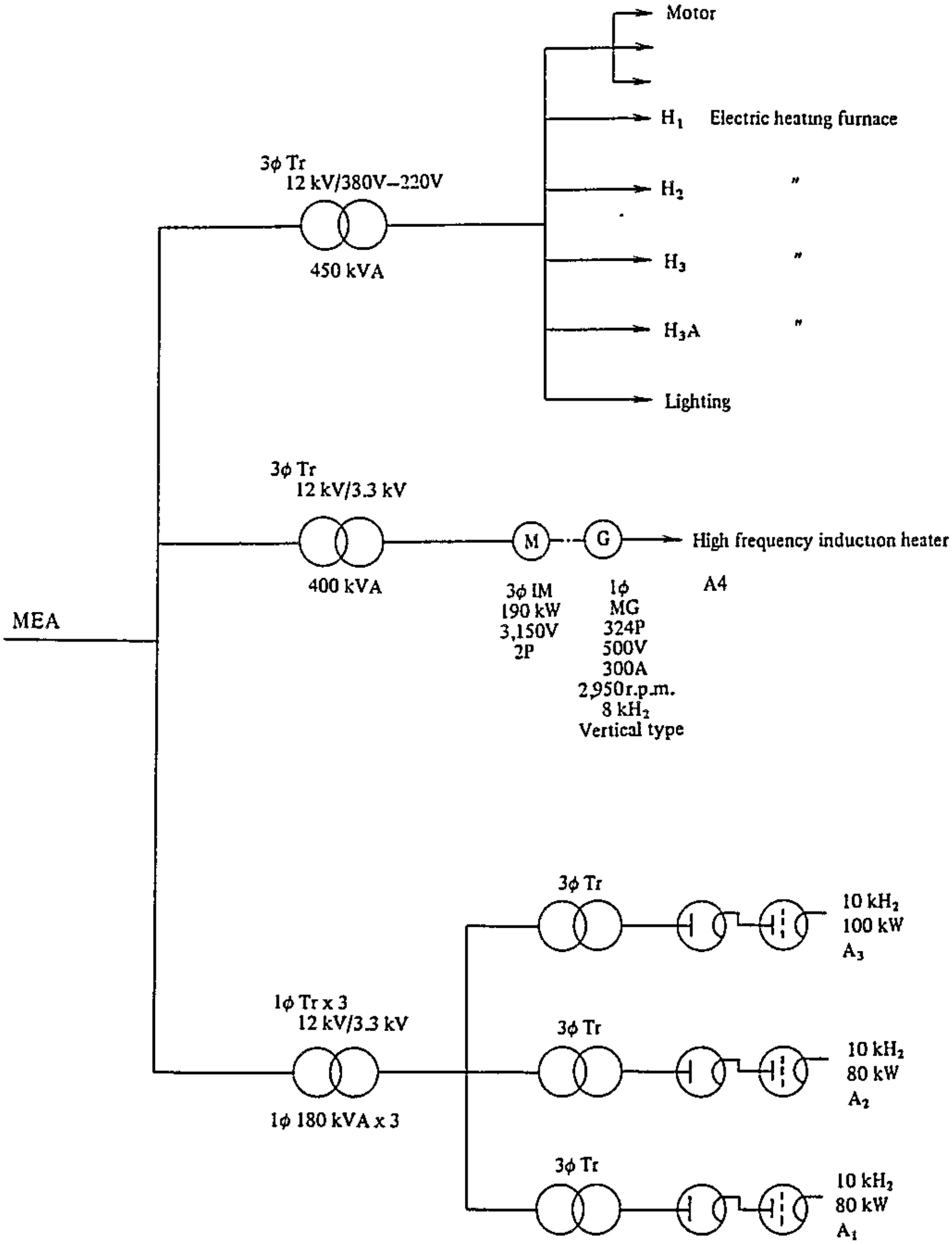
5.2. Electric Power Consumption Rate

The total output of the factory's three types of products is 1,000 t/year with an electric power consumption rate of 848 kWh/t.

5.3. Distribution of Electric Power Consumption

- Induction Heater : 17%
- Heating Furnace : 15%
- Roller : 8%
- Cutting : 7%
- Office : 18%
- Other : 35%

5.4. One-Line Diagram



6. Problems in Electric Power Control and Potential Solutions

6.1. Adoption of High-Efficiency High-Frequency Oscillator

Since a high-frequency generator using an electronic tube have to heat a cathode, heat loss is large and efficiency is poor, (efficiency: 40 ~ 45%).

When the electronic tube type frequency converter of 100 kW output is replaced with a thyristor inverter, its effect is as follows:

Efficiency of electronic tube type frequency converter: 44%

Efficiency of thyrister inverter: 96%

It is assumed that 17% of the electric energy used in the factory is consumed by the induction heater and half of this is used by the electronic tube type frequency converter.

Amount of electric Power conservation $= 848{,}000$ kWh/year x 0.17 x 0.5 x $(1 - \frac{0.44}{0.96})$

$= 39{,}043$ kWh/year (57,400 Bt/year)

In addition, a reduction in the peak demand can be expected.

$$100 \text{ kW} \times (\frac{1}{0.44} - \frac{1}{0.96}) \times 95 \times 12 = 140{,}000 \text{ Bt/year}$$

In total, the savings amount to about 200,000 Bt/year.

The cost of installation is estimated at approx. 1,000,000 Bt and can be recovered within about five years.

It is recommended that the A3 frequency converter, which is the most frequently used of the A1 to A3 converters, be replaced at an appropriate time considering repair costs, etc.

For the M-G device, its economic effect of replacement is small.

6.2. Transformer

To investigate how large a transformer is required, reactive power, apparent power and power factor were calculated as shown in the attached table from a list of electric power charges for the previous year. Apparent power exceeds 500 kVA only in three cases.

Since three 1ϕ 180 kVA bank are not operated on January 14, loads applied to the 450 kVA and 400 kVA banks were measured, and the records shown in the attached tables 2 and 3 were obtained.

Because the secondary side voltage of the 450 kVA transformer is low, measurement was made by clip-on wattmeter. However, since the voltage is high for the 400 kVA transformer, the load was measured at the M-G input board and output board.

As a result, it can be considered that the M-G of 8 kHz is connected to the secondary side of the 1ϕ 180 kVA, 12 kV/3.3 kV transformer, and thus the 400 kVA transformer can be removed from the circuit.

Attached Table 1 Peak Demand and Datas

Month	1	2	3	4	5	6	7	8	9	10	11	12
Peak demand kW	320	280	348	460	360	400	297	359	380	399	380	360
Reactive power kVar	340	220	307	300	240	340	298	259	280	379	280	280
Apparent power kVA	467	356	464	549	433	52.5	421	443	472	550	472	456
Power factor %	68.5	78.7	75	83.8	83.1	76.2	70.6	81	80.5	72.5	80.5	78.9

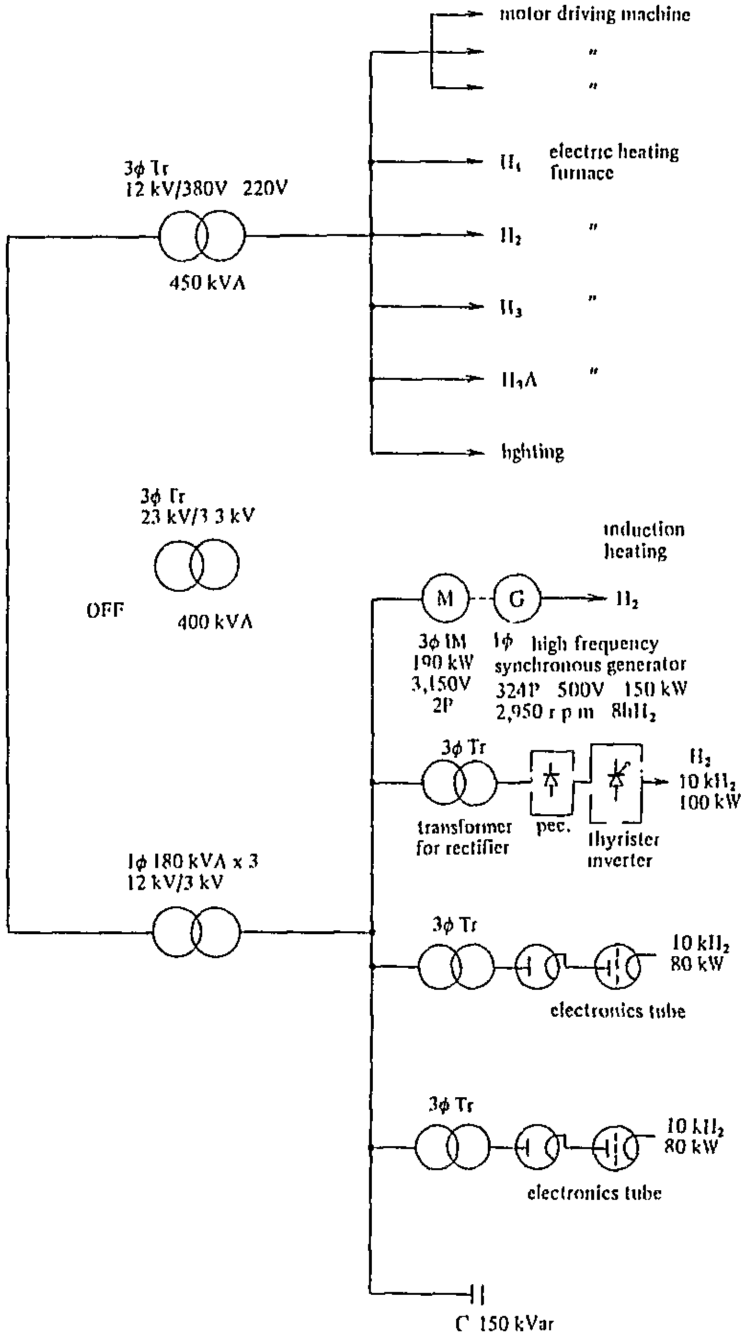
Attached Table 2 Record of Transformer

	Time	Volt V	Amp. A	Apparent power kVA	Power kW	Power factor	Remarks
450 kVA trans-former	3.20' PM	390	280	189	180	95.2	Load is electric heating furnace and motor.
	4 PM	390	280 ~320	189 ~216	185 ~212	97.9 ~98.1	
400 kVA trans-former	11 AM	460	360	165.6	120	72	M–G output power G = 1ϕ 150 kW 8kHz
	3 PM	500	270	135	115	85	↑ I_f = 9A 5 kVar ← I_f = 13A 1 kVar
M–G input power	3.10 PM	3,100	35	188	175	93	M = 190 kW IM 2P 2,950 r.p.m.
	3.15 PM	3,100	10	54	20	37	Input power when induction heater A4 is stopped.

– Attached Table 3 –

	Time	Volt V	Amp. A	Power kW	Furnace temperature °C	Remarks
Electric heating furnace H1	11 AM	360	18	11.2	210	Power factor 100%
	3 PM	370	74	47.4	510	"
Electric heating furnace H3	11 AM	160	10	2.8	180	"
	3 PM	150	60	15.6	480	"
Electric heating furnace H3A	11 AM	370	12	7.7	175	"
	3.30 PM	370	72	46.1	660	"

One line diagram (after improvement)



The resulting amount of energy conservation is calculated as follows, assuming that the iron loss is 2.5 kW and the copper loss at full load is 4.2 kW, and that the time during which M-G is operating but the induction furnace is not operating is one fourth and other loads are neglected:

$$2.5 \times 8.769 + 4.2 \times (\frac{188}{400})^2 \times 2{,}476 \times \frac{3}{4} + 4.2 \times (\frac{54}{400})^2 \times 2{,}476 \times \frac{1}{4}$$

$$= 23{,}670 \text{ kWh/year}$$

Then, the increase in the copper loss of the three 1ϕ 180 kVA transformers is as follows:

$$2.4 \times 3 \times (\frac{188}{540})^2 \times 2{,}476 \times \frac{3}{4} + 24 \times 3 \times (\frac{54}{540})^2 \times 2{,}476 \times \frac{1}{4} = 1{,}665 \text{ kWh/year}$$

Therefore, energy savings achieved by removing the 400 kVA transformer become 22,005 kWh/year or 32,347 Bt/year.

6.3. Power Factor

Power factor was 68.5% at minimum and 83.8% at maximum, as shown in attached table.

Since reactive power corresponding to the penalty is 138 kVar max., the power factor at peak demand by inserting a 150 kVar condenser becomes more than 85%, even at minimum.

Since most of the load of the 450 kVA transformer is from the electric resistance furnace, the power factor is high and is estimated to be about 95%.

Therefore, the power factor is reduced and a penalty is imposed because of the induction heater. A condenser had better connected to the secondary side of the three 1ϕ 180 kVA transformers to which induction furnaces are connected.

The advantages which can be achieved by connecting a 150 kVar condenser to the secondary side of the 1ϕ 180 kVA transformer are as follows:

(1) Exemption of penalty: 11,820 Bt/year

(2) Reduction in copper loss of 1ϕ 180 kVA transformer

It is estimated that the apparent power of the induction heater is 360 kVA and the power factor is approx. 61% from the attached tables 1 and 3 (Where two induction furnaces A_3 and A_4 are operated).

Since improvements of the apparent power to 272 kVA and the power factor to approx. 91% are attained by the connection of the 150 kVar condenser, the copper loss of the 1ϕ 180 kVA transformer is reduced as follows:

$$(\because 360 \times 0.61 + j(360\sqrt{1 - 0.61^2} - 150) = 248 + j111 = 272)$$

$$2.4 \times 3 \times \{(\frac{360}{540})^2 - (\frac{272}{540})^2\} \times 2{,}476 \times \frac{1}{2} = 1{,}729 \text{ kWh/year (2,541 Bt/year)}$$

In this case, it is assumed that A_3 and A_4 are operated at the same time for half of the total annual operating time.

Therefore, annual savings due to an improvement of the power factor become

14,362 Bt/year.

The approx. 50,000 Bt required for the 150 kVar condenser and switchgear can be depreciated in three and a half years.

6.4. Voltage

Because the voltages of electric resistance furnaces H_1 and H_{3A} at 370 V are lower than the rated voltage, adjustment of tap of 450 kVA transformer is recommended.

6.5. Lighting

The mercury-arc lamps are used in plant building and the daylight fluorescent lamps in office.

However, plastic sheets used partly as the roof material of the plant, allowing sufficient daylight, made possible to turn off almost all of the mercury-arc lamps.

It is recommended that the fluorescent lamps at the end of their service lives be replaced with energy-conservation type white fluorescent lamps which are currently manufactured in Thailand.

When 150 lamps in the offices light ten hours per day and go out on holidays, the resulting power conservations becomes as follows:

$(40 - 35) \times 150 \times 10 \text{ h} \times 304 \text{ days} \times 10^{-3} = 2,280$ kWh/year

3,306 Bt/year

6.6. Tempering Furnace

This is a batch type heating furnace which consumes a large amount of electric power to heat the furnace body and carriage.

Therefore, the following measures must be taken:

(1) Insulation bricks must be provided on the upper surface of the carriage.

(2) After heating is completed, the carriage should be returned to its original position in the furnace as soon as the heated materials are discharged, and the door should be closed to prevent a drop in temperature.

(3) The thickness of the plate of the case and shelf on which the heated materials are placed must be reduced to save weight.

7. Summary

The abovementioned remedial measures, if actually taken, will bring about energy-conservation effects as shown below.

		10^3 kWh/year	%
Improved efficiency of high-frequency power source	:	39.0	4.6
Reduction of transformers	:	22.0	2.6
Improvement of power factor	:	1.7	0.2
Replacement of fluorescent lamp	:	2.3	0.3
Total		65.0	7.7

Report No. 18: Metal

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Kang Yong Manufacturing Co., Ltd. —

June, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Kang Yong Manufacturing Co., Ltd. —

1. Outline of the Factory

Address	50 Moo 11 Soi Watsungsom T. South Samrong A. Prapradaeng Samutprakarn	
Capital	5 million Bt at establishment	
Type of industry	Metal	
Major products	Screw, Nail	
Annual product	8,940	
No. of employees	135	
Annual energy consumption	Electric Power	1,200,000 kWh.
Interviewees	Deputy Managing Director, Komol Vongsthongsri Chief Engineer, Tawewat Poonnimuand	
Date of diagnosis	Jan. 31 ~ Feb. 1, 1983	
Diagnosers	T. Nakagawa, T. Noda, K. Kurita	

The factory belongs to the Kang Yong Group and was founded 21 years ago. The factory started from producing nails and is now producing bolts and nuts, as well. Recently, the factory started to manufacture bright steel bar and tapping screws. The factory is a typical machine-processing factory using wire as materials manufactured in Thailand and imported from abroad.

Almost all of the facilities and equipments are made in Japan.

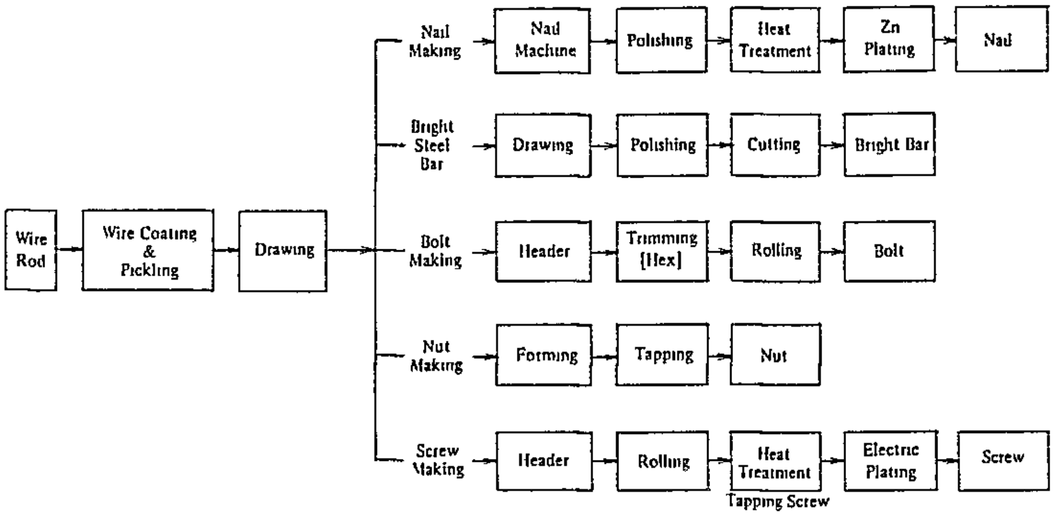
The factory is receiving technology from Nitto Seiko for the manufacture of tapping and machine screws. The factory receives privileges from BOI on the manufacture of tapping and machine screws.

The following is the factory's production capacity.

Common Nail		400 t/month
Square Nail		20 t/month
Concrete Nail		50 t/month
Bright Steel Bar		150 t/month
Bolt, Nut	each	50 t/month
Tapping and Machine Screw		25 t/month
Total		745 t/month

The total annual production capacity is 8,940 tons. The factory is operating at 50% capacity, on one shift and with some overtime work. When operating at full capacity, the factory works on two shifts.

2. Manufacturing Process

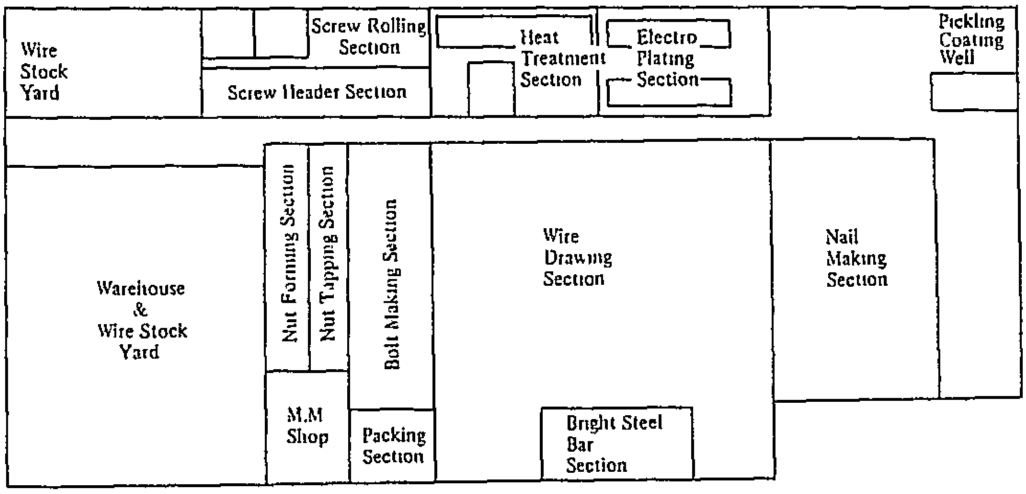


3. Major Equipment

3.1. Major Equipment

Name	No. of units installed	Type, etc.
Nail making machine	1 set	
Wire drawing machine	1 set	
Bright steel bar machine	2 units	
Bolt making machine	1 set	
Nut making machine	1 set	
Screw making machine	1 set	
Heat treatment furnace	1 set	
Electric plating	2 units	

3.2. Layout



4. State of Energy Management

4.1 Investment in Energy Conservation

The factory has no set energy conservation targets in particular. However, the factory wishes to implement concrete energy conservation measures in the future.

In the past, no investments in energy conservation have been made. An investment recovery period of less than three years has been planned for future investments.

4.2 Grasp of Energy Consumption

The electric power is the only energy used by the factory, and no fuel is consumed. Electric energy consumed every month is recorded. However, fluctuations in electric energy used are not analyzed to calculate the consumption rate and to study reasons for fluctuations.

Electric energy consumed is not broken down into principal products or processes.

Power consumption is not recorded every hour, and daily load curves are not plotted, either. This data will be useful to suppress the peak demand and sould be plotted.

4.3 Energy Conservation Committee and Suggestion System

The factory is planning to form an organization to promote energy conservation in March, 1983, and the manager and the assistant manager of the Technical Section are scheduled to be appointed as committee members.

The factory has no suggestion system yet.

4.4 Employee Training

The factory staff participated in seminars outside the factory 3 to 4 times last year.

Intracompany seminars will be considered in the future, and the Energy Conservation Committee will study the details of the plans.

The factory staff has visited factories of other industries, but not factories of the same industry.

The company is not making direct appeals to its employees for their cooperation in energy conservation. Appeals are made through section managers and assistant managers.

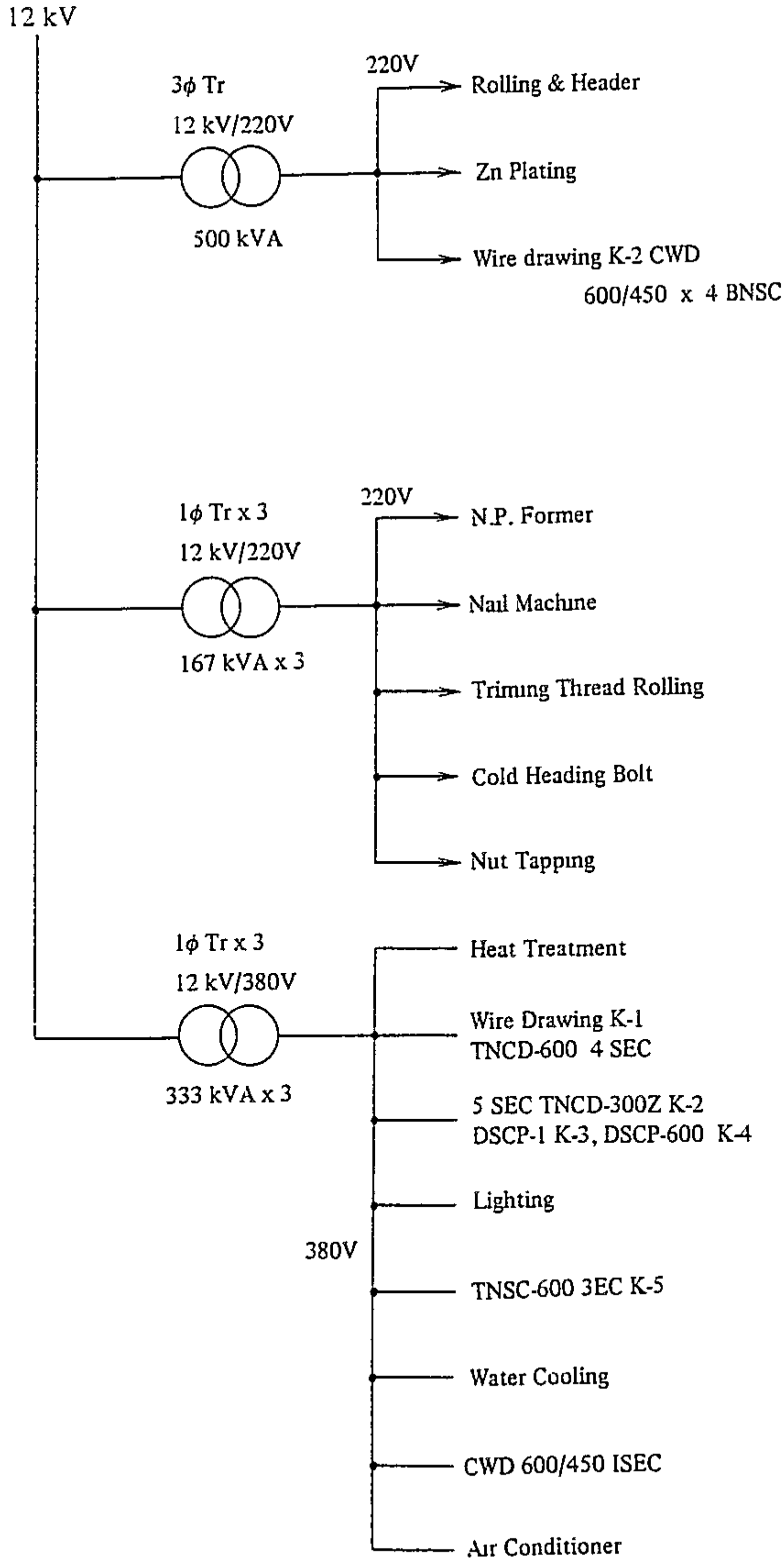
5. State of Power Consumption

The bulk of the electric power is consumed by the wire drawing process. The power to motors larger than 30 kW is supplied at 380 V, and to motors less than 30 kW, at 220 V.

5.1 Principal data relating to power consumption is shown in the following.

- Power company : MEA
- Peak demand : 740 kW
- Power consumption : 1,200,000 kWh/year 2,350,000 Bt/year
- Load factor : Annual working hours 2,400 hours
  Average power 500 kW
  $\frac{500}{740} = 0.676$ 67.6%
- Power fator : 71%
  No power factor improvement by condensers.
  Penalties are paid every month.
- Transformers : 3ϕ 500 kVA 12kV/220 V 1 bank
  : 1ϕ 167 kVA x 3 12 kV/220 V 1 bank
  : 1ϕ 333 kVA x 3 12 kV/380 V 1 bank
- Electricity energy consumption rate : 134 kWh/t

5.2 One Line Diagram



6. Problems in Power Control and Potential Solutions

6.1 Transformers

Motors are divided into two systems—220 and 380 V systems, and there are three banks of transformers. Two banks are for 220 V, and one bank, for 380 V. A study for the possiblity to reduce the number of transformer banks is as follows:

Of the tables shown in the following, the top three tables show values measured during the factory survey, and the other table, data logged by the factory for 6 months in 1982.

1φ 167 kVA x 3 12 kV/220 V

Measured by clip-on power meter

Time	Volt. V	Amp. A	Apparent power kVA	Power kW	Power factor %	Remarks
1. 31 2 PM	229	490	194	105	54.1	
3 PM	233	257	104	49	47.3	Cannot measure amp. and power at same time
2. 1 10.25 AM	230	222	88.8	51.2	57.9	
11.30 AM	231	506	179.7	110	61.2	

3φ 500 kVA 12 kV/220 V

Measured by clip-on power meter

Time	Volt. V	Amp. A	Apparent power kVA	Power kW	Power factor %	Remarks
1. 31 2 PM	227	275	108	86	79.6	
3 PM	226	182	71	59.7	84 1	
2. 1 10.25 AM	226	200	78	56	71.8	
11.30 AM	228	155	61	39	63.9	

1φ 333 kVA x 3 12 kV/380 V

Measured by clip-on power meter

Time	Volt. V	Amp. A	Apparent power kVA	Power kW	Power factor %	Total power by contract power meter of MEA
1. 31 2 PM	397	600	413	310	75.1	
3 PM	405	670	470	352	74.9	2.07' PM~3.07' PM 470 kwh
2. 1 10.25 AM	396	780	535	460	86	
11.30	401	642	446	364	81.6	2.1 10.40' AM~11.40' AM 490 kwh

Factory record in half year at 1982

kwh	Peak demand kw	Peak demand fee Bt	Penalty kVar	Penalty fee Bt	Reactive power kVar	Apparent power kVA	Power factor %
209,000	740	70,300	254	3,810	720	1,032	71.7
122,000	640	60,800	227	3,405	630	898	71.3
119,000	640	60,800	227	3,405	630	898	71.3
142,000	670	63,650	278	4,170	700	969	69.1
112,000	670	63,650	238	3,570	660	940	71.3
113,000	630	59,850	223	3,345	620	884	71.3

Even when the power at the same time shown in the top three tables is added, the total power consumption is smaller than the maximum value (740 kW) of the peak demand in the data for six months in 1982.

Therefore the apparent power for 740 kW in March, 1982 is compared with the transformer capacity. The apparent power is 1,032 kVA when the peak demand was 740 kW. Assuming one bank (167 kVA x 3) is cut off.

500 kVA + 3 x 333 kVA > 1,032 kVA.

Thus, unless the 200-V load exceed 500 kVA, one bank (167 kVA x 3) can be omitted easily. Separation of one bank of 1ϕ 167-kVA x 3 will offer the following advantage.

Reduced no-load losses.

167 x 3 x 0.005 kW x 24 h x 365 days = 21,944 kWh

Calculations of reduced copper losses are made using data at 2 p.m. with 500 kW, close to the average power. Assuming the transformer copper losses to be 10 kW,

$$10 \times \left(\frac{194}{167 \times 3} \right)^2 \times 2{,}400 = 3{,}606 \text{ kWh/year}$$

the load of 1ϕ 167 kVA x 3 transformers shifts to the 3ϕ 500 kVA transformer, and the copper loss of the 3ϕ 500 kVA transformer will be

$$8 \times \left\{ \left(\frac{297}{500}\right)^2 - \left(\frac{108}{500}\right)^2 \right\} \times 2{,}400 \text{ h} = 5{,}879 \text{ kWh/year}$$

and the copper losses increase by 5,879 − 3,606 = 2,273 kWh. Therefore, by separating 1ϕ 167 kVA x 3 transformers, an energy saving of 21,944 − 2,273 = 19,671 kWh/year will result.

6.2 Power Factor

Because of the low power factor, the factory is paying a penalty every month. Judging from the data described in the previous section, payment of a penalty seems to be avoided by using condensers of 300 kVar.

Probably because there are many small motor loads on the 220-V side, the power factor of the 220-V side is lower than that of the 380-V side. So, it is preferable to install condensers in the 220-V side by a larger proportion than that of the transformer capacity. When condensers of 150 kVar are installed in each sides, the following results will be possible.

Measuring date	Before improvemen of power factor		After improvement of power factor		Remarks
	Apparent power kVA	Power factor %	Apparent power kVA	Power factor %	
1.31 2 PM	191 + j 228 = 297	64.3	191 + j 78 = 206	92.7	C = 150 kVar 200 V
2.1 11.30' AM	149 + j 189 = 241	61.8	149 + j 39 = 154	96.8	C = 150 kVar 200 V
1.31 2 PM	310 + j 273 = 413	75.1	310 + j 123 = 334	92.8	C = 150 kVar 380 V
2.1 11.30 AM	364 + j 258 = 446	81.6	364 + j 108 = 380	95.8	C = 150 kVar 380 V

Calculating the reduction in copper losses using larger values in the foregoing table, the energy saving for the 500 kVA transformer will be:

$$8 \times \{(\frac{297}{500})^2 - (\frac{206}{500})^2\} \times 2{,}400 \text{ h} = 3{,}515 \text{ kWh/year}$$

and energy saving for the 1ϕ 333 kVA x 3 transformers will be:

$$3 \times 5 \text{ kW} \times \{ (\frac{446}{3 \times 333})^2 - (\frac{380}{3 \times 333})^2 \} \times 2{,}400 \text{ h} = 1{,}966 \text{ kWh/year}$$

All in all, energy saving of 5481 kWh/year will be possible. The average monthly penalty for the six months in review was 3617.5 Bt, and penalties of 43,410 Bt can be saved a year. The advantage is 51,357 Bt combined with energy saving for 5481 kWh (7947 Bt). The cost required for this improvement is approximately 100,000 Bt and can be recovered in about two years.

6.3 Peak Demand

The load factor of 67.6% is not low for the machinery industry. However, the peak demand has varied between 630 and 740 kW. It will be possible to reduce the peak demand of every month by 50 kW on an average using demand controllers. Reducing the peak demand of last year by 50 kW on an average, saving of 95 x 50 x 12 = 57,000 Bt/year will be possible, and the cost of 200,000 Bt. for demand controllers can be recovered in three years.

6.4 Motor Operating State

When the rated output of a motor is too large compared with the load, the load becomes light and the power factor lowers.

Although replacement of a motor having excessive capacity with smaller one would bring about some cost savings through improved power factor, it will take a long time to recover such replacement cost by cost savings alone. So, it is more practical to replace it only when a proper spare motor is at hand.

The operating state of the motors is described in the table below. Those motors with a low load current (measured value) relative to the rated current are shown in the following.

(1)	Wire drawing K5	30 kW	41.1%
(2)	Wire drawing K3	50 HP	44.7
(3)	MP Bormer-19B	30 HP	29.4

In addition to them, there were two motors showing load factors on the 50% level (one motor each 30 and 15 kW).

Operation of Motors

Use	Capacity	No.	Rated volt. V	Rated (A) A	Amp. Measured (B) A	(B)/(A) %	Rotation speed r.p.m.	Power factor %	Remarks
Wire drawing M/C K5	30 kW	1	380	60.8	26.3	41.1	965	66	Measured volt 396 V
"	30	1	"	60.8	45	74	965	84	396 V
" K3	50 HP (37 kW)	1	"	75.3	33.7	44.7	980	61	396
" K1	30 kW	1	"	60.8	59.3	97.5	965	79.5	394
" K1	30	1	"	60.8	33.9	55.8	965	68	392
" K1	30	1	"	60.8	38.9	64	965	74	396
Bright steel bar polishing	18.5	1	"	35	32.8	93.7		84	400
Bolt MP Bormer 19B	30 HP	1	220	96	28.2	29.4	705	46	223
" NP325	15 kW	1	"	56	28.8	51.4	960	64	224
" NP330	18.5	1	"	80	56.7	70.9	725	53	225
Drawing M/C K2	30 HP	1	"	75	72.2	96.3	1,465	86	220
"	30	1	"	75	51.9	69.2	1,465	79.5	221
	30	1	"	75	57.1	76.1	1,465	82	221
Furnace									
	kW	set	V	A	A	%			V
Annealing furnace T	3x30	1	380	136.7	106.1	77.6			394
" Q	40.5	1	"	106 6	75.5	70.8			393

6.5 Lighting

40-W daylight fluorescent lamps are used. By changing them to energy-saving type white fluorescent lamps, 5 W can be saved per lamp. A total of 172 lamps are used, and these should be replaced with energy-saving type white lamps when they are worn out. Energy savings of

$5 \times 172 \times 10^{-3} \times 10h \times 300d = 2{,}580$ kWh/year

will be possible a year. Plastic daylight intake openings should be provided on the factory roofs, and lights should be turned off whenever possible.

6.6 Voltage

The voltage on the 380-V side was high, indicating maximum 400 V on the motor panel as shown in the data supplied in Paragraph 6.4. Overexcitation is caused when the voltage is high, to increase no-load losses. Therefore, the voltage applied to motors should be monitored in the morning, afternoon, and at night, every day, and the secondary voltage should be adjusted by the transformer taps. When the motor rated voltage is 380 V, the voltage actually applied should be within the range of 380 ± 10 V.

6.7 Motor Belts

Transmission of motive power is performed in the factory by V belts. In many instances, fewer belts than what are required are installed. This may cause uneven rotation and substandard products, deteriorating the product yield. It is necessary to correct the belt looseness or numbers of belts required, to smoothly transmit motive power and to improve the yield, in order to save energy. The V belt state by each process is described in the following.

(1) Nail Manufacture

3 belts are required and 3 belts are installed	20 Spots
3 belts are required and 2 belts are installed	14 Spots
3 belts are required and 1 belt is installed	1 Spot
2 belts are required and 2 belts are installed	8 Spots
2 belts are required and 1 belt is installed	4 Spots

(2) Wire Drawing

7 belts are required and 6 belts are installed	1 Spot
6 belts are required and 5 belts are installed	2 Spots
6 belts are required and 4 belts are installed	2 Spots
5 belts are required and 5 belts are installed	6 Spots
5 belts are required and 4 belts are installed	4 Spots
5 belts are required and 3 belts are installed	2 Spots
4 belts are required and 4 belts are installed	3 Spots
3 belts are required and 3 belts are installed	2 Spots
2 belts are required and 2 belts are installed	1 Spots

2 belts are required and 1 belt is installed — 3 Spots.

(3) Nut Forming and Tapping

8 belts are required and 7 belts are installed	1 Spot
5 belts are required and 5 belts are installed	1 Spot
5 belts are required and 4 belts are installed	1 Spot
4 belts are required and 4 belts are installed	7 Spots
3 belts are required and 3 belts are installed	9 Spots
3 belts are required and 2 belts are installed	8 Spots
2 belts are required and 2 belts are installed	8 Spots
1 belt is required and 1 belt is installed	Omitted

(4) Screw Header

2 belts are required and 2 belts are installed	9 Spots
1 belt is required and 1 belt is installed	Omitted

Of 117 spots, 74 spots, or 63.2%, had the required numbers of belts installed, except for those spots that require only one belt.

The foundations of some motors were insecure, and the motors were vibrating. These foundations should be repaired.

6.7 Less Furnace Cooling Water

The furnace cooling water outlet temperature was below 40° C. Normally, the facilities are not troubled even when the outlet temperature is raised up to 50° C. The cooling water amount should be reduced little by little and the temperature be adjusted to about 50° C.

Motive power to feed the cooling water will decrease about 1% by this method.

6.8 Smaller Tempering Furnace Charging Opening

High temperature air was blowing out from the charging opening of the tempering furnace. This means that cold air was being sucked in from the lower section of the charging opening.

The charging opening area should be made smaller even by a little to prevent cold air suction.

6.9 Improved Charging Hood of Quenching Furnace

RX gases were blowing out from the charging opening of the quenching furnace and was burning.

As the heat quantity lost is large, the hood installed in front of the charging opening should be made longer and the combustion heat should be utilized to preheat products.

7. Summary

The abovementioned remedial measures, if actually taken, will bring about energy-saving effects as shown below.

	10^3 kWh/year	%
Integration of Transformers	19.7	1.6
Improvement of power factor	5.5	0.5
Replacement of fluorescent lamp	2.6	0.2
Total	27.8	2.3

APPENDIX

7. Summary

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	10^3 kWh/year	%
Integration of Transformers	19.7	1.6
Improvement of power factor	5.5	0.5
Replacement of fluorescent lamp	2.6	0.2
Total	27.8	2.3

APPENDIX

Study Team Members

Part	Name	Present Post
Team Leader	Mitsuo Iguchi	Managing Director, ECC
Textile Group		
Heat	Kaoru Nakao	Registered Diagnoser, ECC
〃	Yoshio Ohno	〃
Power	Motoki Matsuo	〃
Metal Group		
Heat	Teruo Nakagawa	Manager, International Cooperation Section, ECC
〃	Toshio Noda	Registered Diagnoser, ECC
Power	Ken-ichi Kurita	〃

Counterparts Names

Part	Name	Organization
Textile	Danai Egkamol	NEA
	Pinyo Tonthumas	〃
	Banphot Diskul	〃
	Thougdee Genjamongkon	〃
	Umporn Koonchonrat	〃
	Derake Wurhichok	MOI
Metal	Supachok Kusolsong	NEA
	Supon Khwankongrai"	
	Thumasak Suwanadhep	〃
	Chadcharachai Teeraslip	〃
	Tawatchai Titivudtiwong	MOI

As observers, members of the following organizations participated in the diganosis occasionally:

Industrial Finance Corporation of Thailand

Thai-Japan Technological Promotion Association

Thammasat Univ.

Itinerary of Study

1983	
Jan. 9	Departed Narita, arrived Bangkok
10	Visits to the JICA Bangkok Office, Japanese Embassy, NEA, and (TPA)
11	Explanation of the checklist to the counterparts
12	Unpacking, checking, adjustments, etc. of measuring instruments. Meeting with NEA Director General and Assistant Director General. Report on summary of outcome of the first study and explanation of plans for the second study.
13 – Feb. 9	Factory diagnosis and data sorting
10	Cleaning, repair, and packing of measuring instruments and data sorting
11	Visits to JICA, Japanese Embassy and TPA. Meeting with NEA Director General
12	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

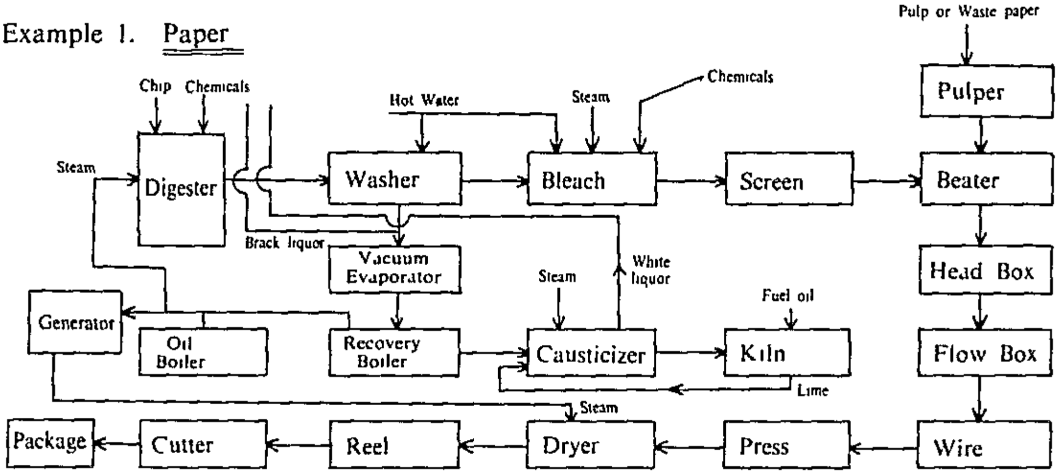
Built(A.D.) 設置(西暦)	Type 型式	Nominal Capacity 公称能力		Kind of Fuel 燃料の種類	Operating period 運転時間	
		Steam Press. kg/cm²G	Evaporating Volume t/h		hrs/day	days/y

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

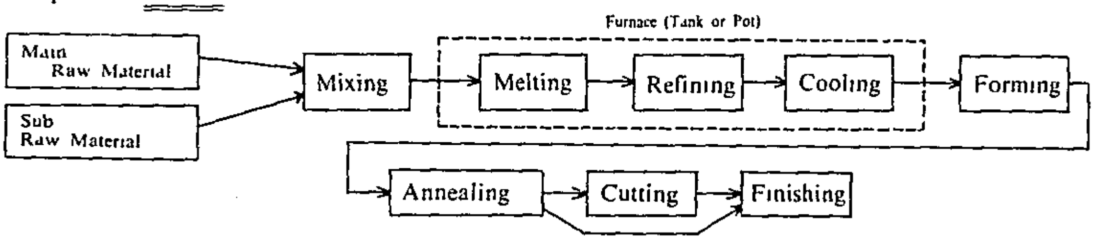
Built(A.D.) 設置(西暦)	Name of Facility 設備名	Products 生産物	Output 生産高		Kind of Energy used 使用エネルギーの種類	Operating period 運転時間	
			Nominal 公称	Present Condition 現状		hrs/day	days/y

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

Example 1. Paper

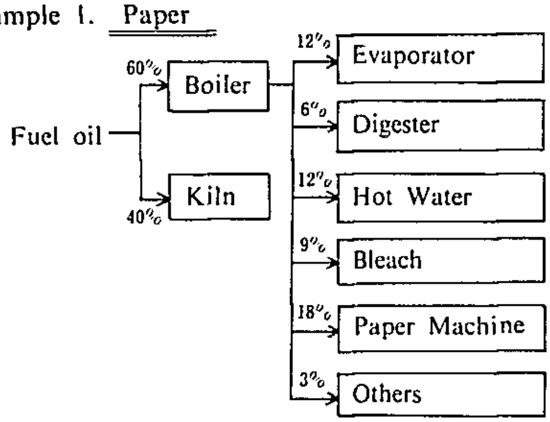


Example 2. Glass

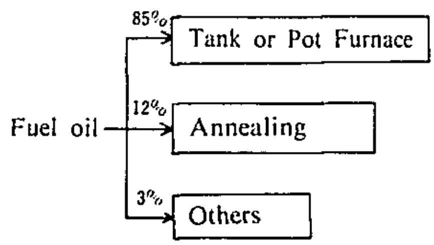


17 Energy Flow-chart, エネルギー流れ図

EXample 1. Paper

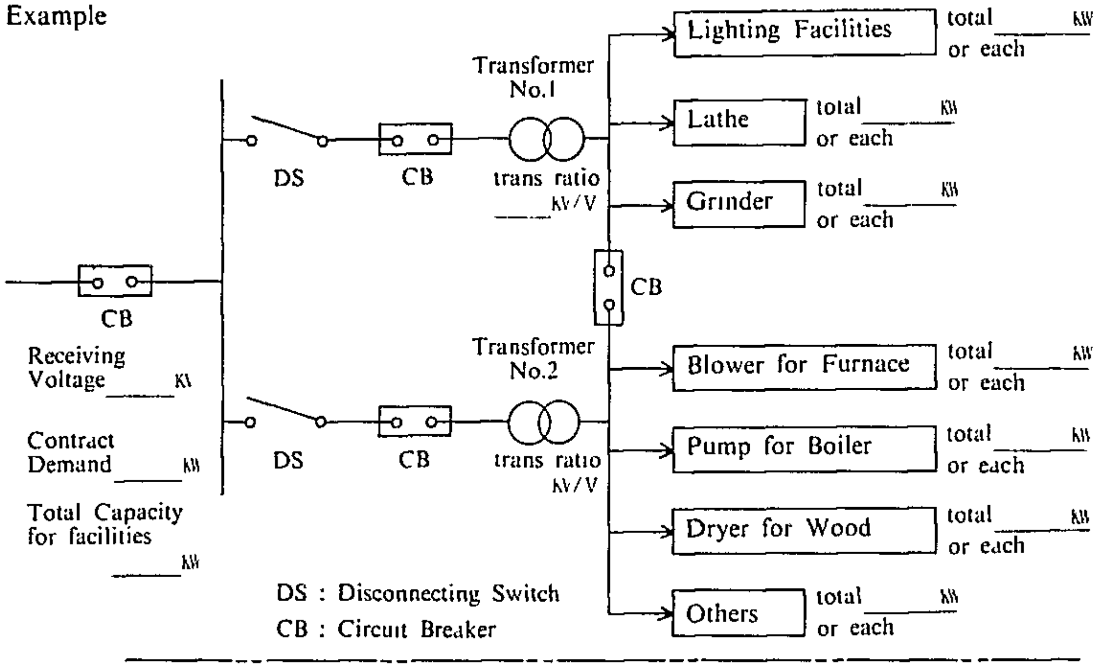


Example 2. Glass



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

APPENDIX 4 添付資料4

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				
			Electric Power		Fuel	
	Measurement of Consumption	消費量計測	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

2-5 Major Facilities Using Heat for Textile

2-6 Textile (Dyeing machine)

2-7 Textile (Dryer)

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	___ m3/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.m^{3}N				
	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^{2}G				
	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.m^3/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	______ m^3/min.
23	Heating	加 熱	
	Furnace Temp.	炉 温	______ °C
	Charging Temp.	装入温度	______ °C
	Extracting Temp.	抽出温度	______ °C
	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

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

	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.m^3/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, not exist 有 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	

2-5 Major Facilities Using Heat for Textile

No. 番号	Name of Facilities 装置名	Heating 加熱方法		Material 素材				Operation 加工条件		Out Put 生産高	Operat'g hour 運転時間	Maker メーカ	Time Built 設置年月
		Heat Source 熱源	Phase 使用形態	Quality 材質	Type 形態	Spec. 仕様	Weight 重量	Speed 加工速度	Temperature				
Example 記入例	Dyeing machine 染色機	Steam 蒸気	Hot water 熱水	Polyester/ Cotton ポリエステル/綿	Nit ニット	breadth 1.12m	g/m^2 110	m/min 200 kg/180min 3 Batch/day		kg/h	h/day 7		1981

Diagnoser	

Date		Factory	

2-6 Textile (Dyeing machine)

Dyeing machine 染色機, Screen printing machine 捺染機, Bleaching machine ブリーチング機, Scouring machine 精練機, Washing machine 水洗機, Sizing machine サイジング機, Steamer スチーマー, Tenter ヒートセッター, Dryer 乾燥機, Crabbing machine 煮でゆう機, Decatizing machine 蒸じゅう機, Singeing machine 毛焼機, Opensoaper オープンソーパー, Lustering machine つや出し機

1 Name of Factory 工場名	2 Part 工程	3 Name of Equipment 設備名	4 Use 用途	5 Material 素材	6 Number of Unit 数量	7 Date of Survey 調査日

No.	Item						
8	Item / No.	番号				
9	Type	型式				
10	Maker	メーカー				
11	Time Built	設置時期				
12	Outer Dimensions Length or Dia. Width Height	外法寸法 長さ, 径 巾 高さ				
13	Capacity Rating Present condition	能力 設備能力 現状				
14	Usage Continuous Batch Operating period	使用状況 連続 不連続 操業時間				
15	Preparatory Part	前工程				

Diagnoser	

Date		Factory	

16	Operating Specifications	加工条件				
	Kind of Material	素材種類				
	Weight	生地重量				
	Breadth	生 地 巾				
	Liquor Ratio	浴 比				
	Treatment Hour	処理時間				
	Pressure	圧 力				
	Temp. Rising	昇温状況				
	Operating Speed	加工速度				
17	Tanks	温 水 槽				
	Number	数				
	Volume	液 量				
	Dimension	寸 法				
	Material	材 質				
	Temperature	温 度				
	Current	流 れ				
	Counter Flow	向流				
	Parallel Flow	順流				
	Cover	ふた				
	Used Water	排 水				
	Temperature	温 度				
	Consumption	水 量				
	Suspended Solid	汚 れ				
	Heater	加熱装置				
	Heat Source	熱 源				
	Coil or Jacket	間 接				
	Others	そ の 他				
	Over-flow	オーバーフロー				

2-6-2

18	Insulation Present Condition Material Thickness Heat-released Surface Temperature	断　熱 保温状況 材　質 厚　さ 放散熱量 表面温度				
19	Heat Recovery Steam Condensate Used Water Others	熱回収 ドレン 排　水 その他				
20	Motor	動力（駆動）	V　HP, kW			
21	Instrument & Controller	計測制御				
22	Improvement done	改造実績				
23	Remarks Sketch	備考 略図				

2-7 Textile (Dryer)

1	Part		工　　程				
2	Name of Equipment		設 備 名				
3	Use		用　　途				
4	Material		素　　材				
5	Number of Unit		数　　量				
6	Dryer Number		番　　号				
7	Type		型　　式				
8	Maker		メ ー カ ー				
9	Time Built		設 置 時 期				
10	Outer Dimension length or Dia. width height	 mm mm mm	外 形 寸 法 長さ，直径 幅 長さ				
11	Capacity Design Actual		設 備 能 力 設　計 現　状				
12	Usage continuous batch operating time	 h/d h/m	使 用 状 況 連　続 不 連 続 操業時間				
13	Preparatory Part		前　工　程				

Diagnoser	

Date		Factory	

14	Operating Specification Material weight Breadth Speed Amount processed Room Temperature	加工条件 素材重量 生地巾 加工速度 処理量 雰囲気温度	 g/m^2 m m/min Kg/h °C			
15	Moisture of Material Inlet Outlet	水分 入口 出口	 % %			
16	Heat source Kind Consumption Pressure Temperature	熱源 種類 使用量 圧力 温度	Steam, Gas, Electric, 蒸気 ガス 電気 Thermal reagent 熱媒			
17	Heating method	熱使用形態	Calendar, Hot Air, 接触加熱 熱風 Direct Heating, 直火 Infra-red 赤外線			
18	Fuel Kind Heat Value Consumption	燃料 種類 発熱量 使用量				
19	Electric heater Capacity Power Consumption	ヒーター 容量 使用電力量	 kW kWh			
20	Motor Number of Unit Power	駆動モータ 数量	 V HP, kW			

21	Air Heater	熱交換器				
	Type	型　式				
	No. of Unit	数　量				
	Heating Surface	伝熱面積				
22	Burner	バーナー				
	Type	型　式				
	No. of Unit	数　量				
	Capacity	能　力				
23	Fan	ファン				
	Type, Use	型式, 用途				
	No. of Unit	数　量				
	Flow Rated/Actual	風量,定格/測定値	m^3/min			
	Static Pressure	静　圧	mmAq			
24	Insulation	保　温				
	Quality	材　質				
	Thickness	厚　さ				
	Finishing	外　装				
25	Surface Temp.	表面温度	°C			
26	Heat released	放散熱量	Kcal/m^2h			
27	Exhaust Gas.	排　気				
	Temperature	温　度	°C			
	Flow	量	m^3/min			
	Humidity	湿　度	%			
	After treatment	排熱処理				

28	Heat Recovery Equipment	熱回収装置				
29	Leakage	開口部よりの漏洩				
30	Condensate Recovery	ドレン回収				
31	Instrument & Controller	計測 制御				
32	Improvement done Time Outline Investment Effect	改造実績 時期 計画概要 投資金額 効果				
33	Remarks Sketch	備考 略図				

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

3-9 Textile

3-10 Metal

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	(see meter table below)
	(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

Meter table for 5 (1):

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						

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	電気熔接機		
	(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 (測定記録)

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	Remarks 備考
	V	A	kVA	kW	%	°C	

Diagnoser		Date		Factory	

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） { ☐ Valve（バルブ） ☐ Speed Control（速度制御） } ☐ Manual（手動） { ☐ Damper（ダンパー） ☐ Others ______ }
9	Speed Control	速　度　制　御	☐ Motor（モーター） { ☐ Pole Change（極数） ☐ Voltage（電圧） } ☐ Mechanical（機械式） { ☐ Frequency（周波数） ☐ Others ______ }
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 $U = \frac{Q}{A}$ (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 （モーターの稼動状況）

Process 工 程	Used for 用 途	Maker メーカー	Year built 製造年	Output 容 量	No. 台 数	Voltage 電 圧	Current 電 流			Revolutions 回転数	Speed control 速度制御	Power factor 力 率	Note 備 考
							Rated 定格Ⓐ	Actual 実測Ⓑ	Ⓑ/Ⓐ				
				kW HP		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）	
	（外気取入ファン）	（室内循環用ファン）	Pump（ポンプ）	Fan（ファン）	Compression Type（圧縮式）	Absorption Type（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） ☐ Both Automatic and Manual	☐ Manual （手動点滅）
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 復数スイッチ） ☐ One Switch per Line (Turn, Line by Line from Window side) （ライン毎に点滅）	
4	Kind of Lamp	ランプの種類	☐ Incandescent Lamp （白熱灯） ☐ Fluorescent Lamp (White) （白熱蛍光灯） ☐ Energy Conservation Type F.L. （省エネ型蛍光灯）	☐ Fluorescent Lamp (daylight color) 昼光色蛍光灯 ☐ Fluorescent Mercury Lamp（蛍光水銀灯） ☐ Good-color High Pressure Sodium Lamp （高演色型高圧ナトリムウ灯） ☐ Others ________
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　Night （夜間） kWh/h　from daily record 日誌から

Diagnoser	

Date		Factory	

3-9 Textile（繊維）

1	Plant プラント	Material 素　材	☐ Natural fibre 天然繊維 ______		☐ Synthetic fibre 合成繊維 ______		☐ Others ______
		Process 工　程					
		Pressure 圧　力	Kg/cm3G				
		Temperature 温　度	°C				
		Motor モーター	___kW x ___	___kW x ___	___kW x ___	___kW x ___	___kW x ___
		Refrigerator 冷凍機					
		(1) Capacity 容　量					
		(2) Number 台　数					
		(3) Refrigerant 冷　媒					
		(4) Pressure 圧　力					
		(5) Cooling 冷却方式					
		(6) Kind 種　類					
2	Weaving Machine 織　機	Type 型式	☐ Mechanical 機械式 ______ unit（台）		☐ Water-jet ウォータージェット式 ______ unit（台）		
		Motor モーター	______ kWOx ______ 台				

Diagnoser	

Date		Factory	

3-9-1

3 Thermal Utilization of Electricity 電熱応用

Process 工程	Temp 温度	Heater ヒーターの種類		Heating Method 加熱方式						Reutilization of Waste Heat 廃熱利用
		Direct 直接	Heat Medium 熱媒	Resistance 抵抗	Hot Air 温風	Far Infra-red Rays 遠赤外線	Electron Beam 電子線	Induction Heating 誘導加熱	Others その他	
Dyeing	°C									

3-9-2

3-10 Metal（金属）(1) Electric Arc Furnace

1	Part	工　程				
2	Name of Equipment	設 備 名				
3	Use	用　途				
4	No. of Furnace	番　号				
5	Type	番　号				
6	Maker	メーカー				
7	Time built	設置時期				
8	Dimension Inner Diameter Height to Cover from bottom Structure of Refractory	炉体寸法 炉体内径 炉底より天井までの高さ レンガ構成				
9	Design Capacity	設備能力				
10	Usage Time/day h/day	使用状况				
11	Transformer	変 圧 器				
	Rating Out Put	定格出力				
	Primary Voltage	一次電圧				
	Secondary Voltage	二次電圧				
	max					
	min					
	Step					
	Condenser	コンデンサー容量				
	Lift up motor for Electrode	電極昇降モーター				

Diagnoser	

Date		Factory	

12	Capacity of Reactor	リアクトルの容量				
13	Diameter of Electrode	電極の直径				
14	Auxiliary Burner	補助燃焼装置				
	Type	形　式				
	Number	本　数				
	Capacity	容　量				
	Fuel	燃料の種類				
	Hℓ	〃　発熱量				
	Consumption	〃　消費量				
	Oxidizer	酸化剤の種類				
	Consumption	〃　の消費量				
15	Induction Mixer	誘導攪拌装置				
	Type	形　式				
	Capacity	容　量	kVA			
16	Dust collector	集塵装置				
	House or Hood	集塵方式	建屋集塵，フード集塵			
	Type	形　式				
	Capacity	処理風量				
17	Scrap preheater	スクラップ予熱装置				
	Type	形　式				
	Capacity	容　量				
	Temp.	予熱温度				
	Heating source	加熱源				
18	Controller	制御装置，計測器				
19	Steel melting time	熔解時間				
	Oxidation refining	酸化精錬				
	Reduction refining	還元精錬				
	Total time	計				

20	Power consumption	電力使用量					
21	Charging material	装入材					
	Kind of material	種類					
	Consumption	使用量	Kg/charge				
	Composition	組成	Mn, P, Cr, C, Si				
22	Additive	添加材					
	Name	種類					
	Consumption	使用量	Kg/charge				
	Composition	組織	C, Si, Mn, P, Cr				
23	Oxidizer	酸化剤					
	Name	種類					
	Consumption	使用量	Kg, Nm^3				
24	Discharged Quantity	出鋼量					
	Steel made	良塊	Kg/charge				
	Scraped quantity	鋳屑	Kg/charge				
		計	Kg/charge				
25	Yield	出鋼歩留	%				
26	Discharging steel Temp.	出鋼温度	°C				
	Composition of steel	溶鋼組成					
	Steel grade	鋼種					
27	Slag	スラグ					
	Weight	重量	Kg/charge				
	Temp.	温度	°C				
	Composition	組成	FeO, Fe_2O_3, SiO_3, P_2O_5				
28	Cooling Water	冷却水					
	Flow rate	使用量	Kg/charge				
	Inlet Outlet temp.	入口出口温度	°C				
29	Ladle preheating	とりべ予熱					

Melting Period 溶解期	Start	Time	時刻			
		Power meter	電力計読み			
	End	Time	時刻			
		Power meter	電力計読み			
	Melting time		溶解時間			
	Power consumption		電力消費量		kWh	
	Amperage	Primary	電流	1次	A	
		Secondary		2次	A	
	Voltage	Primary	電圧	1次	V	
		Secondary		2次	V	
	Power factor		力率		%	
Refining Period 精錬期	Start	Time	時刻			
		Power meter	電力計読み			
	End	Time	時刻			
		Power meter	電力計読み			
	Refining time		精錬時間			
	Power consumption		電力消費量		kWh	
	Amperage	Primary	電流	1次	A	
		Secondary		2次	A	
	Voltage	Primary	電圧	1次	V	
		Secondary		2次	V	
	Power Factor		力率			
Total time			合計時間			
" (tap to tap)			〃			
Total Power consumption			合計電力量		kWh/ch.	
					kWh/m,g	
Weight of discharging steel			出鋼トン数		t/ch.	
					t/m,y	

3-10-4

(2) Induction Furnace（誘導炉）

1	Part		工程				
2	Name		名称				
3	Use		用途				
4	Furnace Number		炉番号				
5	Type		型式				
	pot type		るつぼ				
	channel type		溝型				
6	Maker		メーカー				
7	Date of built		設置時期				
8	Dimension		寸法				
	length	mm	長さ				
	width	mm	幅				
	height	mm	高				
9	Capacity	t/ch	容量				
10	Usage	h/d	使用状況				
		d/y					
11	Rating Power	kW	定格容量				
12	Frequency	Hz	周波数				
13	Frequency converter		周波数変換装置				
	Thyristerinverter		サイリスタインバーター				
	MG		M G				
	others		その他				
14	Condenser	kVr	コンデンサー				
15	Voltage	V	電圧				
	Amperage	A	電流				
	Power factor	%	力率				

Diagnoser	

Date		Factory	

16	3 phase balancer		三相平衡装置					
17	Melting Material		溶解材料					
18	Refractory material		炉材材質					
	thickness	mm	厚み					
	maker		メーカー					
19	Controller		制御装置					
	Radiation thermometer		放射温度計					
	Power counter		電力カウンター					
	Timer		タイマー					
	Others		その他					
20			残湯量，保持電力					
21	Furnace cover		炉蓋					
22	Dust collector		集塵装置					
23	Cooling water		冷却水					
	inlet temperature	°C	入口温度					
	outlet temperature	°C	出口温度					
	flow rate	t/h m^3/h	流量					
24	Melting temperature	°C	溶解温度					
25	Ladle preheating		とりべの予熱					
26			始業時間					
			終業時間					

Equipment List

No.	equipment	type
1	Portable Doppler Flowmeter	PD3
2	Hotwire Anemometer	V-02-A700
3	Heat Insulation Tester	MH2
4	Oxygen Meter	OX61 (6232)
5	Pocket Thermometers	2542
6	Thermopetter	#400
7	Portable Radiation Thermometer	IR-HP2
8	Pocket Conductivity Meter	SC51
9	Pocket PH Meter	PH51
10	Working Efficiency Check Meter	ECM-IR
11	Lux-Meter	ANA-999
12	Clip-on AC Power Meter	2433
13	Clamp-on Power Hi Tester	3136
14	Integrator	3141
15	Digital Printer	3142
16	Micro Hi Corder	8202
17	Volt Slider	S-260
18	Multitester	3009
19	Digital Hygrometer	2577

List of Information Material Collected

1. NEA, Thailand Energy Situation, 1981, '82
2. NEA, Oil and Thailand, 1981-'82
3. NEA, Electric Power in Thailand, 1981

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